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Alternatives to Conventional Nitrogen Fertilization on Tall Fescue and Bermudagrass

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I am submitting herewith a thesis written by Michael Dereck Corbin entitled "Alternatives to Conventional Nitrogen Fertilization on Tall Fescue and Bermudagrass." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Plant Sciences.

Renata Nave Oakes, Major Professor

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(Original signatures are on file with official student records.)

Alternatives to Conventional Nitrogen Fertilization on Tall Fescue and Bermudagrass

A Thesis Presented for the
Master of Science
Degree
The University of Tennessee, Knoxville

Michael Dereck Corbin
December 2017

DEDICATION

To my wife

Ashley N. Corbin

my son

Grey A. Corbin

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ABSTRACT

Alternatives to conventional nitrogen (N) fertilization on tall fescue [*Schedonorus arundinaceus (Schreb.) Dumort., nom. cons.* cv. Kentucky-31] and Bermudagrass [*Cynadon dactylon* (L.) Pers. cv. Vaughns # 1] were studied at the University of Tennessee Plateau Research and Education Center in Crossville, TN. Experimental period occurred from April-September 2016 and 2017, and the experimental design for each experiment was a completely randomized block design with six treatments and four replications per treatment (*n = 24*). For both experiments treatments were as followed: 1) control (CN) without N fertilization; 2) grass and white clover (WC) [*Trifolium repens* (L.) cv. Ladino-Will] at a rate of 2.2 kg ha^{-1}; 3) grass and red clover (RC) [*Trifolium pretense* (L.) cv. Cinnamon Plus] at a rate of 4.5 kg ha^{-1}; 4) grass and cowpea (CW) [*Vigna unguiculata* (L.) cv. 'Iron & Clay'] at a rate of 56 kg ha^{-1} 5) fertilization with broiler litter (BL) at a rate of 4,500 kg ha^{-1}; and 6) fertilization with ammonium nitrate (AN) at a rate of 67.2 kg ha^{-1}. Differences between least squares means by treatments for botanical composition variables of legume and grass were tested for each species. For each analysis, the dependent variable was herbage mass (HM), crude protein (CP), acid detergent fiber (ADF) and neutral detergent fiber (NDF). There were significant year x treatment interactions for each species for all dependent variables. Red clover treatments resulted in highest for total HM for 2017, which was 1986 kg ha^{-1} more than other treatments in tall fescue. Red Clover treatments resulted in highest for HM for 2016, 4526 kg ha^{-1} more than other treatments and 2017, 4289 kg ha^{-1} more than other treatments in bermudagrass. Treatments containing BL and AN showed no differences for total HM and CP for 2016 and 2017 in both experiments. Treatments containing CW presented over-all lower results compared to other treatments. Utilizing these results in combination with cost associated with each source could assist producers in choosing a more sustainable source of N or a method of reducing their amount and annual-overall cost associated with conventional N.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABREVIATIONS AND SYMBOLS

ADF	acid detergent fiber, g ADF kg^{-1} DM
AN	ammonium nitrate
BL	broiler litter
C^3	cool-season
C^4	warm-season
CN	control treatment
CP	crude protein, g CP kg^{-1} DM
CW	cowpea
°C	Degrees Celsius
DM	dry matter
HM	herbage mass, kg DM ha^{-1}
N	nitrogen
NDF	neutral detergent fiber digestibility, g NDF kg^{-1}
NIRS	near-infrared spectoscopy
RC	red clover
WC	white clover
UT	University of Tennessee

SECTION 1: INTRODUCTION

Tall Fescue and Bermudagrass Pastures

In the southeastern US, managing grazing pastures can come with challenges. Some challenges arise due to the growth rate of desired forages through the seasons. The humid transition zone of the Southeast is characterized by mixture of tall fescue and bermudagrass pastures (Hoveland et al., 1997). In the southeast, tall fescue serves as an excellent forage crop due to its persistency, high nutritive value and high HM potential (Nave et al., 2016). Also, being a cool-season (C_3) perennial grass, it reaches its maximum productivity during the spring months, i.e., March through early May, declining as warmer month's approaches. During the reduced growth rate of the tall fescue, other forages such as bermudagrass, a warm-season (C_4) perennial grass, can be integrated to complement tall fescue and fill in the gap with the potential to increase forage production in the summer (Fribourg et al., 1979).

A factor that defines and distinguishes cool-season from warm-season plants, is their photosynthetic pathway. Cool-season plants are defined as C_3 plants due to their photosynthetic carbon fixation cycle or pathway of photosynthesis. The symbol C_3 is derived by the 3-carbon acid that is formed from the reaction between CO_2 and ribulose bisphosphate (Furbank and Taylor, 1995). Under cooler temperatures, cool-season grasses are more productive and efficient, which occurs during spring and fall. The photosynthetic pathway of C_3 grasses enables photorespiration during high temperatures (Taiz and Zeiger, 2002). Photorespiration is the result of O_2 fixation, which is obtained by the work of an enzyme called Rubisco. Rubisco is responsible for the fixation of carbon but is also responsible for the fixation of O_2. Due to the competition between O_2 fixation and CO_2 fixation, photorespiration occurs reducing the amount of carbon and becoming less efficient and productive during higher temperatures (Furbank and Taylor, 1995). However the photosynthetic pathway of warm-season plants (C_4) aids in preventing photorespiration from occurring (Taiz and Zeiger, 2002). It achieves this by increasing the CO_2 concentration levels. Warm-season plants reduce captured CO_2 during photosynthesis by converting CO_2 to oxaloacetate, a 4-carbon acid (Furbank and Taylor, 1995). They also carry a very efficient photosynthetic pathway and a low amount of fixed CO_2 is lost through photorespiration (Furbank and Taylor, 1995).

Tall fescue is a C_3 perennial bunchgrass, deep rooted with short rhizomes growing from 60 to 122-cm tall (Ball et al., 2007). Establishment for pasture is recommended at 17 to 22 kg ha^{-1} of drilled seeds, and it is known to tolerate low fertility soils, but responds well to fertilization. It is a non-native grass that has been introduced to the majority of North America, and major uses include pastures, hay production and erosion control (Ball et al., 2007). Tall fescue is very persistent, which is one of the reasons it serves as the primary forage base for cow-calf producers in Tennessee, with optimum nutritive value in spring and fall (Kallenbach & Bishop-Hurley, 2004). Decrease growth rate during summer requires provisions to achieve maximum grazing efficiency, along with utilizing a warm-season forage to complement tall fescue during these months.

Bermudagrass [*Cynodon dactylon*] is a non-native warm-season perennial grass that spreads by rhizomes and stolons and can grow up to 70-cm tall (Ball et al., 2007). Bermudagrass can be established by seeds at 5.5 to 11 kg ha^{-1} and sprigs planted at 224 kg ha^{-1} or broadcasted at 560 to 896 kg ha^{-1}. It is also highly responsive to N (Ball et al., 2007) and is primarily used in pasture and hay. Due to its C_4 photosynthetic pathway, its maximum forage production is achieved during the summer months. Bermudagrass is considered an abundant and easily managed forage in the Southeast US, and based on its growing season can serve as replacement or complementing forage during summer months when tall fescue has decreased growth and nutritive value. However, due to low temperature intolerance, management and variety selection is important. For example, variety Vaughn's #1 is a recommended variety for Tennessee because of its hardiness in the winter, excellent feed quality, and ease of planting (Vaughn's, 1994).

When it comes to grazing pastures, management is key to maximizing forage potential. The optimum N application can be determined by proper forage management, which is consist of adequate soil testing and understanding and comparing relative growth rates of cool and warm-season grasses and timing of N application (Anderson and Shapiro, 1978). Based on soil recommendations, liming and fertilizing is key to improving forage nutritive value and HM (Ball et al., 2007). Utilizing the information on the plants N status, HM of dry matter (DM) and nutritive value is useful in forage management (Starks et al., 2006). Therefore, HM and nutritive value in the Southeast grasslands can be increased when N is present in the soil.

Nitrogen Fertilization

Economical rates of applied N can more than double forage production, given proper soil moisture. In addition to increasing grass production applying N can improve forage quality (Anderson and Shapiro, 1978). When N is applied both HM and CP content improve. Applying N fertilizer just before rapid grass growth assures most of the N applied will be available to the grass, reducing loss of available N by leaching or run-off, and also when proper N application and management is achieved there is an improvement in grass vigor, producing a thicker stand and serving as a weed suppressor (Anderson and Shapiro, 1978).

There are different methods of N application, as well as different sources of N. In recent years, the relative prices of synthetic N fertilizers have increased, and the amount of research that compares the different N sources economically is scarce (Poore and Drewnoski, 2010). With prices increasing for N fertilizer, it is important to evaluate different N application alternatives.

Conventional synthetic N fertilizers, such as urea or AN, are the most common method of applying N for forage growth. However, this method can become very costly to the producer. Local prices of urea for 2017 were US$ 69.58 ha^{-1} and AN were US$ 78.27 ha^{-1}. It can also have serious negative environmental impacts such as N losses due to leaching through the soil (Ball and Keeney, 1983). Most soil nitrates are mobile during cool and wet periods when pasture growth is at its lowest and more drainage occurs, resulting in a possible increase of nitrate leaching (Malcolm et al., 2014). The characteristics of commercial AN consist of dry solid or granular material containing about 34% N. It is 100% water soluble, readily available, can be blended or applied directly to the soil surface and has low volatilization potential. The characteristics of commercial urea consist of dry granular material that contains about 45% N. It is also 100% water soluble, readily available and it can be blended or applied directly to the soil surface. However, urea has high volatilization potential when applied in warm dry weather (Alley, 2001).

A renewable source method of applying N to pastures in the Southeast is the application of BL (Marshall et al., 2001). Manure sources of N should be analyzed and applied according to their nutrient content (Alley, 2001). In comparison to other animal manures, BL is a good source of nutrients for plants because of its high nutrient content (Evers, 1998). Because most of the United States' broiler production takes place in the Southeast, BL is a common source of fertilizers applied to pastures in Tennessee (Marshall et al., 2001). BL consists of broiler manure, as well as bedding material, and it provides producers with an effective source of N at a low cost (Marshall et al., 2001). However, when not properly managed, BL can also have some negative environmental impacts. When animal manure is over applied to soil, N loss can occur due to leaching, which may affect the quality of the groundwater supply by increasing the nitrate concentration. Some field studies have shown that there was a loss of more than 7% of the applied N when BL was applied to the soil surface (Marshall et al., 2001). Also the application of BL increases soil P concentrations (Pierson et al., 2000). Since phosphorus lacks the ability to leach through the soil, continuous applications of animal manures such as BL may result in P losses to surface water due to erosion and surface runoff (Webber et al., 2010; Eghball et al., 1996).

Another sustainable method of N source that can be incorporated in pastures is inter-mixing legumes into grass pastures. Intercropping forage legumes and grasses can come with positive interactions. By intercropping different forage species in grazing pastures, producers can increase overall forage nutritive value, providing a better opportunity for their livestock to meet their requirement needs (Provenza et al., 2003). One of the benefits of a legume-grass mixed pasture is the reduction of conventional synthetic N application. Legumes such as RC and WC have the ability to fix N. In order for biological **N** fixation to occur a symbiotic relationship between the rhizobium strain in the soil and legume's roots need to form (Ledgard and Steele, 1992). Once the infection from rhizobium has occurred, root nodules begin to form, becoming the site of atmospheric N_2 fixation (Ledgard and Steele, 1992). If the rhizobium bacteria are not accessible in the soil due to low count, poor soil pH, or other environmental factors, an inoculant can be added or coated to seeds before planting to help ensure N fixating nodules will form. The rhizobia can also convert soil nitrate into N and N_2 by denitrification (Ledgard and Steele, 1992). The relationship between the rhizobium and host plant characteristics will influence the amount of fixed N_2. One major benefit of legume-grass mixtures is their potential to retain and supply N at optimum levels in many types of environmental conditions (Schipanski and Drinkwater, 2012). Many factors, such as soil conditions, environment, pest, disease and management may affect the outcome of interacting legumes with grasses. The amount of fixed N transferred to the companion grass from the legume determines the production status of a legume-grass mixture (Ledgard and Steele, 1992). When mixing legumes with grasses, it is essential to carry out a suitable grazing management plan to reduce the risk of overgrazing legumes, resulting in a scarcity of these species in the subsequent seasons and also potentially causing bloating which may lead to death. Forages that can cause bloat are normally digested rapidly (Majak et al., 2003). Many common legumes with thin cell walls and low tannin levels can cause bloating (Majak et al., 2003).

In the Southeast, it is common to over-seed cool-season legumes into grass pastures, but the integration of warm-season legumes into these pastures has not been fully investigated. This is due to the limited selection of species and the lack of persistence due to over-grazing (Hoveland, 2000). Warm-season legumes have the potential to benefit cool and warm-season grass pastures. For example, cowpea (CW) [*Vigna unguiculata*] is a warm-season legume used as a cover crop and wildlife feed. It is very adaptable, versatile, nutritious, and can withstand high temperatures and drought conditions compared to other legumes (Ehlers and Hall, 1997).

Furthermore, due to its ability to effectively fix N, it can decrease the demand for conventional N fertilization and increase nutritive value and HM during the warmer months (Ehlers and Hall, 1997). The act of incorporating a warm-season legume into a cool-season and/or warm-season pasture *would* benefit a producer's rotation and grazing management program.

Sustainability and Economic Viability

Comparing alternative sources of N and their affect cool and warm-season perennial grasses found in common pastures of the Southeast can help lead to decisions on sustainable N sources. Sustainable agriculture has been described as managing and utilizing the agricultural ecosystem in a way that maintains biological diversity, productivity and the ability to function for the present and future without harming other ecosystems (Lewandowski et al., 1999). A few key principles for sustainability are to integrate biological and ecological processes such as N fixation, minimize the use of non-renewable inputs that cause harm to the environment, producers and consumers, substituting human capital for costly external inputs and credit management (Pretty, 2007). Producers that integrate more sustainable farming practices can make greater cuts in input use for external inputs, such as legumes for inorganic N sources (Pretty, 2007). In order to decide which source is more sustainable in the field, certain methods and frameworks must be used for determination. Previous frameworks such as Sustainability Assessment of Farming and the Environment (SAFE) have been designed to help assess the sustainability of agricultural systems based on Principles, Criteria and Indicators (Cauwenbergh et al., 2007). Based on the SAFE framework by Cauwenbergh et al., 2007 an agro-ecosystem that can be based on "on-farm" production cycles, has the potential to be assessed. Three pillars are of main concern in this frame work, Environmental, Economic and Social.

Understanding the positive and negative impacts that are associated with each source is a process of eliminating certain N sources. Examining ecosystems with mixtures of legume species and legume-grass mixtures can be used to help design agroecosystems that are more sustainable by being more efficient in N use (Schipanski and Drinkwater, 2012).

Objectives

The objective of this study was to evaluate different sources of N in tall fescue and bermudagrass, to determine its effect on HM and nutritional values. Our hypothesis is that alternative sustainable sources of N when compared to conventional methods, will reduce costs associated with forage production. If significant relationships between forage nutritive value, HM and cost are detected, this information could allow us to make informed recommendations on effective and cost saving alternative N sources. This information can be helpful to producers in the Southeast by providing recommendation guidelines on **N** fertilization of cool and warm season pastures based on forage production.

SECTION 2: MATERIALS AND METHODS

Site Description

This study was conducted at the University of Tennessee Plateau Research and Education Center (PREC) in Crossville, TN (36° 0' N, 85° 7' W, 580-m elevation). Two experiments (one for each species) were established with tall fescue cv. Kentucky-31 and bermudagrass cv. Vaughn's #1. Experimental period occurred from April-September 2016 and 2017. The experimental design for each experiment was a completely randomized block design with six treatments and four replications per treatment ($n = 24$). For both experiments treatments were as followed: 1) control without N fertilization; 2) grass and WC cv. Will; 3) grass and RC cv. Cinnamon Plus; 4) grass and CW cv. Iron & Clay 5) fertilization with BL; and 6) fertilization with AN. Individual plots for both species measured 6.09 m (length) x 1.54 m (width) with the exception of 4 plots containing grass and CW mixture measured 6.09 m (length) x 3.04 m (width) in order to accommodate the size of the no-till drill (Great Plains, Salina, Kansas).

Soil conditions on both experiments locations were 85% Lily, 5% Gilpin, 5% Lonewood and 5% Ramsey. Initial soil samples for both sites were collected at a 15-cm depth in 2015 and 2016 and sent to the University of Tennessee Soil, Plant and Pest Center laboratory for analysis located in Nashville, TN (Hanlon and Savoy, 2007) (Table 3 & 5)(*All tables/figures can be found in appendix*). Prior to treatment applications of BL in both 2016 and 2017, composite samples were collected from a broiler producing farm in Cleveland, TN, then sent to the University of Arkansas Agriculture Diagnostic Laboratory (Fayetteville) for analysis (Peters et al., 2003) (Table 4). This type of BL was applied to both experiments. Ammonium nitrate was applied to the desired plots at a rate of 67.2 kg ha^{-1} only once for the entire growing season for comparison among other treatments receiving only one application of N.

Experiment 1:

On October 09, 2014, tall fescue was drilled at seeding rate of 17 kg ha^{-1} utilizing the no-till drill model (Great Plains, Salina, Kansas) into existing tall fescue cv. Kentucky-31 area to ensure tall fescue coverage. Following soil recommendations, based on the pH level from soil analysis of 2015 (Table 3), lime was applied at a rate of 4,500 kg ha^{-1} on Oct. 26, 2015. On Oct. 5, 2015 both RC and WC were drilled into existent tall fescue plots utilizing a Hege seed drill (Hege Company, Waldenburg (Germany, F.R.) with 18-cm spacing. Seeding rate for RC was 4.5 kg ha^{-1} and WC was 2.2 kg ha^{-1}. On April 5, 2016 and 2017 BL at a rate of 4,500 kg ha^{-1} and AN at a rate of 67.2 kg ha^{-1} was applied to the desired tall fescue plots and on April 10, 2016 potassium (0-0-60) (33.6 kg ha^{-1}) was applied following recommendations from soil test analysis (Table 3). On February 23, 2017 a 2,4-D herbicide application was applied to plots that did not include legume mixtures. Prior planting on June 2, 2016 and May 30, 2017 CW seeds were inoculated with NDURE premium peanut inoculant at a rate of 140 g of inoculant per 45 kg of seeds, then no-till drilled into plots at a rate of 56 kg ha^{-1}. (*See time line table:* Table 1).

Experiment 2:

On May 27, 2015, glyphosate was applied to plots in preparation for tilling ground for bermudagrass establishment. On July 14, 2015 plots were tilled and fertilized with 13-13-13 at a rate of 560 kg $^{ha-1}$ followed by establishment of bermudagrass via vegetative propagation with small bales of bermudgrass cuttings at a rate of 14 bales/ ha. On April 28, 2016 and May 2, 2017 BL and AN treatments were applied to desired plots. On May 4, 2016 and February 23, 2017 a 2,4-D herbicide application was applied to plots that did not include legume mixtures. Based on recommendations from soil test analysis (Table 5), potassium (0-0-60) (33.6 kg ha^{-1}) was applied to bermudagrass (experiment 2) on the same dates as tall fescue (experiment 1), then on May 31, 2016 a second application of potassium (0-0-60) (33.6 kg ha^{-1}) was applied to bermudagrass following 1st harvest. Both RC and WC were drilled, with same drill used in experiment 1 into bermudagrass plots on the same dates as experiment 1. CW planting and establishment followed same procedures applied to experiment 1. (*See time line table*: Table 2)

Measurements (Experiment 1 and 2)

All plots were harvested utilizing a 0.91 m wide carter forage harvester (Carter, Brookston, Indiana), at a 15 cm height. Tall fescue plots were harvested on April 26, May 31, June 28, July 26 and August 31 of 2016, and April 28, May 26, July 10, August 14 and September 6 of 2017. Bermudagrass plots were harvested on May 31, June 28 July 26, August 26 and September 28 of 2016 and May 26, July 10, August 14 and September 6 of 2017.

During each harvest, a subsample was collected from the harvested material from each plot and wet weights were recorded. The samples were then dried at 60°C for 72 h up to constant weight and DM weight was recorded to determine HM. Samples were then ground to 1-mm particle size with a Wiley Mill Grinder (Thomas Scientific, Swedesboro, NJ) in preparation for near-infrared spectroscopy (NIRS) analysis. Nutritional values ADF, NDF and CP were predicted using a Unity Spectrastar XL instrument (Unity, Brookfield, CT). Equations for the forage nutritive analyses were standardized and checked for accuracy with the 2014 Grass Hay Equation developed by the NIRS Forage and Feed Consortium (NIRSC, Hillsboro, WI). Software used for NIRS analysis was Win ISI II supplied by Infrasoft International (State College, PA). The Global H statistical test compared the samples against the model and samples from distinct data sets within the database for accurate results, in which all forage samples fit the equation with the ($H < 3.0$) and are reported accordingly (Murray and Cowe, 2004).

Samples to characterize botanical composition were collected from a 0.1 m^2 area at a 12.7 cm stubble height, selected at random with in each legume blend experimental unit. Sampling dates were August 26th and September 9th in 2016 and August 10th and September 6th of 2017. Samples were separated by species, dried at 60°C and separately weighed.

Statistical analyses (Experiment 1 and 2)

Differences between least square means by treatment for HM, all nutritive value variables and all species were evaluated using the PROC MIXED procedures of SAS (SAS for Windows V 9.4, SAS Institute, Cary, NC). For each analysis, the dependent variable was HM, CP, ADF and NDF. Fixed effects were the alternative sources applied or implemented to each experimental unit (treatments) and dates. Replications were random effects. There were significant year x treatment interactions for each species for all dependent variables. Therefore, results of each experiment are displayed separately by year for all variables. Differences between least squares means by treatments for botanical composition variables of legume and grass were tested for each species using the PROC MIXED procedures of SAS (SAS for Windows V 9.4, SAS Institute, Cary, NC). Treatment was a fixed effect and replication was a random effect.

SECTION 3: RESULTS AND DISCUSSION

Weather

In 2015, April through September mean air temperature was 0.1°below the 30-yr average. Precipitation in 2015 from April through September was 55% above the 30-yr average (722 mm). In 2016, April through September mean air temperature was 0.4°C above the 30-yr average. Precipitation in 2016 from April through September was 39% below the 30-yr average. In 2017, April through September mean air temperature was 0.7°C above the 30-yr average. Precipitation in 2016 from April through September was 30% above the 30-yr average (Fig. 1). With the exception of the below 30-yr average amount of precipitation in 2016, precipitation and air temperature in other stated years were considered adequate for forage growth during the study period.

Tall Fescue

Botanical Composition

Knowledge of botanical composition is key in managing mixed pastures. Botanical composition analysis showed that WC was lower than CW when mixed to existent tall fescue plots in 2016 and lower than both CW and RC in 2017 (Table 7). Many studies suggest that WC is often mixed with tall fescue to increase production (Dobson et al., 1976), improve forage quality and serve as an N supply (Watson and Watson, 1989). However our results are not in agreement with past research. One of the reasons for the low percentage of WC measured in tall fescue mixed plots may be due to poor establishment, resulted from using a Hege seed drill (Hege Company, Waldenburg (Germany, F.R.). This drill is primarily intended for cultivated ground instead of drilling WC in already established tall fescue pastures. However, RC was drilled with the same Hege seed drill and establishment did not seem to be a major concern. This may be due to the difference in seed size of RC versus WC and seeding depth recommendations for RC (0.5-1-cm depth) versus WC (0-0.5cm depth) (Ball et al., 2007).

Percentage of RC was comparable to both CW and WC in 2016, but it was higher than both other legumes in 2017 (Table 7). This may be due to RC having a longer growing season (April – October) since it is a cool-season legume versus CW, a warm-season legume, with a shorter growing season (June – August) (Ball et al., 2007). Even though RC is a cool-season legume, it is also fairly tolerant to drought conditions (Ball et al., 2007). Also RC is considered a cool-season biennial or short lived perennial versus CW being a warm season-annual (Ball et al., 2007). Climatic conditions for the area allowed RC to grow and perform well over a longer period throughout the season when compared to CW, suggesting RC as a good alternative source of N in existent tall fescue plots, even under extreme drought as observed in 2016 (Fig. 1). Percentage of CW was higher in 2016 than 2017 (Table 7). Considering CW is drought tolerant (Ehlers and Hall, 1997), CW grown in a mixture of tall fescue performs better when tall fescue is more stressed by drought conditions. This also suggests CW may serve as an alternative source of N in existent tall fescue plots during the warmer months when tall fescue is not thriving and stressed due to unfavorable weather conditions.

Herbage Mass

In summary for 2016 and 2017, HM averaged 675.1 kg ha-^{1}, with a minimum of 42.5 kg ha-^{1} and a maximum of 3645 kg ha-^{1} across all treatments (Table 6).

Total Herbage Mass

In 2016, treatments containing AN and BL showed higher HM than CN and legume mixtures (with the exception of RC) (Fig. 2). In 2017, treatments containing RC had the highest total HM, followed by AN and BL. This may be due to larger amounts of precipitation recorded for 2017 versus 2016 (Fig. 1), and possibly due to the fact that RC is a short lived perennial, usually two years in the south making it a biannual, and its ability to fix N (Kallenbach & Bishop-Hurley, 2004; Ball et al., 2007). A study showed that the annual uptake of transferred N from RC was greater in the second year (Mallarino et al., 1990), suggesting RC as a good alternative source of N in existent tall fescue plots. These results also suggest that BL and RC both serve as a good alternative source to synthetic N in tall fescue swards. As expected, CN treatment had the lowest total HM and did not differ from treatments containing CW and WC in both years. These results could be attributed to the low percentage of these legumes in tall fescue plots (Table 7), suggesting there was no increase in HM when these legumes were added, therefore not different from CN plots (Fig 2). Although CW treatments resulted in low HM compared to other treatments for the 2016 and 2017 growing season (Fig. 2), they did not differ from RC (P = 0.4143) in 2016. This may be due to RC and CW both having drought resilient characteristics (Ball et al., 2007; Ehlers and Hall 1997), which allowed them to be comparable during the 2016 growing season. Our results are in agreement with past research done in Georgia that showed RC varieties combined with fescue more than doubled fescue alone when measuring HM. Their results of over three years showed fescue mixed with RC averaging 10.4 metric tons of dry forage/ha, and fescue alone averaging 4.5 metric tons of dry forage/ha (Dobson et al., 1976).

Herbage Mass per Harvest Period

Even though AN is considered to be readily available and has a quick response when applied (Alley, 2001), BL showed higher HM the 1st harvest of 2016. For the remaining of 2016 and 2017, BL and AN did not differ in the amount of HM produced during each harvest period. During both years, HM values for all treatments containing a forage legume (CW RC and WC) did not differ during the 1st harvest period. However, as the season progressed, plots containing RC showed higher HM among tall fescue and legume mixtures (Table 7). In 2017, the RC and tall fescue mixture had the highest HM among all treatments during the 3rd harvest (Table 7). This may be due to climatic conditions being favorable for RC mixed with tall fescue during the experimental period at the experimental site. Red clover is known to perform best from March to June as long as soil drains properly and adequate grazing management is practiced (Ball et al., 2007). Also, in 2016, CW showed best results during the 4th harvest, which occurred in July (Table 7). Cowpea is a warm-season annual legume, normally established in late May, also considered a drought tolerant legume (Ball et al., 2007; Ehlers and Hall, 1997). Foster et al., 2009 showed CW grown alone in Florida had a linear increase in HM when precipitation was adequate and peaked in HM around 10 weeks after planting, however performed favorably during drought conditions peaking around 7 weeks after planting. In addition, as it can be observed on the CN treatment, tall fescue production decreases during the summer months. Studies have shown perennial grass-legume mixtures typically increase in total biomass and RC mixed with orchardgrass resulted in higher biomass and higher soil N uptake compared to orchardgrass alone, (Schipanski and Drinkwater, 2012). Treatments with RC and CW during summer months provided additional N fertilization required to increase HM production during a period of reduced growth rate (Nave et al. 2013; Nave et al., 2014). As observed in (Fig. 2), the RC mixture showed approximately 40% more HM in 2017 (6390 kg ha^{-1}) than 2016 (3750 kg ha^{-1}), which can also be observed on individual HM per harvesting period of 2017 compared to 2016 (Table 7). This may be due to RC being a biennial forage legume with higher production during the second year after establishment (Wiersma et al., 1998). In addition, even though RC is drought tolerant, no drought occurred for the growing season of 2017 (Fig. 1), favorably benefiting the RC and tall fescue mixture. As expected and previously discussed, WC treatments were comparable to CN treatments, due to poor establishment (Table 7).

Forage Nutritive Value

Across all treatments, CP content averaged 136.6 g kg-^{1} with a minimum of 86.9 g kg-^{1} and a maximum of 212.4 g kg-^{1}. Acid detergent fiber averaged 330.5 g kg-^{1} with a minimum of 260 g kg-^{1} and maximum of 396.1 g kg-^{1}, and NDF analysis resulted in a mean value of 563.0 g kg-^{1} with a minimum of 433.8 g kg-^{1} and a maximum of 640.7 g kg-^{1} (Table 6).

Overall Forage Nutritive Value

Crude protein can be affected by the amount of available N in the soil (Minson, 1990). In 2016, average CP for treatments containing AN, BL and RC were significantly greater than CW, WC and CN treatments (Table 8). In 2017, RC and BL treatments showed highest CP content. Red clover, as a legume, will generally have higher CP content than grasses, with a study showing that mean concentrations of CP in legumes was 55 g kg^{-1} DM higher than temperate grasses (Minson, 1990). Broiler litter results may be explained due to BL containing organic matter, which aids in nutrient holding capacity (Evers, 1998) allowing tall fescue to retain the available N and increase CP. Based on these results, RC and BL are not only good alternative sources of N in existent tall fescue plots, but also enhancing CP content. Average CP for CW treatment was comparable to CN and WC treatments in 2016 (Table 8). However, CW was only comparable to CN in 2017, once that WC treatment had the lowest CP content. It was expected to observe CP content of tall fescue mixed with CW to be low, once that CW is known to have a shorter growing season. However, WC had contrary results from what was expected. This may be due to poor establishment of WC in 2015. Also, the fact that tall fescue plots mixed with WC had lower CP content than CN may be due to mixed plots being under stress and competition. In 2016 CN, CW, RC and WC showed higher overall ADF content. In 2017, RC and WC had the highest ADF content (Table 8). Cool-season legumes are known to have a high amount of indigestible fiber when mature, and in many instances these values are superior to those of cool-season grasses, especially for stem digestibility versus leaf digestibility (Buxton, 1996). Average ADF values were lower for AN and BL treatments in both years (Table 8). Nitrogen fertilization of tall fescue plots may contribute to production of young leaves, prolonging immature status of these plants, increasing forage nutritive value (Buxton, 1996). Neutral detergent fiber levels for CW and RC treatments were lower than all other treatments in 2016 growing season and RC treatments were lower than all other treatments in 2017 (Table 8). Our research is in agreement with other studies (Kleen et al., 2011) showing that CP was associated with legume percentages (Table 7). Also, under grazing, CP values for RC were higher than that of WC (184 g kg^{-1} vs. 154 g kg^{-1}, respectively) (Kleen et al., 2011).

Per Harvest Period

Average CP values for RC treatments were consistently higher from second to fifth harvest period during both years (Table 9). Red clover, even though it is a cool-season legume, performs well under drought conditions and high temperatures (Ball et al., 2007), therefore it had an advantage over other legume mixtures. In addition, its ability to fix N increases CP content may serve well in aiding tall fescue nutritional values during warmer months, especially since CP levels is expected to be decreasing as the cool-season grass matures reducing the leaf to stem ratio (Buxton, 1996). The CW mixture showed high CP content for the third harvest of both years, which occurred in late June. As a warm-season annual legume, CW has a shorter growing season but produces high amount of forage mass one month after establishment, maintaining high CP value for the mixture for two to three months after establishment (Table 7 & 9). Foster et al. (2009) showed CW grown alone in Florida having a slight increase in leaf to stem ratio for 6-8 weeks after planting. This increase in leaf to stem ratio could explain the high CP values in the CW mixture during the third harvest of our experiment. Tall fescue plots fertilized with AN showed higher CP than all other treatments for the first harvest of 2016 (Table 9). However, AN showed no CP differences to BL for the remaining of 2016, and earlier in the 2017 season (Table 9). We suspect this may be due to the amount of nutrient carry over rate associated with BL and its ability to retain nutrients well (Evers, 1998). Also some studies show that in the beginning of the growing season, not all of the total N from BL was readily available (Teutsch et al., 2005; Bitzer & Sims, 1988).

There were only a few differences among treatments for average ADF content in 2016, which occurred mostly during the second and third harvest period (Table 9). All legume mixed treatments showed consistently higher ADF content throughout the season in 2016, and that is consistent with findings showing legumes under high maturity tend to show higher amount of indigestible fiber (Buxton and Hornstein, 1986; Buxton et al., 1985). Acid detergent fiber is directly correlated to digestibility (Buxton, 1996). In 2017, RC and WC treatments were higher in average ADF values for most of the 2017 growing season (Table 9). This may be due to accelerated rate of maturity of cool-season legumes under warmer temperatures that could have increased ADF values. Most of the differences for NDF content occurred mid-season during both

2016 and 2017, with very few differences occurring during the first and fifth harvest periods (Table 9). This may be due to the fact that all legume treatments were still developing early in the season and slowly improving forage quality within tall fescue plots. Ledgard and Steele, (1992) showed that legume growth and amount of fixed N is decreased when grown in grass mixtures that are aggressive and already established. Therefore the amount of available N can directly affect nutritional values such as CP, ADF and NDF content (Buxton, 1996).

Bermudagrass

Botanical Composition

Botanical composition analysis showed that percentage of legume in a bermudagrass mixed sward was higher for treatment containing RC in both years (Table 11). Percentage of cool-season legumes were expected to be high once that bermudagrass is a warm-season grass, therefore allowing the cool-season legume to get a head start and have less competition in the beginning of the growing season. However, WC treatments did not seem to have the same effect of vigorous growth as RC did. This may be due to drought conditions in 2016 (Fig. 1) where growth and legume N fixation, especially of non-drought tolerant species such as WC, can be reduced undergoing stress associated with drought or water depletion (Engin & Sprent, 1973). Red clover is considered a biennial legume, which may grow more vigorous and quickly with a tendency to produce higher yields for the year after establishment (Weirsma et al., 1998). Also, RC is drought tolerant and the fact that there was a severe drought in 2016, could have given RC an advantage when compared to WC. Amount of rainfall affects the persistence of legumes, more so to WC due to it being shallow rooted compared to RC being deep rooted (Ledgard & Steele, 1992). Cowpea showed lower percentage in bermudagrass mixed swards in both years (Table 11). Since CW and bermudagrass are both warm-season species, competition was expected to be a factor. Legume growth and amount of fixed N is decreased when grown in grass species that are aggressive and already established (Ledgard & Steele, 1992). Even though CW is known for being drought tolerant (Ehlers and Hall, 1997), bermudagrass thrives in warm temperatures and is known as being invasive due to its growth habit of spreading by rhizomes and stolons (Ball et al., 2007). Bermudagrass may have been highly competitive, impeding CW to thrive in as a mixture. Perhaps increasing the seeding rates of CW in bermudagrass swards may benefit the warm-season legume growth in these mixtures.

Herbage Mass

In summary for 2016 and 2017 HM averaged 1184.5kg ha-^{1}, with a minimum of 48.2 kg ha-^{1} and a maximum of 6030 kg ha-^{1}across all treatments (Table 10).

Total herbage Mass

Overall, RC treatments showed higher total HM than all other treatments for both 2016 and 2017 growing seasons (Fig. 3). As previously mentioned, this may be due to RC growth pattern, of being a short-lived perennial or biannual, and resilience, allowing the species to have an advantage throughout the season (Weirsma et al., 1998; Ball et al., 2007). Based on total HM of bermudagrass sward mixed with RC suggests that the legume may be a viable option to increase productivity of bermudagrass during the growing season. Treatments containing CW did not differ from AN, BL and WC in 2016 (Fig. 3). This may be due to drought conditions recorded in 2016 (Fig. 1), allowing CW to use its drought tolerant characteristic as a benefit and result in a more positive interaction with bermudagrass. However, CW was lower than AN, BL and WC in 2017 (Fig. 3). This may be due to more rainfall in 2017 compared to 2016 (Fig. 1), implying bermudagrass is thriving and being more productive, therefore more aggressive resulting in decreased CW growth (Ledgard & Steele, 1992). Broiler litter and WC were comparable to AN for average HM in 2016 and 2017 (Fig. 3), which is in agreement with finding from (Evers, 1998). These results suggest that BL and WC may serve as good sources of N in bermudagrass pastures. Our results of RC treatments showing higher HM than CN treatments are in agreement with past research done in Southeastern Texas, which showed subterranean clover and arrowleaf clover mixed with bermudagrass had higher average HM compared to bermudagrass alone for two years. These results can potentially allow grazing to begin earlier in the late spring due to cool-season legumes forage availability and biological N fixation (Evers, 1985).

Herbage Mass per Harvest Period

The number of harvests in 2016 was higher than the number of harvests in 2017 due to the amount and timing of rainfall pushing the harvest dates later in the middle of the growing season. Based on the results presented in Table 11, treatments did not differ for the last two harvests in 2016 and last harvest in 2017. This may be due to bermudagrass approaching the end of its growing season during this time, which occurred late August and September. Based on results from (Evers, 1985), coastal bermudagrass grown in southeastern Texas showed decreased percentage of DM by about 20% from June to September. Because productivity of bermudagrass is declining, it is no longer responding to the N sources applied. Therefore, HM showed less variance at the end of the season, resulting in no differences among treatments. Treatments containing RC were higher than all treatments for the first and second harvest of 2016 and second harvest of 2017 (Table 11). This was expected due to RC being a cool-season (Ball et al., 2007), having an earlier start for production. Cowpea treatments showed its highest HM on the third and second harvest of 2016 and 2017 respectively, but overall it produced accumulative more HM during the 2016 growing season (Table 11). This may be due to the drought that occurred in 2016 (Fig. 1). This is in agreement with, (Foster et al., 2009) showing CW grown alone in Florida had a linear increase in HM when precipitation was adequate and peaked in HM around 10 weeks after planting, however performed favorably during drought conditions peaking around 7 weeks after planting. Cowpea, being a warm-season legume with a drought tolerant characteristic may serve as an excellent source of additional HM and N in bermudagrass swards under drought conditions. However in 2017, CW treatments usually showed the lowest HM values. There was no drought recorded for 2017 unlike 2016 (Fig. 1), which suggests that bermudagrass thrives in warm temperatures when grown in ideal environmental conditions. Also, its known invasive growth habit (Ball et al., 2007) may have caused it to outcompete CW. Bermudagrass plots containing AN also showed lower HM (Table 11), and this may be due to the fact that AN quickly releases N into the soil, and when applied to a warm season grass under rapid growth rate (Gelley et al., 2016), the amount of N available from AN may be reduced during the growing season when compared to slower release of N provided by legumes, and manures due to the organic matter which holds nutrients. (Ledgard & Steele, 1992; Evers, 1998). In addition, split applications of synthetic N fertilizer may be ideal in this situation to increase efficiency (Alley, 2001). Also most soil test recommendations suggest to split applications of N due to bermudagrass growth habit of spreading by stolons and rhizomes and ability to quickly retain and respond to N. Bermudagrass production has been known to increase as fertilizer rate increased (Evers, 1998).

Forage Nutritive Value

Across all treatments, CP content averaged 132.9 g kg-^{1} with a minimum of 76 g kg-^{1} and a maximum of 225.8 g kg-^{1}. Acid detergent fiber averaged 330.2 g kg-^{1} with a minimum of 260.7 g kg-^{1} and maximum of 389.5 g kg-^{1} and NDF analysis resulted in a mean value of 589.2 g kg-^{1} with a minimum of 402.9 g kg-^{1} and a maximum of 723.9 g kg-^{1} (Table 10).

Overall Forage Nutritive Value

Bermudagrass has been known to respond well to N (Evers, 1998). Crude protein content is highly influenced by the amount of N the plant uptakes from the soil (Minson, 1990). Legumes, with their ability to fix N have usually higher CP content compared to most grasses (Buxton, 1996). Based on the results from this study, RC had greater CP content during both 2016 and 2017 growing seasons (Table 12), which suggests that among all treatments, RC highly improves forage nutritive value of bermudagrass in a mixed sward. In addition, based on results from total HM (Fig. 3), RC appears to improve overall productivity as well, and could be considered as a viable option as a sustainable N source to bermudagrass swards. Again, this may be due to RC growth pattern, of being a short-lived cool season perennial or biannual, and resilience to drought, allowing the species to have an advantage throughout the entire growing season (Weirsma et al., 1998; Ball et al., 2007). Cowpea treatment unexpectedly showed the lowest CP content in 2016, and did not differ from AN, BL and CN for the lowest CP values in 2017 (Table 12). Even though legumes tend to have high CP content, CW had lower values than RC and WC possibly due to their different growing seasons. Also, CW is considered a warm-season annual legume and may have been outcompeted by bermudagrass in a mixed sward. This may also be due to bermudagrass being aggressive and already established to allow proper performance of a warm-season annual legume (Ledgard & Steele, 1992) such as CW mixed with bermudagrass.

For the variable ADF analyzed, WC had lower values than all other treatments in 2016 (Table 12), but no differences occurred among treatments for ADF in 2017 (Table 12). White clover may have been lower in 2016 due to weather conditions (Fig. 1) not favorable for its establishment and productivity. Also a recent study showed mixtures containing more erect growing legumes such as RC had higher NDF and ADF values compared to mixtures with low growing legumes such as WC (Kleen et al., 2011). Stems are usually less digestible compared to leaves and stem elongation increases with maturity (Buxton, 1996). Red clover treatments were lower than all other treatments for NDF in 2016 and 2017. This may also be due to the growth habit of RC, delaying maturity of RC in a bermudagrass mixed sward, preserving forage nutritive value throughout the season. .

Per Harvest Period

In both years, concentration of CP was consistently higher for treatment containing RC throughout the whole growing season (Table 13). Earlier in the season, as WC developed, it showed an increase for CP content, being comparable to RC at times; however, once temperatures were increasingly higher, N release from WC were decreased. As mentioned, legume growth and N fixation, can be reduced undergoing stress associated with drought or water depletion (Engin & Sprent, 1973). As expected and similarly to HM and botanical composition results, cowpea treatments seemed to have been outcompeted by bermudagrass, maintaining low CP content comparable to legume absent treatments during all harvesting periods in both years (Table 13). This suggests that CW may not be suitable as a mixture to improve bermudagrass productivity and nutritive value. Contrary to CW, our results suggest that RC ability to fix N and tolerance to warmer temperatures and drought conditions (Ball et al., 2007), may serve well in aiding bermudagrass nutritive value throughout the season.

There were no differences in ADF values late in the growing season for both 2016 and 2017 (Table 13). Very few differences occurred for ADF content in 2016, with WC and legume absent plots being for the most part lower in NDF content for most of the harvesting periods. This suggests that legumes may have increased total fiber content to the bermudagrass mixture, potentially decreasing digestibility. As for NDF values RC and WC were lower than all other treatments for the 1st and 2nd harvest in 2016 and 2017. Red clover treatments were lower than all other treatments in NDF for the 4th and 5th harvest of 2016 and 3rd and 4th harvest of 2017 (Table 13). Based on botanical composition (Table 11), leaf to stem ratio most likely played a role in these results. Fiber content differences between legumes and grasses can be associated with leaf to stem ratio, considering that NDF in leaves of grasses are usually greater than legumes (Buxton, 1996).

SECTION 4: CONCLUSION

Based on total HM produced and CP content from all treatments tested in this study, mixtures containing tall fescue or bermudagrass with RC were highest in both years. Our results suggest that RC is considered a good alternative source of N for both either a cool-season or a warm-season grass, even in drought conditions as it was observed in 2016. With the implementation of this vigorous biannual cool-season legume in these grasses, RC has the potential to increase growing season for both tall fescue and bermudagrass. In addition, RC appears to improve overall productivity and should be considered as a viable option for a sustainable N source to tall fescue and bermudagrass. Our results showed WC treatments performing poorly in tall fescue and adequate in bermudagrass, which suggests that establishment of WC into these grasses, especially tall fescue, is a major factor affecting successful productivity. Treatments containing CW resulted most of the time the lowest HM and nutritive value, although it did perform its best under drought conditions in tall fescue. Cowpea has a relatively short growing season, and it did perform best two months after establishment, which could be useful to increase cool-season grass productivity and nutritive value in months of shortage. Future studies involving different seeding rates and dates when mixed with these grasses should be consider. As for the mixture of CW with bermudagrass, our results indicate that since both are warm-season species, there is too much competitiveness and CW was not suitable to improve productivity and nutritive value in bermudagrass swards. Even though BL may have the potential to negatively impact the environment effects when not managed properly, it still serves as a renewable alternative source of N comparable and in many instances showing higher productivity than AN in both experiments. Utilizing these results in combination with cost associated with each source could assist producers in choosing a more sustainable source of N or a method of reducing their overall cost of production associated with N fertilization.

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APPENDIX

Table 1. Experiment 1 (tall fescue) time line.

Experiment 1: Tall Fescue		
Date	**Description**	**Rate/Cutting Height**
10/09/2014	Drilled tall fescue cv. Kentucky-31 seed in existing tall fescue area.	17 kg ha^{-1}
10/05/2015	Collected soil samples.	N/A
10/05/2015	Drilled RC and WC into desired tall fescue plots	(RC: 4.5 kg ha^{-1}), (WC: 2.2 kg ha^{-1})
10/26/2015	Lime was applied to entire tall fescue area.	4,500 kg ha^{-1}
03/01/2016	Re-seeded RC and WC into desired tall fescue plots.	(RC: 4.5 kg ha^{-1}), (WC: 2.2 kg ha^{-1})
04/05/2016	Ammonium Nitrate and BL were applied to desired tall fescue plots.	(AN: 67.2 kg ha^{-1}), (BL: 4,500 kg ha^{-1})
04/10/2016	Applied potassium (0-0-60) to entire tall fescue area.	34 kg ha^{-1}
04/26/2016	First harvest of 2016.	Height: 15 cm
05/31/2016	Second harvest of 2016.	Height: 15 cm
06/02/2016	Inoculated CW seeds with NDURE premium peanut inoculant	140 g of NDURE per 45 kg of seeds
06/02/2016	Drilled CW seeds into desired tall fescue plots.	56 kg ha^{-1}
06/28/2016	Third harvest of 2016.	Height: 15 cm
07/26/2016	Fourth harvest of 2016.	Height: 15 cm
08/26/2016	Botanical composition samples were collected from plots containing legumes as treatments.	0.1 m^2 area at a 12.7 cm stubble height
08/31/2016	Fifth harvest of 2016	Height: 15 cm
09/09/2016	Botanical composition samples were collected from plots containing legumes as treatments.	0.1 m^2 area at a 12.7 cm stubble height
11/16/2016	Collected soil samples	N/A
02/23/2017	Applied 2,4-D herbicide to plots containing no legumes as treatments.	2.4 L ha^{-1}
04/05/2017	Ammonium Nitrate and BL were applied to desired tall fescue plots.	(AN: 67.2 kg ha^{-1}), (BL: 4,500 kg ha^{-1})
04/28/2017	First harvest of 2017	Height: 15 cm
05/26/2017	Second harvest of 2017	Height: 15 cm
05/30/2017	Inoculated CW seeds with NDURE premium peanut inoculant	140 g of NDURE per 45 kg of seeds
05/30/2017	Drilled CW seeds into desired tall fescue plots.	56 kg ha^{-1}
07/10/2017	Third harvest of 2017	Height: 15 cm
08/10/2017	Botanical composition samples were collected from plots containing legumes as treatments.	0.1 m^2 area at a 12.7 cm stubble height
08/14/2017	Fourth harvest of 2017	Height: 15 cm
09/06/2017	Botanical composition samples were collected from plots containing legumes as treatments.	0.1 m^2 area at a 12.7 cm stubble height
09/06/2017	Fifth harvest of 2017	Height: 15 cm

Table 2. Experiment 2 (bermudagrass) time line.

Experiment 2: Bermudagrass		
Date	**Description**	**Rate/Cutting Height**
05/27/2015	Applied glyphosate to entire experiment 2 area in preparation for planting bermudagrass.	
07/14/2015	Experiment 2 area was tilled and fertilized with 13-13-13.	560 kg ha^{-1}
07/14/2015	Spread bales of bermudagrass clippings over entire area, then disked and cultipacked for proper establishment	14 bales ha^{-1}
10/05/2015	Collected soil samples.	N/A
10/05/2015	Drilled RC and WC into desired bermudagrass plots	(RC: 4.5 kg ha^{-1}), (WC: 2.2 kg ha^{-1})
10/26/2015	Lime was applied to entire bermudagrass area.	4,500 kg ha^{-1}
03/01/2016	Re-seeded RC into desired bermudagrass plots.	(RC: 4.5 kg ha^{-1})
04/10/2016	Applied potassium (0-0-60) to entire bermudagrass area.	34 kg ha^{-1}
04/28/2016	Ammonium Nitrate and BL were applied to desired bermudagrass plots.	(AN: 67.2 kg ha^{-1}), (BL: 4,500 kg ha^{-1})
05/04/2016	Applied 2,4-D herbicide to plots containing no legumes as treatments.	
05/31/2016	First harvest of 2016.	Height: 15 cm
05/31/2016	Applied more potassium (0-0-60) to entire bermudagrass area.	34 kg ha^{-1}
06/02/2016	Inoculated CW seeds with NDURE premium peanut inoculant	140 g of NDURE per 45 kg of seeds
06/02/2016	Drilled CW seeds into desired bermudagrass plots.	56 kg ha^{-1}
06/28/2016	Second harvest of 2016.	Height: 15 cm
07/26/2016	Third harvest of 2016.	Height: 15 cm
08/26/2016	Botanical composition samples were collected from plots containing legumes as treatments.	0.1 m^2 area at a 12.7 cm stubble height
08/31/2016	Fourth harvest of 2016.	Height: 15 cm
09/09/2016	Botanical composition samples were collected from plots containing legumes as treatments.	0.1 m^2 area at a 12.7 cm stubble height
09/28/2016	Fifth harvest of 2016.	Height: 15 cm
11/16/2016	Collected soil samples	N/A
02/23/2017	Applied 2,4-D herbicide to plots containing no legumes as treatments.	
5/2/2017	Ammonium Nitrate and BL were applied to desired bermudagrass plots.	(AN: 67.2 kg ha^{-1}), (BL: 4,500 kg ha^{-1})
05/26/2017	First harvest of 2017	Height: 15 cm
05/30/2017	Inoculated CW seeds with NDURE premium peanut inoculant	140 g of NDURE per 45 kg of seeds
05/30/2017	Drilled CW seeds into desired bermudagrass plots.	56 kg ha^{-1}
07/10/2017	Second harvest of 2017	Height: 15 cm
08/10/2017	Botanical composition samples were collected from plots containing legumes as treatments.	0.1 m^2 area at a 12.7 cm stubble height
08/14/2017	Third harvest of 2017	Height: 15 cm
09/06/2017	Botanical composition samples were collected from plots containing legumes as treatments.	0.1 m^2 area at a 12.7 cm stubble height
09/06/2017	Fourth harvest of 2017	Height: 15 cm

Table 3. Soil characteristics of the tall fescue experimental site for each year collected in 2015 & 2016.

Year	Sampling date	pH	P	K	Ca	Mg
			-----------------kg ha^{-1}---------------			
2015	10/14	6.0	59	135	1928	65
2016	11/30	6.2	47	147	2048	149

Table 4. Average nutrient concentration (dry-matter basis) of BL used in both experiments.

Year	**pH**	**%Moisture**	**NO_3-N**	**NH_4-N**	**N**	**P**	**K**	**Ca**
			mg/kg			Total %		
2016	7.1	5.1	240	4319	4.15	1.63	3.28	2.91
2017	7.9	30.7	95.0	7823	5.43	1.41	3.98	2.80

Table 5. Soil characteristics of the bermudagrass experimental site for each year collected in 2015 & 2016.

Year	**Sampling date**	**pH**	**P**	**K**	**Ca**	**Mg**
					kg ha-1	
2015	10/14	5.8	38	141	1701	63
2016	11/30	5.9	71	239	1808	146

Table 6. Summary statistics for all variables analyzed of a tall fescue and tall fescue mixed sward during the growing season in two consecutive years of 2016 & 2017.

Variable	***n***[†]	**MIN**[†]	**MAX**[†]	**Mean**	**SD**
Herbage mass, kg DM[§] **ha^{-1}**	240	42.5	3645	675.1	590.7
CP[§], g kg^{-1}	240	86.9	212.4	136.6	23.6
ADF[§], g kg^{-1}	240	260	396.1	330.5	29.2
NDF[§], g kg^{-1}	240	433.8	640.7	563.0	42.9

[†] *n*, number of observations; MIN, minimum observation; MAX, maximum observation. Each observation was the average of four replicates.

[§] DM, dry mater; CP, crude protein; ADF, acid detergent fiber; NDF, neutral detergent fiber.

Table 7. Average herbage mass of tall fescue and tall fescue mixed sward per harvesting period for 2016 & 2017. Botanical composition means of tall fescue and legume mixed swards for Harvest 4 and 5 combined in 2016 & 2017.

Year	Treatment	Harvest 1	Harvest 2	Harvest 3	Harvest 4	Harvest 5	Botanical Composition	
		Herbage mass, kg DM§ ha^{-1}					% Legume	% Grass
2016	**AN†**	$1021^{b\ddagger}$	2153^{a}	363^{ab}	324^{b}	567^{ab}		
	BL	1695^{a}	1988^{ab}	339^{ab}	336^{b}	555^{ab}		
	CN	370^{c}	1058^{bc}	283^{b}	325^{b}	440^{b}		
	CW	370^{c}	1058^{bc}	263^{b}	743^{a}	497^{b}	27^{a}	73^{b}
	RC	452^{c}	1248^{abc}	546^{a}	678^{a}	825^{a}	24^{ab}	76^{ab}
	WC	296^{c}	897^{c}	289^{b}	282^{b}	489^{b}	10^{b}	90^{a}
	P	<.0001	.0047	.0061	.0001	.0162	.0370	.0370
2017	**AN**	921^{ab}	800^{a}	861^{b}	629^{b}	179^{ab}		
	BL	1191^{a}	881^{a}	1182^{b}	901^{ab}	248^{a}		
	CN	212^{d}	214^{b}	583^{b}	506^{b}	195^{ab}		
	CW	444^{bcd}	292^{b}	608^{b}	499^{b}	146^{ab}	20^{b}	80^{b}
	RC	778^{abc}	966^{a}	3374^{a}	1112^{a}	158^{ab}	38^{a}	62^{c}
	WC	406^{cd}	250^{b}	645^{b}	497^{b}	73^{b}	4^{c}	96^{a}
	P	<.0001	<.0001	<.0001	.0003	.0255	<.0001	<.0001

AN†, ammonium nitrate; BL, broiler litter; CN, control; CW, cowpea; RC, red clover; WC, white clover.

DM§, dry matter.

Botanical Composition¶, percent values are the means from botanical samples collected, dried and weighed during harvest 4 and harvest 5 periods.

‡ Means within a column per year without a common superscript letter differ ($P < 0.05$).

Table 8. Concentration of crude protein (CP), neutral detergent fiber (NDF) and acid detergent fiber (ADF) of tall fescue and tall fescue mixed swards averaged across 5 harvesting dates during the growing season of 2016 & 2017.

	2016			**2017**		
Treatment	**CP g kg^{-1}**	**ADF g kg^{-1}**	**NDF g kg^{-1}**	**CP g kg^{-1}**	**ADF g kg^{-1}**	**NDF g kg^{-1}**
AN[†]	138^{a}[‡]	329^{c}	574^{ab}	149^{bc}	308^{bc}	585^{a}
BL†	135^{a}	332^{bc}	585^{a}	159^{ab}	299^{c}	581^{a}
CN†	114^{b}	353^{a}	570^{ab}	140^{c}	313^{b}	587^{a}
CW†	119^{b}	341^{abc}	543^{bc}	142^{c}	306^{bc}	573^{a}
RC†	138^{a}	343^{abc}	521^{c}	166^{a}	339^{a}	492^{b}
WC†	114^{b}	349^{ab}	569^{ab}	122^{d}	348^{a}	573^{a}
P	<.0001	.0024	.0002	<.0001	<.0001	<.0001

AN[†], ammonium nitrate (34-0-0); BL, broiler litter; CN, control; CW, cowpea; RC, red clover; WC, white clover.

‡ Means within a column per year without a common superscript letter differ ($P < 0.05$).

Table 9. Concentrations of crude protein (CP), neutral detergent fiber (NDF) and acid detergent fiber (ADF) of tall fescue and tall fescue mixed sward averaged per harvesting date in 2016 & 2017.

Year	Treatment	Harvest 1	Harvest 2	Harvest 3	Harvest 4	Harvest 5
				CP, g kg^{-1}		
2016	**AN**[†]	178^{a}[‡]	115^{ab}	133^{ab}	138^{b}	125^{bc}
	BL[†]	149^{b}	118^{a}	131^{ab}	145^{ab}	133^{ab}
	CN[†]	125^{c}	100^{bc}	105^{b}	126^{b}	113^{c}
	CW[†]	125^{c}	100^{bc}	124^{ab}	129^{b}	115^{c}
	RC[†]	126^{c}	111^{abc}	145^{a}	161^{a}	146^{a}
	WC[†]	120^{c}	99c	108^{b}	129^{b}	113^{c}
	P	<.0001	.0015	.0021	.0005	<.0001
2017	**AN**[†]	176^{ab}	161^{bc}	124^{a}	130^{b}	153^{bc}
	BL[†]	191^{a}	171^{ab}	136^{a}	137^{b}	162^{b}
	CN[†]	147^{bc}	147^{c}	134^{a}	131^{b}	140^{c}
	CW[†]	148^{bc}	152^{c}	137^{a}	130^{b}	141^{c}
	RC[†]	152^{bc}	183^{a}	139^{a}	170^{a}	183^{a}
	WC[†]	125^{c}	122^{d}	93^{b}	123^{b}	147^{bc}
	P	.0005	<.0001	<.0001	<.0001	<.0001
				ADF, g kg^{-1}		
2016	**AN**[†]	295^{b}	333^{b}	332^{b}	346^{a}	338^{a}
	BL[†]	320^{a}	347^{ab}	333^{ab}	337^{a}	325^{a}
	CN[†]	315^{a}	366^{a}	368^{a}	367^{a}	350^{a}
	CW[†]	315^{a}	366^{a}	342^{ab}	335^{a}	346^{a}
	RC[†]	319^{a}	354^{ab}	356^{ab}	350^{a}	339^{a}
	WC[†]	321^{a}	362^{a}	362^{ab}	357^{a}	346^{a}
	P	.0118	.0020	.0188	.2087	.1332
2017	**AN**[†]	282^{b}	289^{bc}	319^{b}	345^{bc}	305^{ab}
	BL[†]	273^{b}	277^{c}	308^{b}	340^{c}	295^{ab}
	CN[†]	291^{b}	303^{b}	314^{b}	346^{bc}	311^{ab}
	CW[†]	292^{b}	300^{bc}	282^{c}	340^{c}	314^{a}
	RC[†]	328^{a}	328^{a}	385^{a}	359^{ab}	293^{b}
	WC[†]	324^{a}	352^{a}	382^{a}	370^{a}	314^{a}
	P	<.0001	<.0001	<.0001	<.0001	.0061
				NDF, g kg^{-1}		
2016	**AN**[†]	530^{a}	550^{a}	587^{a}	591^{a}	611^{a}
	BL[†]	545^{a}	567^{a}	594^{a}	606^{a}	611^{a}
	CN[†]	537^{a}	563^{a}	576^{ab}	579^{a}	595^{a}
	CW[†]	537^{a}	563^{a}	545^{bc}	472^{b}	598^{a}
	RC[†]	522^{a}	550^{a}	513^{c}	495^{b}	524^{b}
	WC[†]	539^{a}	591^{a}	564^{ab}	548^{ab}	605^{a}
	P	.6506	.5216	<.0001	<.0001	.0003
2017	**AN**[†]	574^{a}	557^{b}	588^{a}	623^{a}	581^{a}
	BL[†]	566^{a}	552^{c}	591^{a}	621^{a}	576^{a}
	CN[†]	580^{a}	593^{a}	564^{a}	608^{a}	589^{a}
	CW[†]	586^{a}	590^{ab}	497^{b}	602^{a}	591^{a}
	RC[†]	508^{b}	458^{d}	500^{b}	502^{b}	490^{b}
	WC[†]	558^{a}	565^{abc}	575^{a}	605^{a}	562^{a}
	P	.0004	<.0001	<.0001	<.0001	<.0001

AN[†], ammonium nitrate; BL, broiler litter; CN, control; CW, cowpea; RC, red clover; WC, white clover.

‡ Means within a column per year without a common superscript letter differ ($P < 0.05$).

Table 10. Summary statistics for all variables analyzed of a bermudagrass and bermudagrass mixed sward during the growing season in two consecutive years of 2016 & 2017.

Variable	***n***[†]	**MIN**[†]	**MAX**[†]	**Mean**	**SD**
Herbage mass, kg DM[§] ha^{-1}	216	48.2	6030.2	1184.5	971.2
CP[§], g kg^{-1}	216	76	225.8	132.9	32.5
ADF[§], g kg^{-1}	216	260.7	389.5	330.2	24.7
NDF[§], g kg^{-1}	216	402.9	723.9	589.2	81.3

[†] *n*, number of observations; MIN, minimum observation; MAX, maximum observation. Each observation was the average of four replicates.

[§] DM, dry mater; CP, crude protein; ADF, acid detergent fiber; NDF, neutral detergent fiber.

Table 11. Average herbage mass of bermudagrass and bermudagrass mixed sward per harvesting period for 2016 & 2017. Botanical composition means of bermudagrass and legume mixed swards for Harvest 4 and 5 combined in 2016 & 2017.

Year	**Treatment**	**Harvest 1**	**Harvest 2**	**Harvest 3**	**Harvest 4**	**Harvest 5**	**Botanical Composition**[¶]	
		Herbage mass, kg DM[§] **ha^{-1}**					**% Legume**	**% Grass**
2016	**AN**[†]	719^{bc}[‡]	1282^{bc}	996^{bc}	1695^{a}	326^{a}		
	BL[†]	765^{bc}	1334^{bc}	1171^{abc}	2145^{a}	456^{a}		
	CN[†]	409^{c}	347^{d}	679^{c}	1562^{a}	561^{a}		
	CW[†]	409^{c}	548^{cd}	2123^{a}	1730^{a}	525^{a}	9^{b}	91^{a}
	RC[†]	3317^{a}	2876^{a}	2018^{ab}	1979^{a}	207^{a}	33^{a}	67^{b}
	WC[†]	1192^{b}	1682^{b}	1918^{ab}	1357^{a}	185^{a}	18^{b}	82^{a}
	P	<.0001	<.0001	.0010	.1338	.0786	.0020	.0020
2017	**AN**[†]	1198^{bc}	1412^{bcd}	305^{b}	364^{a}			
	BL[†]	1541^{bc}	2427^{b}	775^{ab}	509^{a}			
	CN[†]	521^{c}	1183^{cd}	483^{b}	311^{a}			
	CW[†]	493^{c}	1006^{d}	381^{b}	345^{a}		13^{b}	87^{a}
	RC[†]	2822^{a}	4736^{a}	1104^{a}	879^{a}		67^{a}	33^{b}
	WC[†]	1795^{ab}	2026^{bc}	490^{b}	319^{a}		16^{b}	84^{a}
	P	<0.0001	<.0001	.0025	.5208		<.0001	<.0001

AN[†], ammonium nitrate; BL, broiler litter; CN, control; CW, cowpea; RC, red clover; WC, white clover.

DM[§], dry matter.

Botanical Composition[¶], percent values are the means from botanical samples collected, dried and weighed during harvest 4 and harvest 5 periods.

‡ Means within a column per year without a common superscript letter differ ($P < 0.05$).

Table 12. Concentration of crude protein (CP), neutral detergent fiber (NDF) and acid detergent fiber (ADF) of bermudagrass and bermudagrass mixed swards averaged across 5 harvesting dates during the growing season of 2016 & 2017.

	2016			**2017**		
Treatment	**CP g kg^{-1}**	**ADF g kg^{-1}**	**NDF g kg^{-1}**	**CP g kg^{-1}**	**ADF g kg^{-1}**	**NDF g kg^{-1}**
AN†	120^{c}	338^{a}	636^{a}	115^{c}	322^{a}	644^{a}
BL†	119^{cd}	342^{a}	640^{a}	124^{c}	319^{a}	646^{a}
CN†	118^{cd}	338^{a}	613^{b}	117^{c}	319^{a}	634^{a}
CW†	109^{d}	343^{a}	598^{b}	117^{c}	313^{a}	615^{a}
RC†	174^{a}	342^{a}	493^{d}	190^{a}	329^{a}	474^{c}
WC†	147^{b}	321^{b}	532^{c}	144^{b}	320^{a}	545^{b}
P	<.0001	.0002	<.0001	<.0001	.1310	<.0001

AN†, ammonium nitrate (34-0-0); BL, broiler litter; CN, control; CW, cowpea; RC, red clover; WC, white clover.

‡ Means within a column per year without a common superscript letter differ (P<0.05).

Table 13. Concentrations of crude protein (CP), neutral detergent fiber (NDF) and acid detergent fiber (ADF) of bermudagrass and bermudagrass mixed sward per harvesting date in 2016 & 2017.

Year	Treatment	Harvest 1	Harvest 2	Harvest 3	Harvest 4	Harvest 5
				CP, g kg^{-1}		
2016	**AN†**	$161^{ab\ddagger}$	118^{b}	120^{c}	98^{c}	100^{bc}
	BL†	149^{bc}	123^{b}	130^{c}	95^{c}	97^{bc}
	CN†	129^{c}	131^{b}	130^{c}	97^{c}	100^{bc}
	CW†	129^{c}	126^{b}	113^{c}	91^{c}	85^{c}
	RC†	170^{a}	198^{a}	197^{a}	159^{a}	146^{a}
	WC†	157^{ab}	177^{a}	164^{b}	123^{b}	113^{b}
	P	<.0001	<.0001	<.0001	<.0001	<.0001
2017	**AN†**	132^{c}	98^{b}	126^{b}	102^{b}	.
	BL†	140^{bc}	107^{b}	132^{b}	116^{b}	.
	CN†	145^{bc}	103^{b}	117^{b}	102^{b}	.
	CW†	137^{c}	101^{b}	126^{b}	104^{b}	.
	RC†	212^{a}	171^{a}	187^{a}	192^{a}	.
	WC†	168^{b}	144^{a}	134^{b}	132^{b}	.
	P	<.0001	<.0001	.0002	<.0001	.
				ADF, g kg^{-1}		
2016	**AN†**	307^{ab}	321^{ab}	344^{a}	354^{a}	362^{a}
	BL†	315^{ab}	324^{ab}	335^{a}	358^{a}	379^{a}
	CN†	326^{a}	315^{b}	337^{a}	347^{ab}	364^{a}
	CW†	326^{a}	309^{b}	340^{a}	357^{a}	383^{a}
	RC†	325^{a}	343^{a}	341^{a}	340^{ab}	361^{a}
	WC†	295^{b}	300^{b}	321^{a}	328^{b}	361^{a}
	P	.0050	.0013	.3018	.0018	.0899
2017	**AN†**	308^{ab}	314^{b}	334^{ab}	333^{a}	.
	BL†	308^{ab}	311^{b}	331^{b}	326^{a}	.
	CN†	299^{ab}	310^{b}	336^{ab}	333^{a}	.
	CW†	303^{ab}	295^{b}	319^{b}	335^{a}	.
	RC†	323^{a}	349^{a}	340^{ab}	304^{a}	.
	WC†	282^{b}	304^{b}	360^{a}	333^{a}	.
	P	.0214	<.0001	.0069	.0781	.
				NDF, g kg^{-1}		
2016	**AN†**	556^{a}	637^{a}	649^{a}	651^{a}	688^{ab}
	BL†	554^{ab}	627^{a}	650^{a}	663^{a}	705^{a}
	CN†	518^{b}	606^{ab}	614^{ab}	641^{a}	687^{ab}
	CW†	518^{b}	551^{b}	561^{bc}	653^{a}	709^{a}
	RC†	426^{c}	462^{c}	479^{c}	495^{c}	603^{c}
	WC†	434^{c}	466^{c}	513^{c}	577^{b}	668^{b}
	P	<.0001	<.0001	<.0001	<.0001	<.0001
2017	**AN†**	632^{a}	646^{a}	638^{ab}	660^{a}	.
	BL†	617^{a}	651^{a}	658^{a}	660^{a}	.
	CN†	612^{a}	632^{ab}	637^{ab}	654^{a}	.
	CW†	623^{a}	584^{b}	586^{b}	668^{a}	.
	RC†	433^{b}	470^{c}	498^{c}	495^{b}	.
	WC†	456^{b}	513^{c}	603^{ab}	609^{a}	.
	P	<.0001	<.0001	<.0001	<.0001	.

AN†, ammonium nitrate; BL, broiler litter; CN, control; CW, cowpea; RC, red clover; WC, white clover.

‡ Means within a column per year without a common superscript letter differ ($P<0.05$).

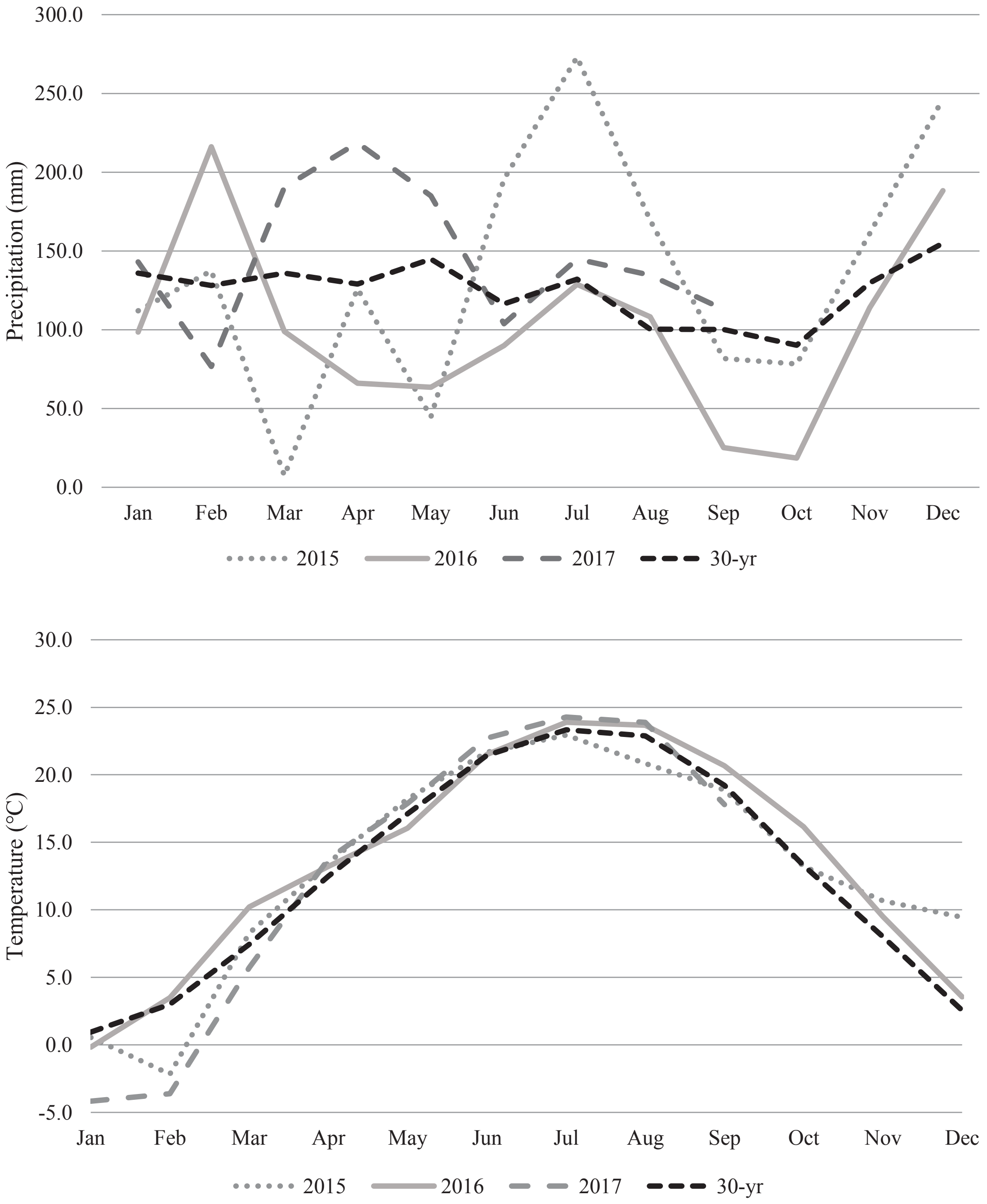

Figure 1. Weather for Crossville, TN, including 30-yr average for growing season of 2015, 2016 & 2017.

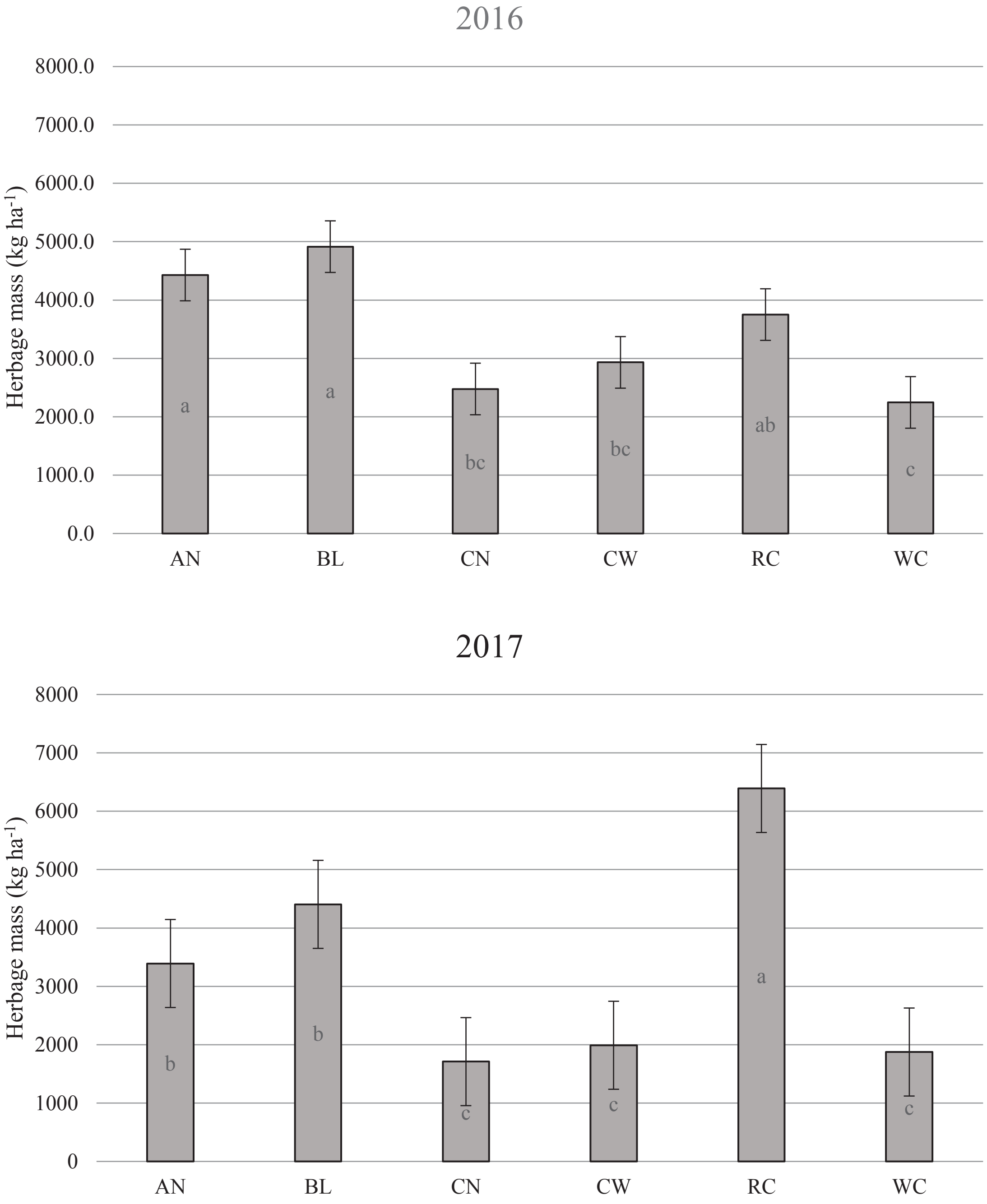

Figure 2. Total herbage mass of tall fescue and tall fescue mixed sward across 5 harvesting dates during the growing in 2016 (P = <0.0001) & 2017 (P = <0.0001).

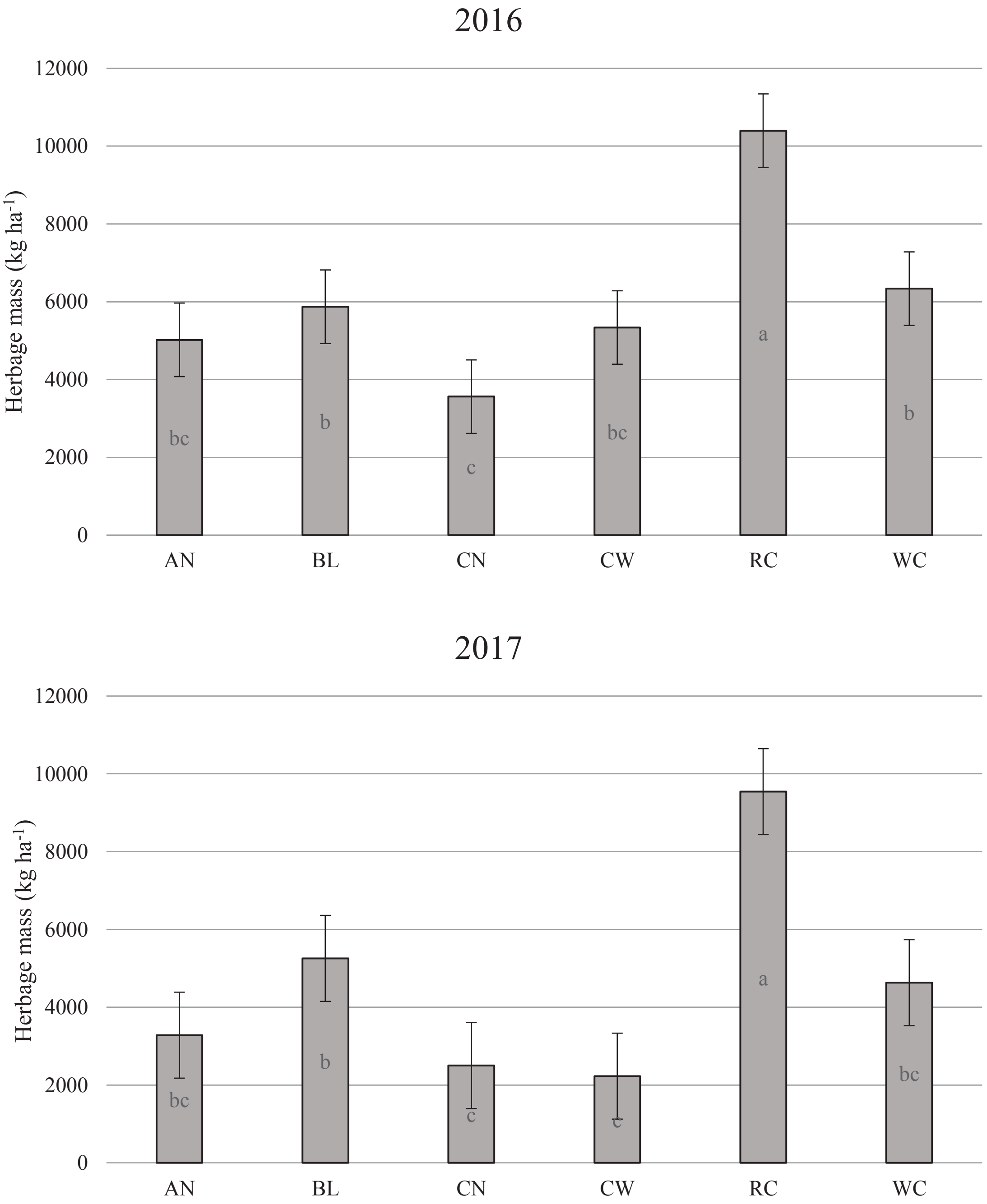

Figure 3. Total herbage mass of bermudagrass and bermudagrass mixed sward across 5 harvesting dates during the growing season in 2016 (*P* = <0.0001) & 2017 (*P* = <0.0001).

VITA

Dereck Corbin was born in Crossville, TN. He is a 2011 graduate of The Tennessee Technological University with a Bachelor of Science Degree in Agriculture. Dereck started working for the Plateau Research and Education Center of The University of Tennessee in January of 2012. In the fall of 2014, Dereck decided to begin his Master's Degree at The University of Tennessee. Following graduation Dereck looks forward to beginning his work toward a Ph.D. in agricultural sciences. Dereck enjoys spending time with his wife Ashley and son Grey and in his free time he enjoys exercising, fishing and kayaking.