The Effects of Phosphorus and Nitrogen Fertilization on Tall Fescue Nutrient Content, Yield and Baleage Quality

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THE EFFECTS OF PHOSPHORUS AND NITROGEN FERTILIZATION ON TALL FESCUE NUTRIENT CONTENT, YIELD AND BALEAGE QUALITY

A Masters Thesis

Presented to

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Master of Science, Plant Science

By

Cheyenne A. Arthur

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THE EFFECTS OF PHOSPHORUS AND NITROGEN FERTILIZATION ON TALL FESCUE NUTRIENT CONTENT, YIELD AND BALEAGE QUALITY

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ABSTRACT

Tall fescue (*Festuca arundinacea* Schreb.) is a cool season perennial grass commonly used in year-round forage production systems. Producers often wrap large round bales of tall fescue in plastic. The fermented product of this practice, termed baleage, allows the forage to be stored for later feeding. During periods of rapid growth in the spring and the fall, the nutrient content of tall fescue can be imbalanced and cause nutritional disorders in grazing animals. To improve the nutrition of tall fescue, it is known that fertilization of phosphorus (P) can help improve leaf nutrient content of P, magnesium (Mg), and calcium (Ca). Additionally, nitrogen (N) fertilization is known to improve forage quality. The objective of this study was to examine the effects of both N and P spring fertilization on tall fescue nutrient content and yield, as well as the effects of these treatments on baleage quality from these pastures. A 2014-2015 field study utilized eight different two-acre pastures, each with a P rate of 0, 25, 50, or 100 lbs P/A and a N rate of 0 or 50 lbs N/A. These studies found that N and P fertilizer did not affect yield and did not change tall fescue leaf calcium or magnesium content; however leaf P was increased with P fertilization. N treatments increased baleage protein content in the 2014-2015 study, but other quality measures were not affected by N and P treatments. The 2015-2016 field study using only P treatments and more replicates will be completed and replicated an additional year to further elucidate effects of P fertilization on tall fescue baleage.

KEYWORDS: tall fescue, baleage, nitrogen, phosphorus, wrapped bales

This abstract is approved as to form and content

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Dr. Melissa Remley
Chairperson, Advisory Committee
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INTRODUCTION

Tall Fescue

Tall fescue (*Festuca arundinacea* Schreb.) is a perennial, cool season grass that originated in Europe, Siberia and North Africa. Tall fescue began to appear in the United States around 1870. The University of Kentucky released the cultivar "Kentucky 31" in 1943, which increased the use of tall fescue. From 1940 to 2013 tall fescue could be found across an additional 37,060,500 acres in the United States, (Rogers and Locke 2013). Tall fescue covers about 17 million acres in Missouri. It is a very competitive plant which allows it to thrive and out compete some of Missouri's native grasses (Ladd 2009). Tall fescue thrives due to its ability to withstand low phosphorus (P) and acidic soils, heat and cold stress, overgrazing, and insect pressures. These characteristics make tall fescue one of the most popular grasses utilized today (Ball et al. 2007, Hoveland 2010, Rogers and Locke 2013).

Blevins et al. (2011) found that due to freezing more nutrient concentrations [phosphorus (P), calcium (Ca) and potassium (K)] are found in the brown growth versus the green growth. Magnesium (Mg) did not show a difference in concentration rates in the old versus the new (Blevins et al., 2011). Sodium (Na) and K are nutrients that leach easily from forages due to their high solubility (Blevins et al. 2011). This is import for producers to know when they are trying to manage their pastures economically with their cattle.

U.S. beef cow-calf production is mainly supported by tall fescue. This equates to about 8.5 million beef cows on 25 million acres and places the value of tall fescue at $5.6

billion (Hannaway et al. 1999). Beef cattle production is an important part of Missouri agriculture, and the state ranks second in beef cattle production behind Texas (USDA 2014). In order to support beef cattle operations throughout Missouri, producers depend on predominantly tall fescue pastures.

As a cool season grass, in Missouri most of its growth occurs in the spring (February-May) and fall (September-December). This growth curve can be well utilized by cattle producers. Spring growth is able to be used for hay or baleage. Baleage is starting to be utilized more often due to its ability to have more moisture than traditional methods during the time of baling. Tall fescue is known for its growth to stay green and in relatively good nutrient quality for a few months after growth has stopped. This trait allows fall growth to be stockpiled and utilized by grazing the forage during the winter months when forage becomes scarce. Tall fescue has also been known to have high nonstructural carbohydrate concentrations, which makes it easier for livestock to digest and absorb nutrients (Sleper and West 1996).

Concerns Using Tall Fescue as a Forage

Tall fescue is a very useful forage for producers, however it does come with some concerns. Tall fescue is known to have an endophyte, a fungus called *Neotyphodium coenophialum* (Ladd 2009). Plants with this endophyte are called endophyte-infected (E+). Ladd (2009) found that around 80% of plants in Missouri are E+.

Tall fescue acts as a host for the endophyte fungus (Rogers and Locke 2013). During the summer months (June, July, and August) the endophyte is known to be at its highest level of concentration (Aljoe 1999).While the plant houses the fungus, the endophyte produces

ergot alkaloids that allow the plant to be insect resistant, however are detrimental to livestock that consume it (Rogers and Locke 2013).

Ergot alkaloid consumption causes vasoconstriction, known to result in increased body temperatures, lameness and ultimately loss of the feet/hooves ("fescue foot"), tail and ear tips. Increased temperatures causes livestock to seek shade or water. This is known as fescue toxicity (ergot poisoning) in livestock. Fescue toxicity is also recognized by slow or no rate of gain, decreased milk production and an affected nervous system. This is typically seen during cold weather when livestock is grazing the toxic (E+) fescue (Ball et al. 2007, Roberts 2009, Rogers and Locke 2013).

Since the endophyte is spread via seeds, endophyte-free (E-) tall fescue was produced by removing the endophyte from the seed. This is done using heat and humidity to kill the endophyte within the seed (Hopkins et al. 2010). Livestock can graze the E- fescue with little issues and increased performance. However, the E- fescue plant is not as vigorous, insect resistant or drought and overgrazing tolerant as E+ fescue plants (Rogers and Locke 2013).

Novel-endophyte-infected tall fescue (Novel E+) is another option for producers. Novel fescue is infected with a naturally occurring endophyte, but the strain of endophyte does not produce ergot alkaloids. Cattle on novel E+ fescue will not be affected by fescue toxicity and shown similar gains as if they were on wheat or rye pastures (Ball et al. 2007, Rogers and Locke 2013). Novel E+ fescue has the same tolerance and resistance traits as E+ fescue (Ball et al. 2007).

Grass Tetany

To reduce the potential of grass tetany (hypomagnesemia) in cattle, several studies have focused on increasing Mg and/or improving the grass tetany ratio in tall fescue leaves. Grass tetany is linked to a K, Ca and Mg levels in the forage. When the ratio K/(Ca + Mg) exceeds 2.2 grass tetany symptoms can be seen. Grass tetany is also seen when Mg is less than 0.2%, and when Ca is less than 0.4% (Blevins and Sanders 1993/94).

Grass tetany is a disorder that can be observed during the spring and fall when there is rapid grass growth. Excessive rainfall is often observed during the spring and fall which can contribute to low soil oxygen levels. Low soil oxygen levels is known to inhibit a plants uptake of Mg. Therefore, Mg in tall fescue plant tissue is decreased, even if soil Mg is sufficient (Ball et al. 2007, Sleper and West 1996). Forages low in Mg can cause cattle to have low blood Mg levels.

Producers in Missouri have spring-calving cows or fall-caving cows. These calving seasons correspond with the periods of rapid tall fescue growth to support the forage needs of the lactating cows. Around 60 percent of cows located in Missouri calve in the spring (February and March). Late gestation and during lactation has shown to increase the cows demand for Mg (O'Kelley and Fontenot 1969). Since producers calve at the same time new tall fescue growth is occurring, their cow herd is at a higher demand for adequate nutrients and at an increased risk for grass tetany.

Cattle whose blood Mg levels are low can be found to show signs of staggering, jerking, teeth grinding, seizures, unconsciousness and ultimately death. Death can occur as soon as two to three hours from the first symptoms. Cattle that are most affected by

grass tetany are cows who recently calved or are at peak lactation. Producing milk for their young requires a substantial amount of Mg (Ball et al. 2007, O'Kelley and Fontenot 1969, Stewart 2013).

Many cattle producers will try to prevent grass tetany by providing a high Mg mineral to their cattle. Most minerals use magnesium oxide as their Mg source, which is not well liked by livestock. Cattle would have to consume four ounces of an 8-12% Mg mineral in order to retain a good nutrient ratio, but it is the most dependable control of added Mg to the producers herd (Ball et al. 2007, Stewart 2013).

Fertilizing has shown to be a producer's best advantage in order to avoid grass tetany (Stewart 2013). Dolomitic limestone can be applied to pastures in order to improve pasture Mg levels. Another option for producers would be to add phosphorus fertilizer, which aids in the plants uptake of Mg (Ball et al. 2007).

Phosphorus Fertilizer

Phosphorus is a key element for seed and root production, and aids in photosynthesis (Ball et al. 2007). Shoot and root growth can be increased by P fertilizer when P is a limiting factor (Martinefsky et al. 2010). Tall fescue grown on soils with low plant-available P have decreased Mg levels in the leaf during the fall and into the spring. For leaf nutrient uptake, both P and Mg can be increased in leaf tissues with P fertilizer applications (Blevins et al. 2004). Blevins et al. (2004) found that fall P fertilizer applications (rates of 0, 12.5 and 50 lbs P/A) increased leaf Mg during the following March and April. Although none of the P treatments increased leaf P enough to meet the dietary requirements of lactating cows, Mg levels reached the needed 0.20% under the 25

lbs P/A treatment. Potassium was also increased by all P treatments (Blevins et al. 2004). These results suggested that fall P fertilization could alter tall fescue leaf nutrients to improve the grass tetany ratio and reduce the risk for grass tetany.

Additional studies have shown that P fertilizer can improve P, Mg and Ca concentrations by improving the nutrient movement from the roots to the shoots and leaves (Reinbott and Blevins 1991, Blevins and Sanders 1993/94). Reinbott and Blevins (1997) found that spring P fertilizer applications not only increased forage quantity, but leaf Ca, Mg and K concentrations could be increased in spring growth. However, these concentrations are diluted when grazed by livestock because of additional consumption of stems that have less concentrated nutrients (Reinbott and Blevins 1997). It has aslo been shown that applying Mg fertilizer alone did not show a change in forage nutrients, however, when Mg and P fertilizers were applied together, it resulted in the best chance at improving leaf and shoot nutrients (Blevins and Sanders 1993/94, Reinbott and Blevins 1997). Calcium (Ca) concentrations were also raised in leaf tissue with P fertilizer, however Reinbott and Blevins (1994) believed this could be due to the presence of Ca in the fertilizer used, triple super phosphate.

Lock et al. (2002) conducted a study with cows grazing tall fescue that was grown on an adequate soil P level (30 lb/acre – P fertilized) and tall fescue grown on soil low in P (6 lb/acre – control). Fertilizer was applied in February and cattle were grazed during the typical grass tetany season, 3 weeks before new fall growth and ended 6-8 weeks later. Results showed that Mg was leached from tall fescue leaves while being stockpiled over the winter months (February), but by day 28 Mg held constant in P fertilized plots, where the control of low P declined in Mg as spring growth occurred. Over time K was

also seen to increase in the forage that had been treated with P fertilizer (Lock et al. 2002). Before rapid growth occurred Ca concentrations did not differ, however once new growth occurred the P fertilized area had greater Ca concentrations over the non-fertilized area. Lock et al. (2002) also calculated the potential for forage to induce grass tetany, which resulted in both treatments being safe for livestock. Phosphorus fertilizer has not only shown to reduce grass tetany, but it also has shown to increase calf rate of gains. Lock et al. (2004) found that calves gained 10% more live weight per day from P fertilized pastures. Lock et al. (2004) used claves ≤ 75 days old, so this is thought to be from greater milk production which may be related to higher nutrition in the pastures (Lock et al. 2004).

Nitrogen Fertilizer

Nitrogen has been used to increase yield of pastures whether it be for grazing after growth or stockpiling in the fall. In order to get a good stand of stockpiled forages, many producers use N fertilizer to increase their production. This ensures enough forage for their livestock when forage quantity is crucial (Johnston 2010).

Nitrogen fertilizer is known to increase quantity of forage grown, as well as, alter characteristics of baleage aiding with fermentation, and increasing crude protein and hemicellulose (Sauvé et al. 2010). Sauvé et al. (2010) found that N helps to improve dry matter and N content, as well as, cellulose digestion in gamagrass baleage. Nitrogen was also seen to increase crude protein, but decreased fiber fractions except for hemicellulose of baleage. Producers are always looking at how their forages will be affected by

different practices. Little research has been done on how different rates of N will affect the characteristics of tall fescue baleage.

Liming Effect

Most Missouri pastures have to be limed in order to keep the soil pH near 6.0, an adequate pH for most forage crops. Lime applications help add Ca and Mg to the soil, and to neutralize hydrogen (H) and aluminum (Al) toxicity. While helping with nutrient availability, lime also helps to increase soil pH and freeing P for plant uptake (Hamiltion et al. 2012).

According to Hamilton et al. (2012), tall fescue leaf Ca was increased greater by calcitic lime over dolomitic lime. Dolomitic lime increased Mg concentrations in both the soil and leaves, while calcitic showed a negative effect on both. Leaf K continually decreased with both calcitic and dolomitic lime applications.

Baleage

Weathering of baled forage, without plastic wrap, has shown to reduce the quality of round bales stored outside. The inside of the bales remain in good quality, where the weathered areas decrease by around 37% over a five month period (Collins et al. 1997). When quality decreases, so does the digestibility (Collins et al. 1997). This makes it hard for livestock to consume.

Previous research has shown that protein is one of the least affected quality components to be affected by storage. Protein form weathered areas of a bale cannot be used as efficiently by livestock (Collins et al. 1997). Hay that has been weathered is

known to be poor quality because the soluble carbohydrates have been leached away or microbial growth has consumed them. When fiber concentrations increase, then the livestock's rumen uses fibrous elements more slowly, which causes livestock to consume less forage.

Since traditionally baled hay is typically baled in the spring, producers have to avoid spring rains during the drying period. Rain causes nutrients to be leached away from the drying forage. Net wrapped bales have been shown to provide some protection, but could not prevent loss of quality (Collins et al. 1997). Baleage is a popular alternative to dry hay because producers do not have to wait for the moisture levels to decrease before baling. Baleage allows producers to bale forage at a higher moisture content (40-60% moisture), rather than having to wait for several dry days to get traditional hay (18-20% moisture) baled (Lemus 2010). The bales are then wrapped in special plastic, which allows the bales to ferment and preserve the forages nutrients. The solid, water resistant, plastic allows the water to run off the bales. Sunlight is also not able to penetrate the bales (Collins et al. 1997). The plastic layer protects the bales against weather damage. Baleage allows the producer to be timelier in putting up forage for later use, as well as, have less probability of complications with rain.

Wrapping bales in plastic allows the bales to have a 7% loss versus a 35% loss found in traditional bales (Collins et al. 1997). The plastic wrap can be applied at the time of baling, which makes it convenient for producers (Collins et al. 1997). It also allows a producer to bale forage even in poor drying conditions (Yan et al. 2011). Baleage bales will be smaller than traditional hay bales due to extra weight from the higher moisture content (Lemus 2010). More nutrients are preserved when the fermentation process

happens quickly. Lactic acid contributes to the fermentation process. Fermentation should take approximately 15-30 days. The anaerobic environment prevents the bales from molding (Lemus 2010).

Baleage allows producers to preserve their forage until it's needed. Bales can be wrapped two ways, singly or in a tube. Tubed bales are more economical and easier to handle for a producer than the single wrapped bales. Wrapped bales show very little deterioration, except for where the plastic may be punctured (Shinners et al. 2009).

Outside storage causes bales to have high moisture levels and little air movement on the bottom of the bales which can add to bale damage (Collins et al. 1997). New technology of plastic wrap has allowed producers to reduce outside storage losses. There are four types of plastic that can be used during the wrapping process white is used for high sunlight areas, black for low sunlight areas, 4 ml plastic for first year use and 8 ml plastic for use required over a year (Lemus 2010). Bales are wrapped with 50% overlap to produce minimal loss. Baleage bales can run a risk of getting over heated, if not properly wrapped. When bales over heat, protein is denatured (Lemus 2010). Damage from heat during the summer months has also shown to be an economic loss to the producer (Yan et al. 2011). Han et al. (2006) found that bales stored for 8 months with a high dry matter (DM) content showed little change in nutrient quality after overheating. DM content at time of baling showed small affects in fermentation (Han et al. 2006). There is less quality and digestibility loss during storage due to the plastic film around the bale. This allows the producer to be more efficient and produce a better product to feed his/her livestock when the harsh winter hits.

Current Study

This study examines P and N fertilization effects on tall fescue (*Festuca arundinacea* Schreb.) based pastures in southwest Missouri, and how nutrient content and quality of baleage made from those pastures are affected. N is commonly applied in the spring and/or fall to tall fescue pastures to increase quantity and quality of spring forage production. P fertilization during the spring and/or fall has been shown to increase leaf nutrient concentrations in tall fescue grown on low P soils by the time forage is ready for harvest. Currently, there is little information on P and N fertilization effects on the quality and quantity of tall fescue when used for baleage.

The objective of the study is to determine if spring P and N fertilization of tall fescue pastures affects leaf nutrient concentration, subsequent spring baleage quality and quantity, as well as, soil quality. My hypothesis is that by increasing the availability of P and N to tall fescue, a subsequent increase in leaf nutrient concentrations and forage quality will occur. Subsequent baleage will also have an increase in nutrient concentrations and quality.

MATERIALS AND METHODS

2014-2015 Field Study

Site Selection. On April 25, 2014, soil from established, predominately tall fescue pastures were sampled from Missouri State University's Baker's Acres farm near Elkland, MO in order to determine soil fertility. Samples were collected to the depth of six inches and a width of a standard soil probe and standard soil analyses were conducted by the University of Missouri, Columbia Soil Testing Laboratory in Columbia, MO. From these results, eight plots were selected for this study based on same soil type, similar salt pH, and similar low (less than 20 lbs./acre) available phosphorus content (Bray I P). Pastures available to choose from were (Figure 1): (1) 3.65 acres, 5.5 pHs, 21 P; (2) 5.70 acres, 5.7 pHs, 17 P; (3) 1.71 acres, 6.4 pHs, 27 P; (4) 4.33 acres, 6.4 pHs, 21 P; (5) 4.67 acres, 6.4 pHs, 22 P; (6) 6.64 acres, 6.1 pHs, 24 P; (7) 3.34 acres, 5.7 pHs, 24 P; (8) 2.95 acres, 5.9 pHs, 40 P; (9) 4.21 acres, 6.7 pHs, 38 P; (10) 2.28 acres, 5.3 pHs, 23 P. Four of these pastures were selected and divided for the 2014-2015 field study (Figure 2).

Experimental Design and Treatments. Fertilizer treatments of 0, 25, 50, and 100 lbs. P/acre, equivalent to 0, 28, 56, and 112 kg P/ha, respectively, were in the form of triple super phosphate (0-46-0). Nitrogen treatments of 0 and 50 lbs. N/acre, equivalent to 0 or 56 kg N/ha, respectively, were in the form of ammonium nitrate (34-0-0). The eight combinations of P and N treatments were randomly assigned to the 8 pastures (Figure 2) and were broadcast- applied on April 25, 2014.

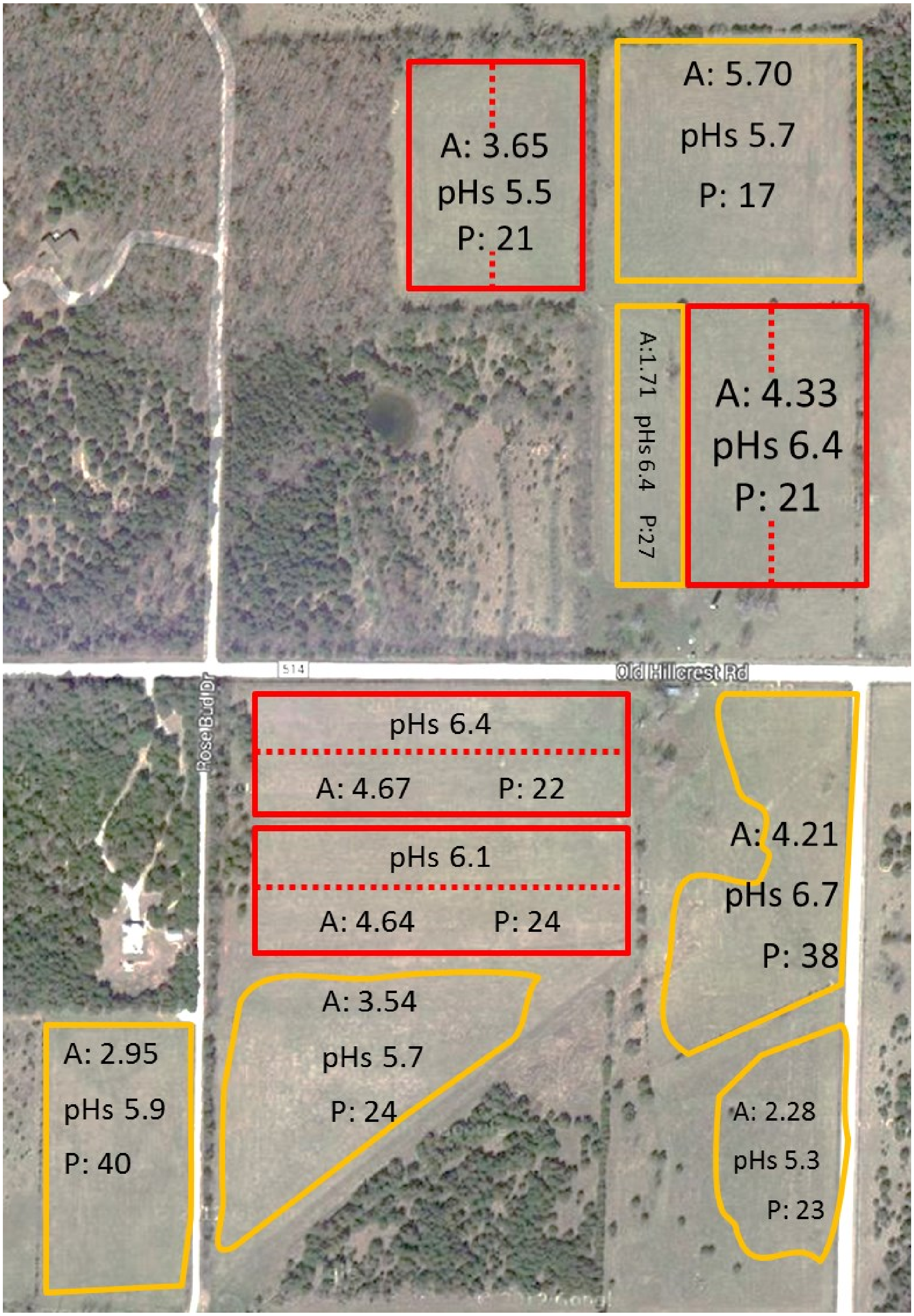

Figure 1. Available pastures to use for 2014-2015 field study. Acreage, phosphorus and pHs is represented in the figure.

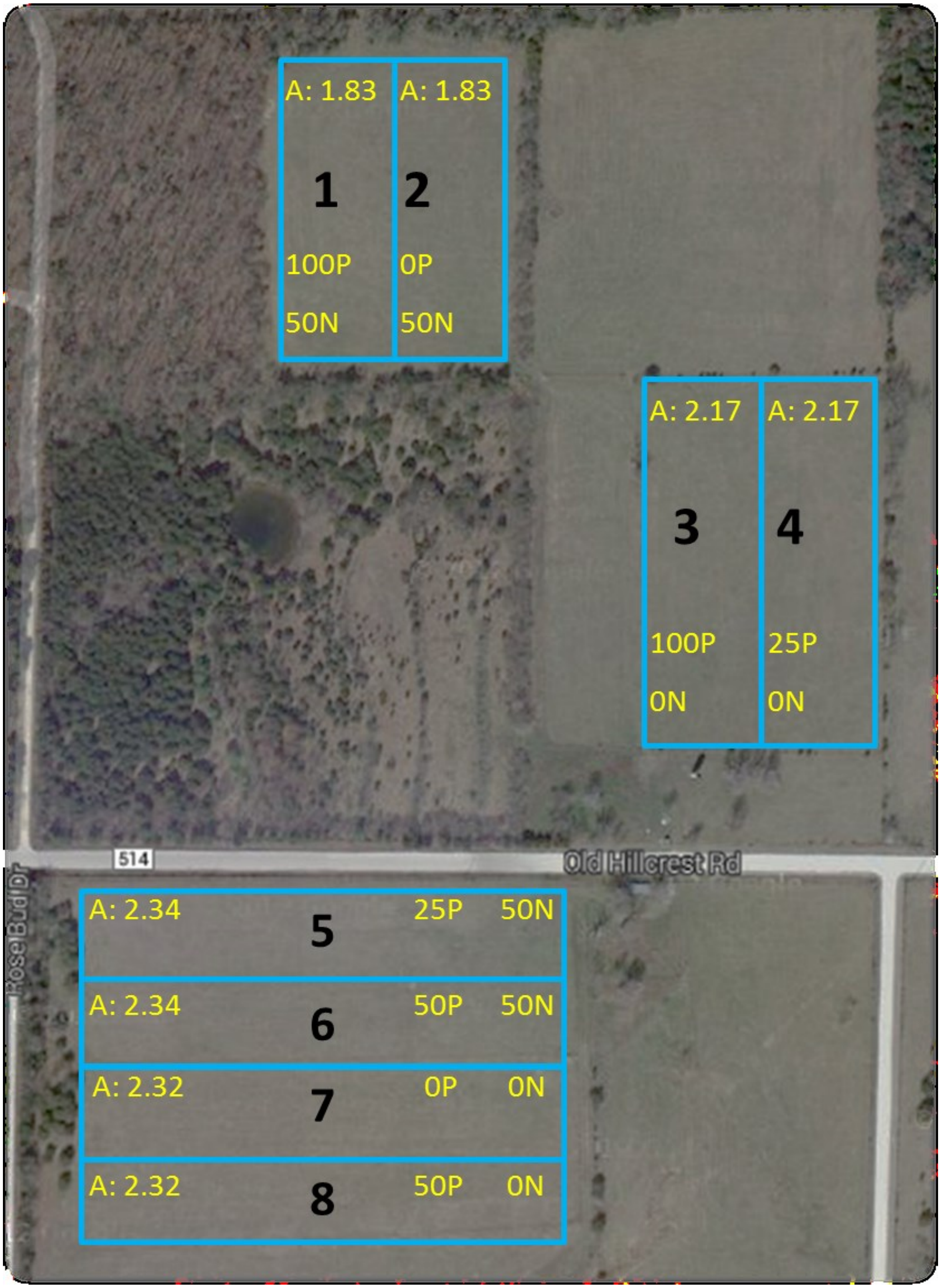

Figure 2. Selected pastures for 2014-2015 field study with plots labeled with plot numbers, acreage and treatments.

Measurements. Soil samples were collected from each of the eight plots before fertilizer treatments (April 25, 2014), at spring harvest 4 weeks after treatment applications (May 27, 2014), and in early autumn 22 weeks after treatments (September 29, 2014). Three samples from each plot were collected, with each sample containing 10 to 15 soil probes to a six inch (15.24 cm) depth collected at random. Soil samples were air dried and analyzed by the University of Missouri Soil Testing Laboratory (Columbia, MO) for salt pH (pHs), nutrient availability (N.A.), percent organic matter, P Bray I, Ca, Mg, K and cation exchange capacity (CEC).

Forage dry matter yield was estimated by harvesting six random swaths in each plot, each swath was three feet by ten feet (0.914 m by 3.048 m) and cut at a four inch (10.16 cm) height with a sickle bar walk-behind mower. This is a total area of 30 sq. ft. (2.79 sq. m) per swath. Yield harvests were conducted on April 24, 2014 (before fertilizer treatments), May 2, 2014 (5 weeks after treatments) to estimate total spring forage production, and on September 26, 2014 (22 weeks after treatment), to estimate fall regrowth. Each swath cut was considered a sample, and for each sample fresh weight was determined on site, a sub-sample was collected [on average 3.97 lbs. (1.8 kg)], dried, and reweighed for dry weight. To ensure sub-samples were thoroughly dried, a sample at random was weighed daily until no further weight reduction occurred. Percent moisture of sub-samples were used to extrapolate dry weight yield of the field samples.

Beginning on April 25, 2014, tall fescue leaf samples were harvested monthly until April 2015. Samples were collected near the first of each month (April 25, May 27, July 1, August 5, September 3, September 29, November 3, December 3, 2014, and January 5, January 29, March 17, and March 27, 2015). For each harvest, three leaf

samples were collected from each plot, with each sample containing 20 most recently collared leaves. Samples were oven-dried then ground using a modified coffee grinder. Ground samples were weighed to 250 mg (0.2500-0.2505 g), placed into Teflon™ tubes, and digested in 5ml of concentrated trace metal grade nitric acid (Fisher Scientific) using an accelerated microwave digestion system (MARS6, CEM Corp.) using the Plant Materials method (CEM Corp.). The Plant Materials method heats up to 200 °F (93.33 °C) in during a 20 minute period and holds that temperature for 10 minutes. The machine then cools for 15 minutes. Each sample was then brought to a final volume of 25ml using deionized water, then filtered through number one filter paper (Fisher Scientific) and stored in a 25ml polypropylene vial

Atomic absorption spectrometry (200 Series AA, Agilent Technologies, Varian, Inc.) was used to determine Ca, Mg, and K concentration of the samples. Phosphorus was determined using a colorimetric assay (Murphy and Riley, 1962) and spectrophotometer (Spectronic20+, Milton Roy).

Forage was cut at a four inch (10.16 cm) height for baleage using a John Deere 630 MoCo with impeller conditioners pulled by a John Deere 5115M tractor once adequate vegetative growth (boot to pre-bloom stage) had occurred on June 3, 2014. Once cut and before baling the forage was raked using a Frontier WR1010 wheel rake pulled by the John Deere 5115M tractor. The forage was then baled with a John Deere 458 round baler and a John Deere 6105M tractor when moisture decreased to 45-55%, within 24 hours of cutting. Bales were individually wrapped in plastic using an Anderson RB600 bale wrapper with the wrapper's computer set at 24 revolutions with 30 inch (76.2 cm) wrap. This setting made at least 6 layers of film in any given location. The bales

were then stored outside to allow fermentation over time. Baleage was sampled using a Colorado Hay Probe (UDY Corp.) that collected cores to an 18 inch (45.72 cm) depth with a 5/8 inch (1.588 cm) diameter through the bale. Baleage samples were collected from three randomly selected bales per plot, and combined into one sample per plot. Each sample contained 18 baleage probes. One subsample was collected to be dried and analyzed for nutrient content using the same methods for tall fescue leaf samples. Another baleage sub-sample was collected from each sample and immediately shipped to Midwest Laboratories (Omaha, NE) for forage quality analyses. Using the F10 package the following parameters were measured in the quality analysis: moisture, neutral detergent fiber (NDF), acid detergent fiber (ADF), crude protein, mineral content, net energy, and relative feed value (RFV).

Statistical Analyses. Soil tests and baleage quality and nutrient measurements were analyzed using the general linear model and Tukey's pairwise comparisons using Minitab 17 statistical software (Minitab, Inc., State College, PA). Yield, and leaf P, Ca, Mg, and K, were analyzed using repeated measures in the general linear model procedure and Tukey's pairwise comparisons of Statistical Analysis Systems software (SAS Institute Inc., Cary, NC). Differences between means were considered significant when $P<0.05$.

2015-2016 Field Study

Site Selection. In spring 2015, the study was redesigned and pastures were again soil tested before the treatments began. These soil samples were sent to University of Missouri, Columbia Soil Testing Laboratory in Columbia, MO and tested for similar salt

pH, and similar low (less than 20 lbs/A) available phosphorus content (Bray I P). Pastures were also selected based on acreage. One plot from the previous study (plot 4) was used and one new pasture was selected at Baker's Acres (Figures 3 and 4).

Figure 3. Area selected for 2015-2016 field study listed with acreage, phosphorus and pHs.

Figure 4. Randomized block design with plot P treatments for the 2015-2016 field study.

Experimental Design and Treatments. A random complete block design was implemented with four blocks, each block containing randomized treatments. Each plot was 40 ft. wide and 460 to 550 ft. in length (12.2 m and 140.2 to167.64 m). On April 6 and 7, 2015, P fertilizer at rates of 0, 25, 50 and 100 lbs P/acres, equal to 0, 28, 56 and 112 kg P/ha, respectively, were applied to randomly selected plots within each block. Phosphorus fertilizer was in the form of triple super phosphate (0-46-0) and broadcasted.

Measurements. One soil sample from each plot was collected on March 27, 2015 before fertilizer treatments, and on October 16, 2015, 28 weeks after treatment. Sampling procedures and soil analyses were the same as the previous year.

The same system of measuring yields was used in the new block design with 3 swaths per plot. Each swath was the same dimensions as the previous year. A spring harvest was done on May 13, 2015 (5 weeks after treatment) and a fall harvest was done October 16, 2015 (28 weeks after treatment).

Tall fescue leaf samples were collected monthly (March 27, May 13, July 6, August 3, September 1, September 29 and November 2015), with one sample per plot of 20 most recently collared leaves. Leaves were not collected during the month of June, due to the shoots having been harvested for baleage before the collection period. Preparation and analyses of leaves were done the same as the previous field study.

Baleage was harvested and wrapped using the same procedures and equipment as the previous year. It was allowed to sit and ferment over the 2015-16 winter, and will be sampled with the Colorado Hay Probe (UDY Corp.) this winter. Samples will be collected using the same method as the 2014-2015 field study. The samples will then be immediately shipped to Midwest Laboratories (Omaha, NE) for forage quality analyses.

Using the F10 package the following parameters were measured in the quality analysis: moisture, neutral detergent fiber (NDF), acid detergent fiber (ADF), crude protein, mineral content, net energy, and relative feed value (RFV).

Statistical Analysis. Soil and yield was analyzed using Minitab general linear model and tukey test. PROC MIXED procedure of SAS was used to look at yield, leaf nutrients and baleage. The treatment, as well as, the treatments interaction with each harvest/date was analyzed. Interactions and effects were marked significant when $p<0.05$.

RESULTS

2014-2015 Field Study

Soil. The initial soil fertility tests showed variation amongst the plots (Table 1). Four weeks after the fertilizer treatments were applied and at the time of baling, a second soil sample was collected. At this time, variation of soil fertility still existed between plots, and the highest P fertilization treatment, 100 lbs P/A showed a significant increase in Bray I P over the 0 P/A plot (Table 2). A fall soil sampling, 22 weeks after treatment, showed significant increases in soil Bray I P as P fertilization increased (Table 3). This increase in soil P with increased fertilization continued into the following spring (Table 4).

Forage Yield. Measurements of forage dry weight before fertilizer treatment applications (April 25, 2014) indicate initial variation across plots (Figure 5, Table 5). Tukey's pairwise comparisons indicated the 50 lb N/A plots were significantly greater than the 0 lb N/A plots and the 100 lb P/A were significantly greater than the other P treatment plots (Table 5).

Five weeks after spring fertilizer treatments, forage yield did not differ between P treatments ($p=0.075$), and variation was evident across N treatments, with the 50 lbs N/A plots exhibiting greater yield than 0 lbs N/A plots. (Figure 6, Table 5). The increase in forage yield due to N fertilization was also significant 22 weeks after treatment, as indicated in the September 26, 2014 harvest (Figure 7, Table 5). Phosphorus fertilization had no significant effect on yield (Figure 7, Table 5).

Table 1. Before treatment (4/25/2014) soil fertility test results (top) and ANOVA *F* values (and p values) (bottom).

Treatment		pHs	N.A. (meq/100g)	%OM	P Bray I (lb/A)	Ca (lb/A)	Mg (lb/A)	K (lb/A)	CEC (meq/100g)
0 P									
	0 N	6.1±0.1b	0.7±0.2a^{y}	1.6±0.2	13±1^{x}	1057±120	266±6ab^{y}	197±13	5.0±0.2
	50 N	5.8±0.1b	1.3±0.2a^{x}	1.5±0.1	12±2^{y}	1100±185	384±40ab^{x}	187±11	5.9±0.6
25 P									
	0 N	6.2±0.1a	0.7±0.2b^{y}	1.4±0.2	9±1^{x}	1450±346	359±43a^{y}	144±5	6.0±0.6
	50 N	6.6±0.1a	0.2±0.2b^{x}	1.6±0.0	10±2^{y}	1617±118	407±12a^{x}	195±16	6.1±0.4
50 P									
	0 N	6.0±0.1b	0.7±0.2ab^{y}	1.5±0.2	10±1^{x}	1057±120	233±19b^{y}	147±9	4.5±0.5
	50 N	6.3±0.0b	0.5±0.0ab^{x}	1.4±0.1	10±1^{y}	1291±76	292±33b^{x}	217±25	5.2±0.3
100 P									
	0 N	6.4±0.0b	0.3±0.2ab^{y}	1.4±0.2	18±2^{x}	1267±123	327±31ab^{y}	195±7	5.1±0.4
	50 N	5.8±0.1b	1.3±0.2ab^{x}	1.4±0.0	8±1^{y}	1231±273	303±30ab^{x}	144±24	5.8±0.4
N	1 df	0.56	5.14	0.07	6.10	0.40	5.73	1.81	3.85
		(0.467)	(0.038)	(0.798)	(0.025)	(0.536)	(0.029)	(0.198)	(0.067)
P	3 df	11.22	5.52	0.37	3.06	2.56	5.56	0.99	2.37
		(0.000)	(0.008)	(0.777)	(0.058)	(0.091)	(0.008)	(0.422)	(0.109)
N*P	3 df	15.96	10.10	1.07	4.87	0.48	1.93	6.35	0.28
		(0.000)	(0.001)	(0.390)	(0.014)	(0.701)	(0.165)	(0.005)	(0.840)

Column means (± Std. Error) across P treatments that are not followed by the same letter (a,b,c,d) are significantly different ($p<0.05$, using Tukey's pairwise comparisons). Column means (± Std. Error) designated by superscript letters (^{x},^{y}) compare N levels across P treatments.

Table 2. Four weeks after treatment (5/27/2014) soil fertility test results (top) and ANOVA *F* values (and p values) (bottom).

Treatment		pHs	N.A. (meq/100g)	%OM	P Bray I (lb/A)	Ca (lb/A)	Mg (lb/A)	K (lb/A)	CEC (meq/100g)
0 P									
	0 N	6.2±0.0b^x	0.5±0.0ab^y	1.6±0.1	15±3b	1209±89b	259±7b^y	200±13^y	4.9±0.2b^y
	50 N	5.7±0.2b^y	1.5±0.3ab^x	1.5±0.1	9±0b	1031±69b	376±29b^x	142±15^x	5.8±0.4b^x
25 P									
	0 N	6.2±0.0a^x	0.8±0.2b^y	1.7±0.1	29±6ab	1328±28a	357±6a^y	115±1^y	5.8±0.2a^y
	50 N	6.4±0.1a^y	0.3±0.2b^x	2.2±0.4	40±20ab	1743±152a	431±30a^x	235±10^x	6.8±0.4a^x
50 P									
	0 N	5.9±0.1b^x	1.2±0.2ab^y	1.5±0.0	26±2ab	1147±49b	263±7b^y	142±3^y	5.3±0.3b^y
	50 N	6.2±0.0b^y	0.7±0.2ab^x	1.7±0.1	40±7ab	1208±121b	326±29b^x	210±1^x	5.3±0.3b^x
100 P									
	0 N	6.3±0.0b^x	0.5±0.0a^y	1.5±0.1	56±10a	1282±61b	341±17ab^y	1173±24^y	5.3±0.2ab^y
	50 N	5.5±0.1b^y	1.7±0.2a^x	1.7±0.1	42±8a	959±142b	334±17ab^x	113±5^x	5.6±0.2ab^x
N	1 df	12.25 (0.003)	6.13 (0.025)	2.37 (0.143)	0.07 (0.797)	0.01 (0.934)	18.51 (0.001)	4.54 (0.049)	7.26 (0.016)
P	3 df	10.99 (0.000)	3.46 (0.041)	1.65 (0.217)	5.74 (0.007)	8.31 (0.001)	8.71 (0.001)	3.54 (0.039)	4.98 (0.012)
N*P	3 df	29.36 (0.000)	15.13 (0.000)	0.97 (0.430)	1.08 (0.385)	5.40 (0.009)	3.20 (0.052)	30.24 (0.000)	1.50 (0.253)

Column means (± Std. Error) across P treatments that are not followed by the same letter (a,b,c,d) are significantly different ($p<0.05$, using Tukey's pairwise comparisons). Column means (± Std. Error) designated by superscript letters (^{x},^{y}) compare N levels across P treatments.

Table 3. Twenty-two weeks after treatment (9/29/2014) soil fertility test results (top) and ANOVA *F* values (and p values) (bottom).

Treatment		pHs	N.A. (meq/100g)	%OM	P Bray I (lb/A)	Ca (lb/A)	Mg (lb/A)	K (lb/A)	CEC (meq/100g)
0 P									
	0 N	6.5±0.0b^{x}	6.5±0.0b^{x}	0.5±0.0b^{y}	7±1d^{y}	1372±43.67bc	310±14b^{y}	168±6a	5.4±0.1b^{y}
	50 N	5.9±0.0b^{y}	5.9±0.0b^{y}	1.5±0.0b^{x}	7±1d^{x}	1057±57.80bc	380±10b^{x}	148±11a	5.9±0.2b^{x}
25 P									
	0 N	6.1±0.0a^{x}	6.1±0.0a^{x}	1.0±0.0c^{y}	18±1c^{y}	1443±94a	350±7a^{y}	132±2a	6.2±0.2a^{y}
	50 N	6.6±0.0a^{y}	6.6±0.0a^{y}	0.3±0.2c^{x}	27±0c^{x}	1907±78a	437±19a^{x}	204±8a	7.2±0.4a^{x}
50 P									
	0 N	6.2±0.0a^{x}	6.2±0.0a^{x}	0.5±0.0c^{y}	36±2b^{y}	1068±53c	290±9c^{y}	148±1a	4.6±0.2c^{y}
	50 N	6.3±0.0a^{y}	6.3±0.0a^{y}	0.5±0.0c^{x}	33±6b^{x}	1028±61c	285±20c^{x}	170±10a	4.5±0.2c^{x}
100 P									
	0 N	6.5±0.0c^{x}	6.5±0.0c^{x}	0.5±0.0a^{y}	35±0a^{y}	1364±16b	370±5b^{y}	154±2b	5.7±0.1b^{y}
	50 N	5.6±0.0c^{y}	5.6±0.0c^{y}	2.2±0.2a^{x}	60±8a^{x}	1113±96b	320±10b^{x}	104±3b	6.4±0.4b^{x}
N	1 df	135.20 (0.000)	135.20 (0.000)	72.00 (0.000)	9.51 (0.007)	0.67 (0.426)	8.10 (0.012)	1.64 (0.218)	10.04 (0.006)
P	3 df	60.53 (0.000)	60.53 (0.000)	39.33 (0.000)	45.63 (0.000)	38.02 (0.000)	23.49 (0.000)	13.84 (0.000)	31.85 (0.000)
N*P	3 df	288.8 (0.000)	288.80 (0.000)	77.330 (0.000)	5.85 (0.007)	16.56 (0.000)	12.94 (0.000)	33.12 (0.000)	1.98 (0.158)

Column means (± Std. Error) across P treatments that are not followed by the same letter (a,b,c,d) are significantly different (p<0.05, using Tukey's pairwise comparisons). Column means (± Std. Error) designated by superscript letters (^{x},^{y}) compare N levels across P treatments.

Table 4. Forty-seven weeks after treatment (3/27/2015) soil fertility test results (top) and ANOVA *F* values (and p values) (bottom).

Treatment		pHs	N.A. (meq/100g)	%OM	P Bray I (lb/A)	Ca (lb/A)	Mg (lb/A)	K (lb/A)	CEC (meq/100g)
0 P									
	0 N	6.3±0.0bc^{x}	0.3±0.2ab^{y}	1.4±0.1ab^{y}	12±1c	1256±52bc	241±16b^{y}	140±5a	4.7±0.2a^{y}
	50 N	5.8±0.0bc^{y}	1.5±0.0ab^{x}	1.9±0.2ab^{x}	10±1c	1294±29bc	381±5b^{x}	120±8a	6.5±0.1a^{x}
25 P									
	0 N	6.2±0.1a^{x}	0.6±0.2c^{y}	1.7±0.1a^{y}	19±2bc	1473±77a	325±16a^{y}	109±7a	5.8±0.3a^{y}
	50 N	6.7±0.0a^{y}	0.0±0.0c^{x}	2.0±0.1a^{x}	21±4bc	1668±69a	409±20a^{x}	172±12a	6.1±0.3a^{x}
50 P									
	0 N	6.0±0.1ab^{x}	0.8±0.3bc^{y}	1.3±0.6b^{y}	21±0b	989±16c	194±3c^{y}	114±16a	4.2±0.2b^{y}
	50 N	6.5±0.0ab^{y}	0.0±0.0bc^{x}	1.6±0.0b^{x}	36±8b	1186±35c	271±14c^{x}	150±15a	4.3±0.2b^{x}
100 P									
	0 N	6.4±0.0c^{x}	0.3±0.2a^{y}	1.8±0.0ab^{y}	74±4a	1401±85b	314±13c^{y}	128±13b	5.3±0.4a^{y}
	50 N	5.3±0.2c^{y}	2.0±0.3a^{x}	1.6±0.0ab^{x}	37±14a	1209±143b	220±3c^{x}	68±7b	6.0±0.1a^{x}
N	1 df	6.63 (0.020)	7.37 (0.015)	7.32 (0.015)	1.80 (0.198)	1.26 (0.277)	30.72 (0.000)	0.38 (0.548)	19.00 (0.000)
P	3 df	18.73 (0.000)	10.40 (0.000)	4.06 (0.024)	21.46 (0.000)	14.71 (0.000)	39.76 (0.000)	5.78 (0.006)	21.71 (0.000)
N*P	3 df	36.33 (0.000)	24.58 (0.000)	3.52 (0.038)	7.33 (0.002)	2.96 (0.062)	28.24 (0.000)	13.06 (0.000)	5.62 (0.007)

Column means (± Std. Error) across P treatments that are not followed by the same letter (a,b,c,d) are significantly different ($p<0.05$, using Tukey's pairwise comparisons). Column means (± Std. Error) designated by superscript letters (^{x},^{y}) compare N levels across P treatments.

Table 5. 2014-2015 forage dry weight yield [before treatments (4/25/2014), 5 weeks after treatment (6/02/2014) and 22 weeks after treatment (9/26/2014)]. Results of the GLM procedure, repeated measures analysis of variance. Tests of hypotheses within harvest across all treatments (top) and univariate tests of hypotheses for within treatment (bottom).

	df	ANOVA *F* value	p value
N	1	112.32	(<0.0001)
P	3	6.89	(0.0008)
N*P	3	0.73	(0.5426)
Harvests	10	285.85	(<0.0001)
Harvests*P	30	4.69	(0.0004)
Harvests*N	10	20.38	(<0.0001)
Harvests*P*N	30	1.72	(0.1267)

Tall Fescue Leaf Nutrients. Leaf Ca content remained fairly stable throughout the 2014-2015 field study, except a dramatic increase in all treatments in the May 27, 2014 harvest (Figure 8). Although some P treatments increase leaf Ca compared to control plots, there was no stable increase or decrease in leaf Ca with treatments over time (Figure 8, Tables 6 and 7). The highest P treatment of 100 lbs P/A significantly increased leaf Ca in a few months. Baleage Ca content showed no difference across treatments (Figure 8).

Leaf Mg increased through the spring and summer 2014, and declined slightly through the winter months (Figure 9). Similar to leaf Ca, some harvests showed an increase in leaf Mg with P applications compared to control, however there was no stable increase or decrease in leaf Mg with treatments over time (Figure 9, Tables 8 and 9). Baleage Mg content showed no difference across treatments (Figure 9).

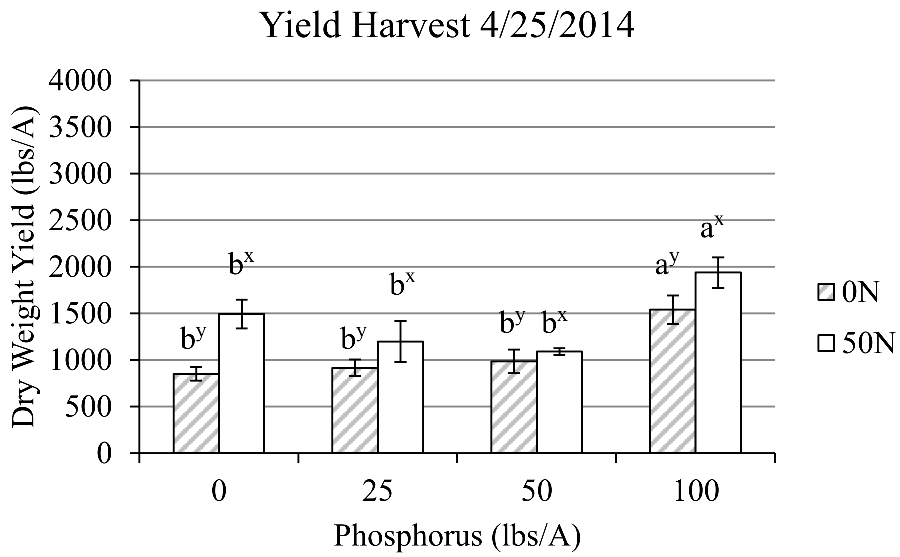

Figure 5. Forage dry matter yield of tall fescue based pastures before P and N fertilizer treatment applications, measured April 25, 2014. Each value is the mean ± Standard Error (n=6). Phosphorus treatments that are not followed by the same letter (a,b,c,d) are significantly different ($p<0.05$, using Tukey's pairwise comparisons). Superscript letters (^{x}, ^{y}) compare N levels across P treatments.

Leaf P content showed a trend of increasing during the spring and summer and decreasing during the winter months (Figure 10). In every monthly harvest following fertilization treatments, leaf P increased in all P fertilization treatments (Figure 10, Tables 10 and 11). In most months, an increase in P fertilization increased leaf P. Nitrogen application resulted in decreased levels of leaf P in most months (Figure 10, Tables 10 and 11). Baleage P content showed no difference across treatments (Figure 10).

Baleage Nutrient Content and Forage Quality. Forage quality measures for baleage showed an increase in protein content with N applications (Table 12). The 25 lbs P/A treatment had significantly different fiber, TDN, NE, and RFV values (Table 12).

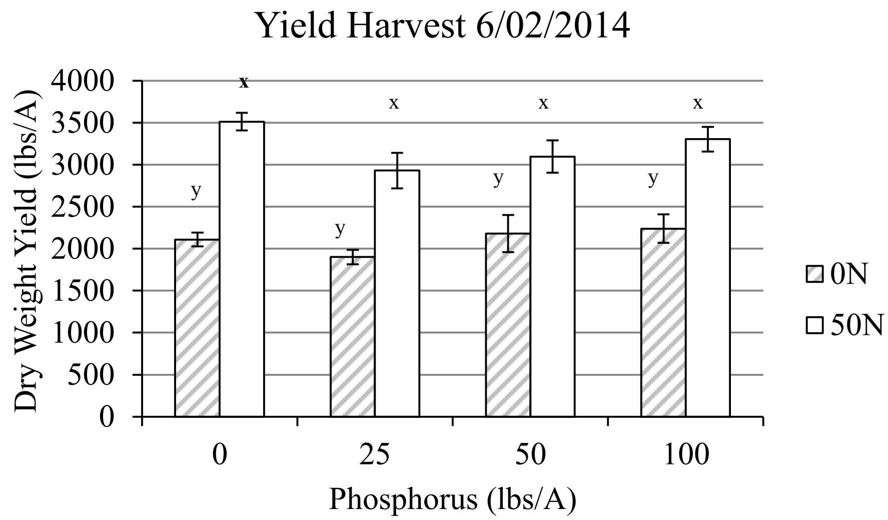

Figure 6. Forage dry matter yield of tall fescue based pastures 5 weeks after P and N fertilizer treatment applications, measured June 02, 2014. Each value is the mean ± Standard Error (n=6). Phosphorus treatments that are not followed by the same letter (a,b,c,d) are significantly different ($p<0.05$, using Tukey's pairwise comparisons). Superscript letters (^{x}, ^{y}) compare N levels across P treatments.

2015-2016 Field Study

Soil. Initial Bray I P was low (less than 12 lbs P/A) and both Bray I P and pH values were consistent across all plots (Table 13). Soil samples from May 13, 2015 and October 2015 have not been analyzed.

Forage Yield. Phosphorus fertilization treatments had no significant effect (p=0.7402) on forage dry matter production measured 5 weeks after treatment applications (Figure 11, Table 14), nor 28 weeks after treatment in the fall harvest (Figure 12, Table 14).

Tall Fescue Leaf Nutrients. Tall fescue leaf Ca content showed an increase in all treatments in the May 13, 2015 harvest (Figure 13). Leaf Mg content increased in the summer months and early fall (Figure 14). Phosphorus treatments had no significant effect on leaf Ca levels (p=0.4234) and leaf Mg levels (p=0.9440) in all harvests (Figure

13 and 14; Tables 15 and 16). However, leaf P was significantly increased with P treatment, with the 100 lbs P/A treatment increasing leaf P (p= 0.0461) in May 2015 (Figure 15, Table 17).

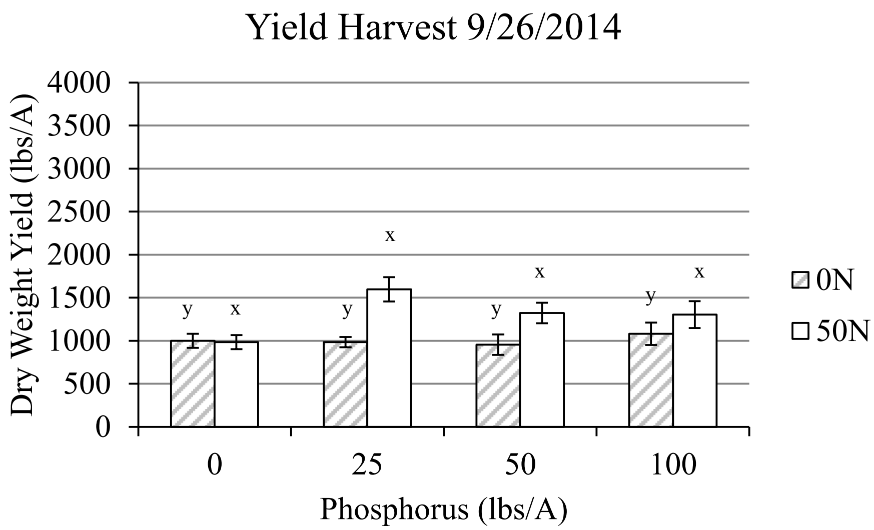

Figure 7. Forage dry matter yield of tall fescue based pastures 22 weeks after P and N fertilizer treatment applications, measured September 26, 2014. Each value is the mean ± Standard Error (n=6). Phosphorus treatments that are not followed by the same letter (a,b,c,d) are significantly different (p<0.05, using Tukey's pairwise comparisons). Superscript letters (^{x}, ^{y}) compare N levels across P treatments.

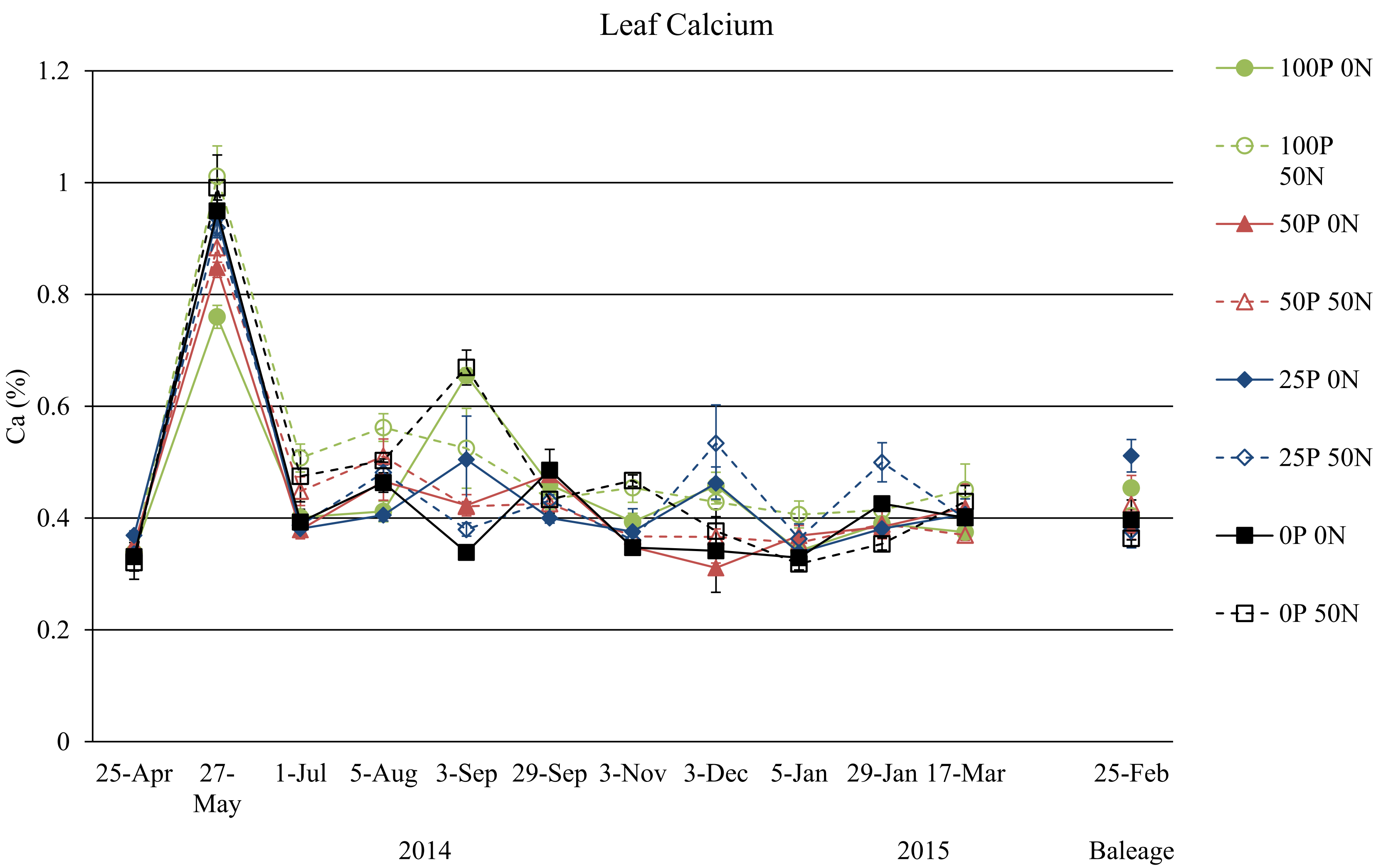

Figure 8. Leaf calcium content of tall fescue treated with P and N over time. Each value is the mean ± Standard Error (n=3).

Table 6. 2014-2015 leaf calcium [before treatment (4/25/2014) and monthly thereafter]. Tukey's pairwise comparisons and repeated measures ANOVA results.

Treatment		4/25/14	5/27/14	7/1/14	8/5/14	9/3/14	9/29/14	11/3/14	12/3/14	1/5/15	1/29/15	3/17/15
0 P												
	0 N		^{y}	^{y}	^{y}	ab		ab^y	b	b		
	50 N		^{x}	^{x}	^{x}	ab		ab^x	b	b		
25 P												
	0 N		^{y}	^{y}	^{y}	b		ab^y	a	ab		
	50 N		^{x}	^{x}	^{x}	b		ab^x	a	ab		
50 P												
	0 N		^{y}	^{y}	^{y}	b		b^y	b	ab		
	50 N		^{x}	^{x}	^{x}	b		b^x	b	ab		
100 P												
	0 N		^{y}	^{y}	^{y}	a		a^y	ab	a		
	50 N		^{x}	^{x}	^{x}	a		a^x	ab	a		

Phosphorus treatments that are not followed by the same letter (a,b,c,d) are significantly different ($p<0.05$, using Tukey's pairwise comparisons). Superscript letters (^{x}, ^{y}) compare N levels across P treatments.

Table 7. 2014-2015 leaf calcium results of the GLM procedure, repeated measures analysis of variance. Tests of hypotheses within harvest across all treatments (top) and univariate tests of hypotheses for within treatment (bottom).

	df	ANOVA *F* value	p value
N	1	25.65	(0.0001)
P	3	7.20	(0.0028)
N*P	3	3.46	(0.0413)
Harvests	10	255.04	(<0.0001)
Harvests*P	30	3.78	(<0.0001)
Harvests*N	10	2.99	(0.0018)
Harvests*P*N	30	5.01	(<0.0001)

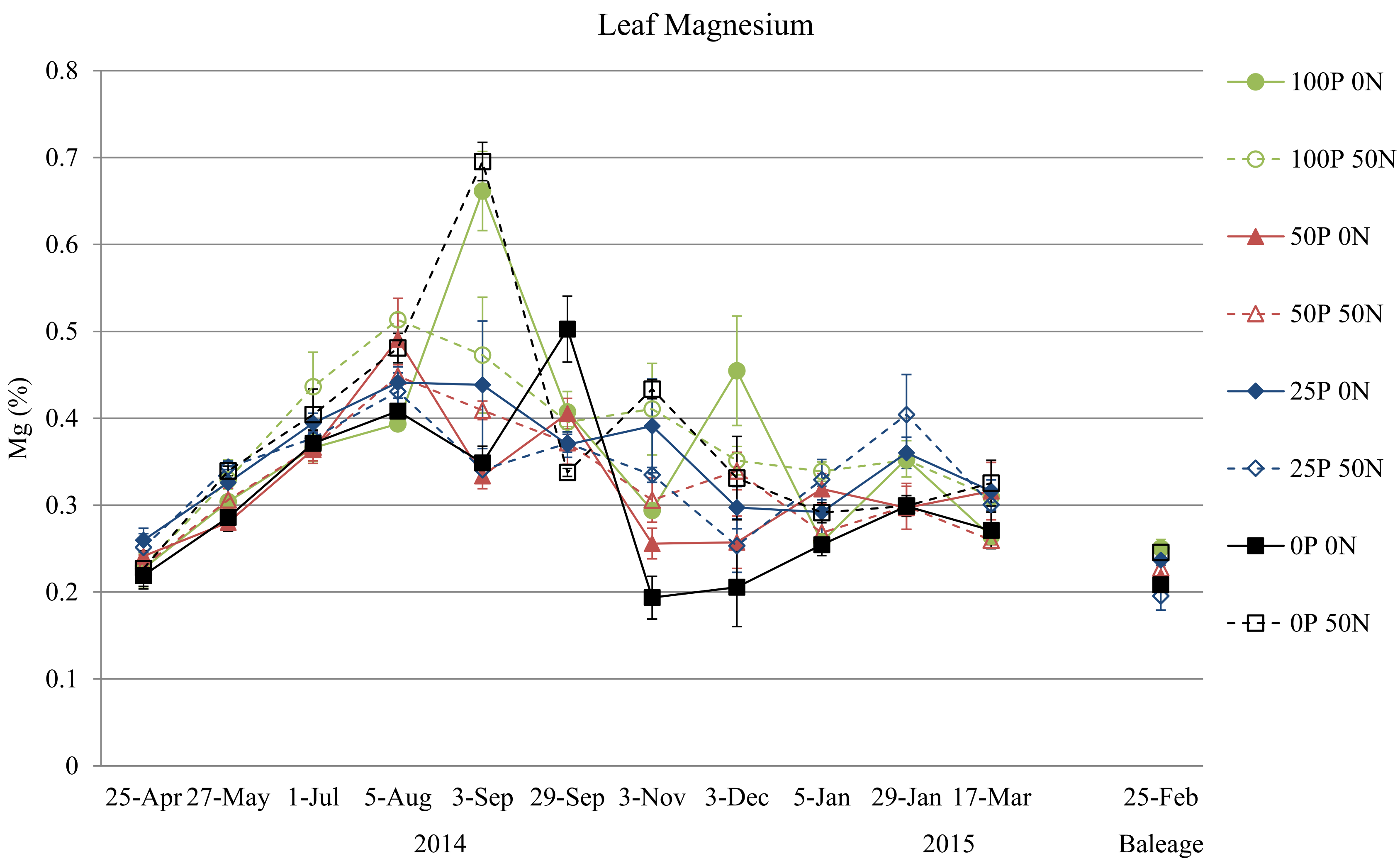

Figure 9. Leaf magnesium content of tall fescue treated with P and N over time. Each value is the mean ± Standard Error (n=3).

Table 8. 2014-2015 leaf magnesium [before treatment (4/25/2014) and monthly thereafter]. Tukey's pairwise comparisons and repeated measures ANOVA results.

Treatment		4/25/14	5/27/14	7/1/14	8/5/14	9/3/14	9/29/14	11/3/14	12/3/14	1/5/15	1/29/15	3/17/15
0 P												
	0 N		ab^{y}		^{y}	a	^{x}	^{y}	b	^{y}	b	
	50 N		ab^{x}		^{x}	a	^{y}	^{x}	b	^{x}	b	
25 P												
	0 N		a^{y}		^{y}	b	^{x}	^{y}	b	^{y}	a	
	50 N		a^{x}		^{x}	b	^{y}	^{x}	b	^{x}	a	
50 P												
	0 N		b^{y}		^{y}	b	^{x}	^{y}	ab	^{y}	b	
	50 N		b^{x}		^{x}	b	^{y}	^{x}	ab	^{x}	b	
100 P												
	0 N		ab^{y}		^{y}	a	^{x}	^{y}	a	^{y}	ab	
	50 N		ab^{x}		^{x}	a	^{y}	^{x}	a	^{x}	ab	

Phosphorus treatments that are not followed by the same letter (a,b,c,d) are significantly different ($p<0.05$, using Tukey's pairwise comparisons). Superscript letters (^{x}, ^{y}) compare N levels across P treatments.

Table 9. 2014-2015 leaf magnesium results of the GLM procedure, repeated measures analysis of variance. Tests of hypotheses within harvest across all treatments (top) and univariate tests of hypotheses for within treatment (bottom).

	df	ANOVA *F* value	p value
N	1	13.84	(0.0019)
P	3	11.99	(0.0002)
N*P	3	14.15	(<0.0001)
Harvests	10	60.59	(<0.0001)
Harvests*P	30	4.48	(<0.0001)
Harvests*N	10	3.18	(0.0010)
Harvests*P*N	30	6.77	(<0.0001)

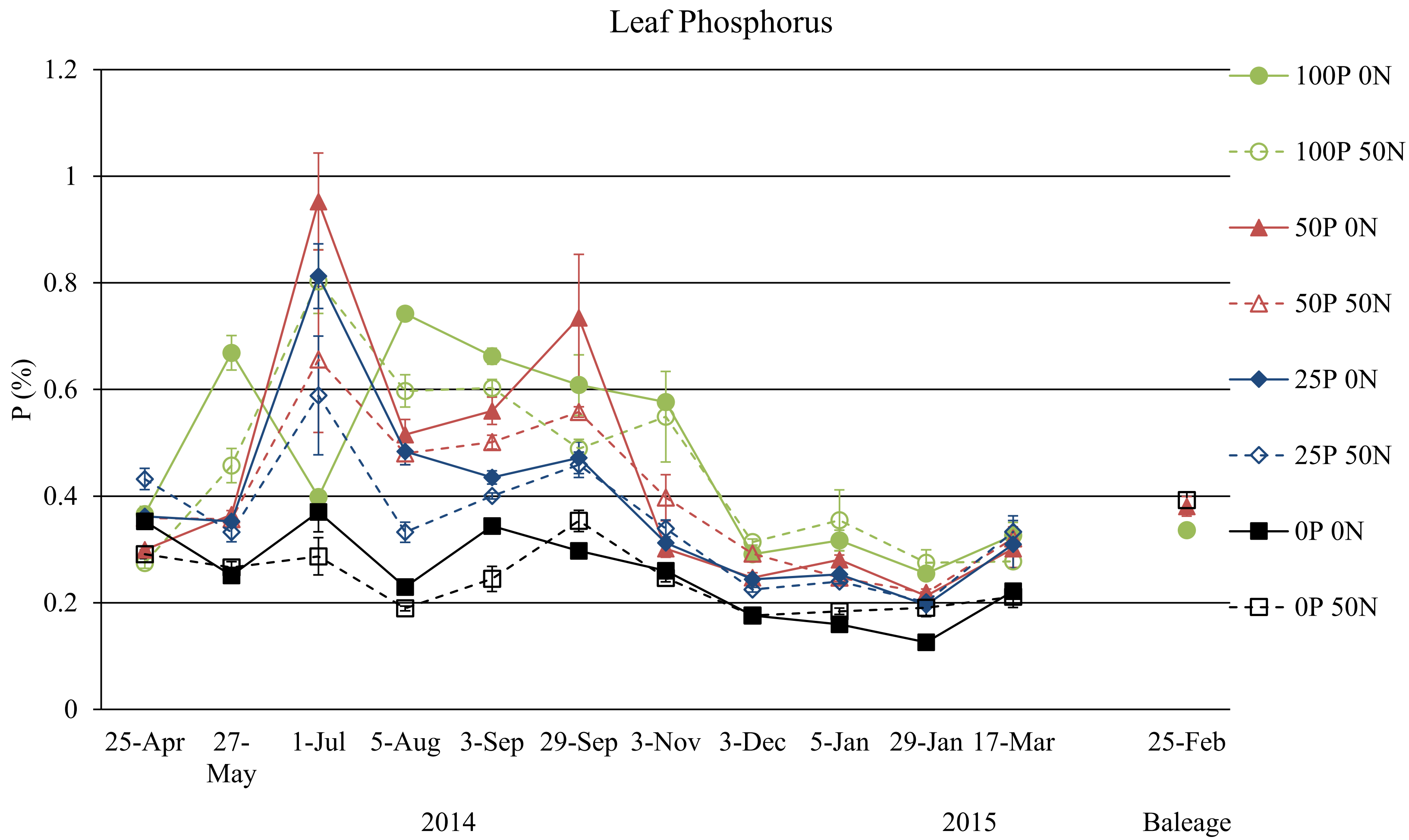

Figure 10. Leaf phosphorus content of tall fescue treated with P and N over time. Each value is the mean ± Standard Error (n=3)

Table 10. 2014-2015 leaf phosphorus [before treatment (4/25/2014) and monthly thereafter]. Tukey's pairwise comparisons and repeated measures ANOVA results.

Treatment		4/25/14	5/27/14	7/1/14	8/5/14	9/3/14	9/29/14	11/3/14	12/3/14	1/5/15	1/29/15	3/17/15
0 P												
	0 N	b	c^x	b	d^x	d^x	c	c	d^y	c	c^y	b
	50 N	b	c^y	b	d^y	d^y	c	c	d^x	c	c^x	b
25 P												
	0 N	a	b^x	a	c^x	c^x	bc	bc	c^y	b	b^y	a
	50 N	a	b^y	a	c^y	c^y	bc	bc	c^x	b	b^x	a
50 P												
	0 N	b	b^x	a	b^x	b^x	a	b	b^y	b	b^y	a
	50 N	b	b^y	a	b^y	b^y	a	b	b^x	b	b^x	a
100 P												
	0 N	b	a^x	a	a^x	a^x	ab	a	a^y	a	a^y	a
	50 N	b	a^y	a	a^y	a^y	ab	a	a^x	a	a^x	a

Phosphorus treatments that are not followed by the same letter (a,b,c,d) are significantly different ($p<0.05$, using Tukey's pairwise comparisons). Superscript letters (^{x}, ^{y}) compare N levels across P treatments.

Table 11. 2014-2015 leaf phosphorus results of the GLM procedure, repeated measures analysis of variance. Tests of hypotheses within harvest across all treatments (top) and univariate tests of hypotheses for within treatment (bottom).

	df	ANOVA *F* value	p value
N	1	16.00	(0.0010)
P	3	212.79	(<0.0001)
N*P	3	0.73	(0.5497)
Harvests	10	104.55	(<0.0001)
Harvests*P	30	12.05	(<0.0001)
Harvests*N	10	2.77	(0.0035)
Harvests*P*N	30	5.96	(<0.0001)

Table 12. Forty-three weeks after treatment (4/25/2015) baleage collection results (top) and ANOVA *F* values (and p values) (bottom).

Treatment		Protein	Fiber (acid)	Fiber (neutral)	TDN	NE (lact.)	NE (maint.)	NE (gain)	RFV
0 P									
	0 N	12.7±0.7[y]	41.8±0.6b	72.8±1.7a	54.9±0.8a	0.56±0.01a	0.53±0.01a	0.30±0.01a	72±2ab
	50 N	13.5±0.7[x]	43.0±1.2b	71.6±0.6a	53.5±1.4a	0.54±0.02a	0.51±0.02a	0.29±0.02a	72±2ab
25 P									
	0 N	11.6±0.6[y]	47.4±0.2a	71.7±0.4ab	48.5±1.4b	0.49±0.01b	0.45±0.02b	0.24±0.01b	68±1b
	50 N	14.8±0.2[x]	44.7±2.0a	72.1±1.8ab	51.6±2.2b	0.52±0.03b	0.49±0.03b	0.27±0.02b	70±4b
50 P									
	0 N	12.4±0.3[y]	40.3±0.4b	67.6±0.6ab	56.6±0.5a	0.58±0.01a	0.55±0.01a	0.32±0.00a	79±0a
	50 N	14.2±0.7[x]	42.6±0.8b	72.7±0.7ab	54.0±0.9a	0.55±0.01a	0.52±0.01a	0.29±0.01a	71±1a
100 P									
	0 N	12.7±0.4[y]	43.0±1.3b	71.8±1.1b	53.5±1.5a	0.54±0.02a	0.51±0.02a	0.29±0.02a	72±2a
	50 N	13.5±0.4[x]	41.3±0.1b	66.3±0.8b	55.5±0.2a	0.56±0.00a	0.54±0.00a	0.31±0.00a	80±1a
N	1 df	21.51 (0.000)	0.05 (0.824)	0.16 (0.696)	0.10 (0.759)	0.12 (0.733)	0.10 (0.760)	0.01 (0.924)	0.25 (0.621)
P	3 df	0.05 (0.985)	7.58 (0.002)	3.86 (0.030)	7.12 (0.003)	7.52 (0.002)	6.97 (0.003)	7.20 (0.003)	5.83 (0.007)
N*P	3 df	2.80 (0.071)	2.72 (0.077)	8.39 (0.001)	2.36 (0.110)	2.35 (0.111)	2.18 (0.130)	2.47 (0.099)	6.28 (0.005)

Column means (± Std. Error) across P treatments that are not followed by the same letter (a,b,c,d) are significantly different ($p<0.05$, using Tukey's pairwise comparisons). Column means (± Std. Error) designated by superscript letters ([x],[y]) compare N levels across P treatments.

Table 13. Initial collection (3/27/2015) for new plots soil fertility test results (top) and ANOVA *F* values (and p values) (bottom).

Treatment		pHs	N.A. (meq/100g)	%OM	P Bray I (lb/A)	Ca (lb/A)	Mg (lb/A)	K (lb/A)	CEC (meq/100g)
0 P		6.0±0.2	1.0±0.2	1.7±0.2	12±4	1568±168	330±25	123±9	6.5±0.7
25 P		6.0±0.1	1.0±0.2	1.9±0.2	12±3	1469±73	285±17	121±17	6.0±0.4
50 P		6.1±0.2	0.8±0.3	1.6±0.1	10±3	1476±77	316±11	110±7	5.9±0.4
100 P		6.1±0.1	0.9±0.1	1.7±0.1	9±2	1407±88	298±22	121±9	5.8±0.2
P	3 df	0.25 (0.857)	0.28 (0.837)	0.83 (0.501)	0.17 (0.914)	0.37 (0.775)	1.05 (0.405)	0.28 (0.838)	0.41 (0.745)

Column means (± Std. Error) across P treatments that are not followed by the same letter (a,b,c,d) are significantly different (p<0.05, using Tukey's pairwise comparisons).

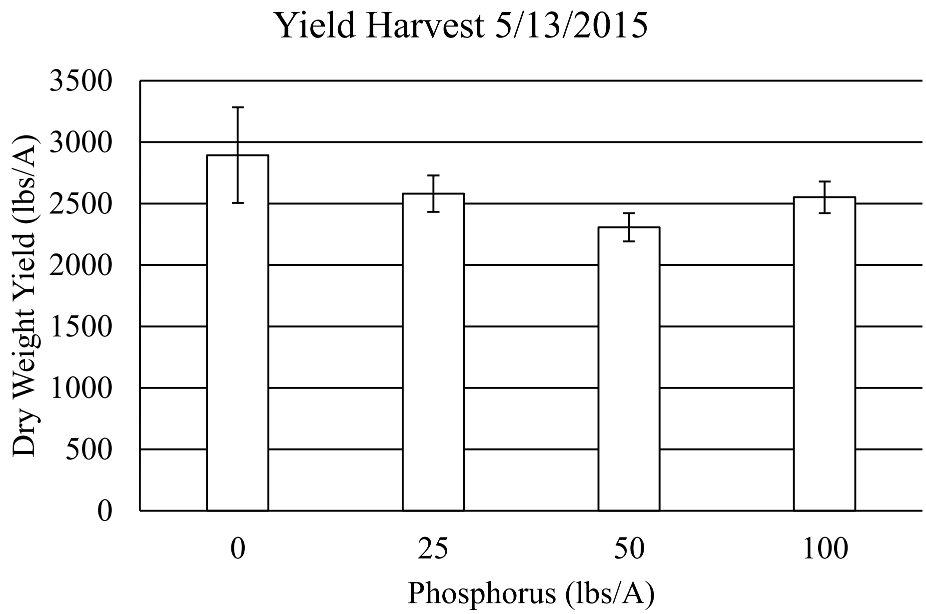

Figure 11. Forage dry matter yield of tall fescue based pastures 5 weeks after P and N fertilizer treatment applications, measured May 13, 2015. Each value is the mean ± Standard Error (n=3). There were no differences in means across P treatments ($p<0.05$).

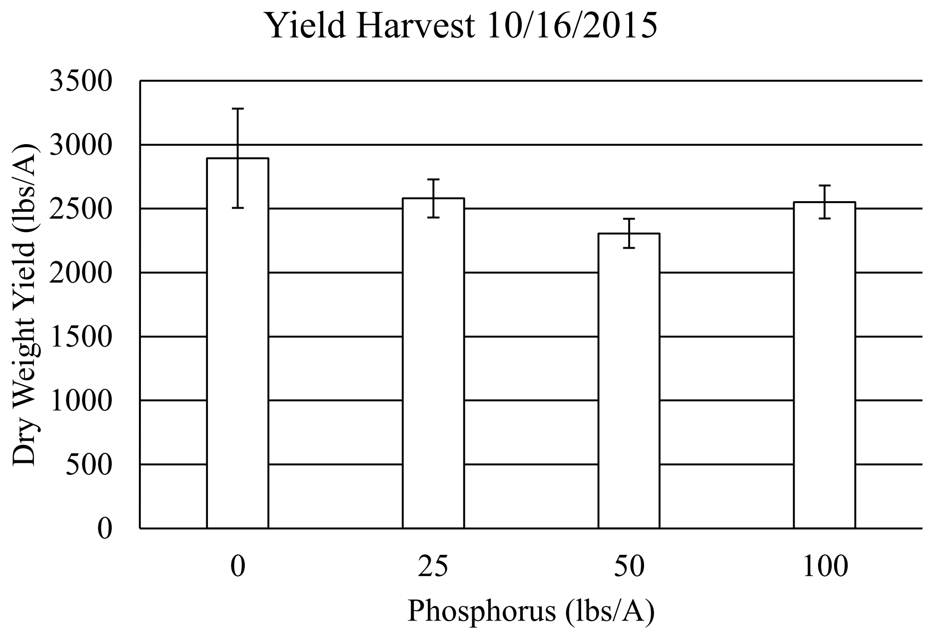

Figure 12. Forage dry matter yield of tall fescue based pastures 28 weeks after P and N fertilizer treatment applications, measured October 16, 2015. Each value is the mean ± Standard Error (n=3). There were no differences in means across P treatments ($p<0.05$).

Table 14. 2015-2016 forage dry weight yield [5 weeks after treatment (5/13/2015) and 28 weeks after treatment (10/16/2015)]. Results of the GLM procedure, repeated measures analysis of variance. Tests of hypotheses within harvest across all treatments (top) and univariate tests of hypotheses for within treatment (bottom).

	df	ANOVA *F* value	p value
P	3	0.42	(0.7402)
Harvests	10	2.39	(0.1296)
Harvests*P	30	1.15	(0.3390)

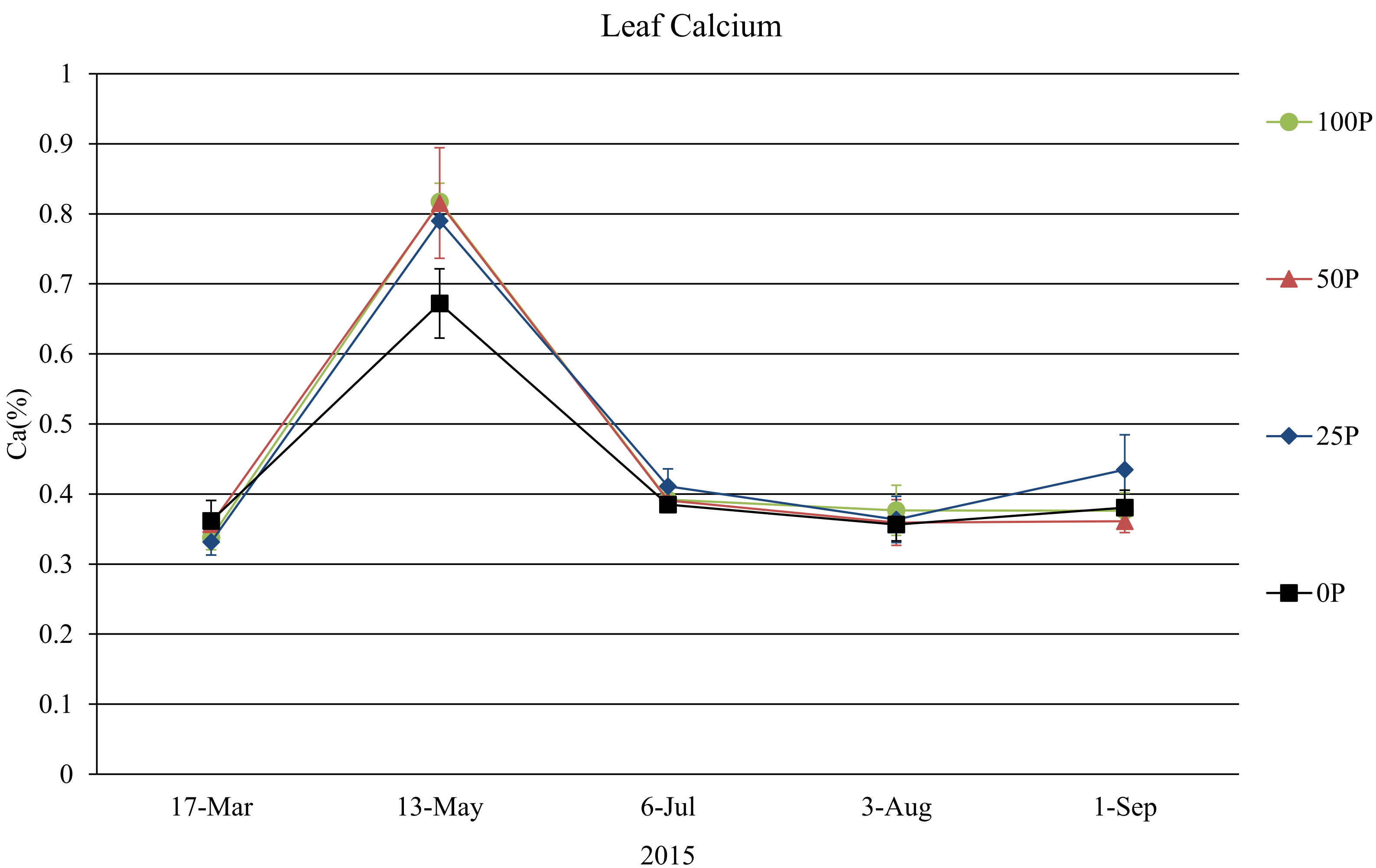

Figure 13. Leaf calcium content of tall fescue treated with P and N over time. Each value is the mean ± Standard Error (n=3). There were no differences in means across P treatments (p<0.05).

Table 15. 2015-2016 leaf calcium [before treatment (3/27/2015) and monthly thereafter]. Results of the GLM procedure, repeated measures analysis of variance. Tests of hypotheses within harvest across all treatments (top) and univariate tests of hypotheses for within treatment (bottom).

	df	ANOVA *F* value	p value
P	3	1.01	(0.4238)
Harvests	10	132.96	(<0.0001)
Harvests*P	30	1.28	(0.2599)

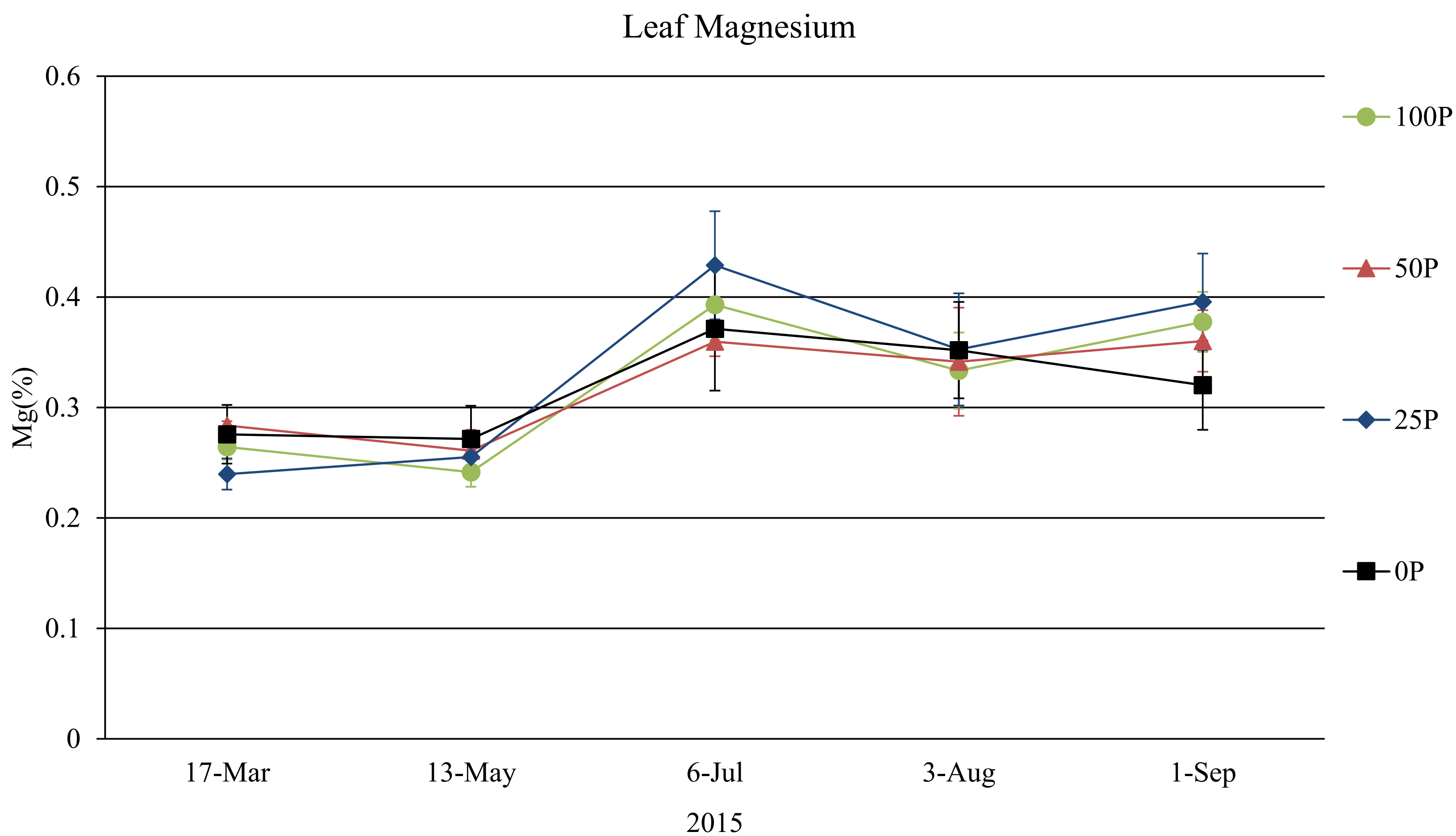

Figure 14. Leaf magnesium content of tall fescue treated with P and N over time. Each value is the mean ± Standard Error (n=3). There were no differences in means across P treatments ($p<0.05$).

Table 16. 2015-2016 leaf magnesium [before treatment (3/27/2015) and monthly thereafter]. Results of the GLM procedure, repeated measures analysis of variance. Tests of hypotheses within harvest across all treatments (top) and univariate tests of hypotheses for within treatment (bottom).

	df	ANOVA *F* value	p value
P	3	0.12	(0.9440)
Harvests	10	15.52	(<0.0001)
Harvests*P	30	0.64	(0.7947)

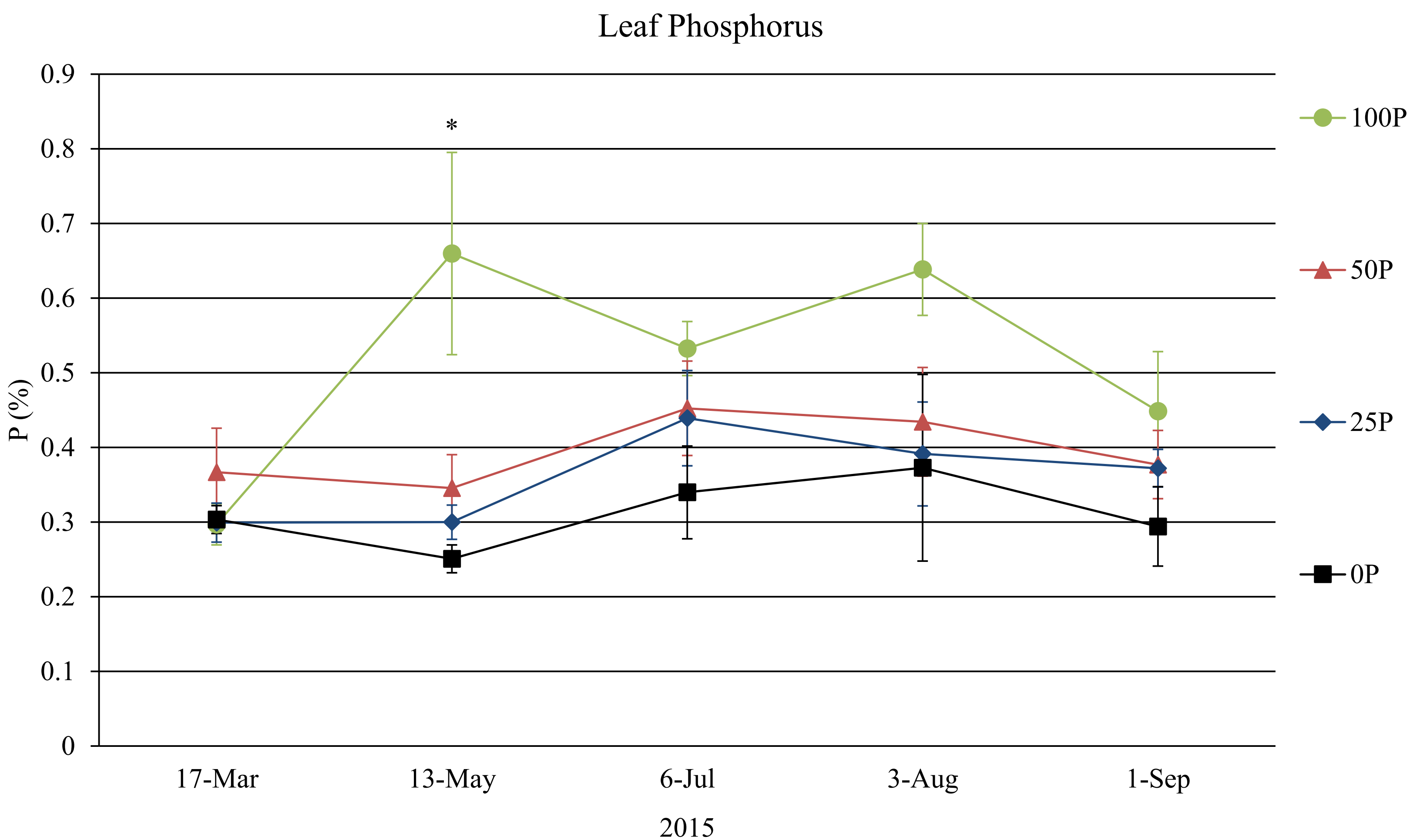

Figure 15. Leaf phosphorus content of tall fescue treated with P and N over time. Each value is the mean ± Standard Error (n=3). Differences in means within harvest across P treatments ($p<0.05$) are indicated with an asterisk (*).

Table 17. 2015-2016 leaf phosphorus [before treatment (3/27/2015) and monthly thereafter]. Results of the GLM procedure, repeated measures analysis of variance. Tests of hypotheses within harvest across all treatments (top) and univariate tests of hypotheses for within treatment (bottom).

	df	ANOVA *F* value	p value
P	3	3.6	(0.0461)
Harvests	10	5.22	(0.0014)
Harvests*P	30	2.32	(0.0199)

DISCUSSION

There were few effects of N and P fertilizer on the tall fescue pastures and baleage in the 2014-2015 study. The increase in protein content of baleage with N fertilization was expected as shown by Sauvé et al. (2010). However, there were no differences in other quality parameters with fertilizer treatments. During the 2014-2015 field study, the initial variation of the plots was observed throughout the other harvests and collections. We found that the plot with 25 lbs P/A and 50 lbs N/A caused some of our results to be skewed in several measurements. It was also the plot that showed an excessive amount of Ca on the soil results. This plot was located along a gravel road, so a possible explanation for the variation in soil tests, forage yield, and nutrient content could be that the dust from the limestone gravel road settled onto this plot more so than other plots further away from the road. This addition of limestone would account for the excess Ca and pH differences in this plot. Additionally, the plots contained various species besides tall fescue. Each plot had different species and density of these species. Therefore, the yield and baleage quality results could affected by species diversity and not a direct measurement on the effects of tall fescue.

Due to these variations in the 2014-2015 field plots, the experiment was redesigned with other pastures at Baker's Acres for the second year of this study (2015-2016). These plots had similar soil characteristics and were predominantly tall fescue. Plots were also replicated and randomized in a complete block design to take into account variability in species, soils, and environment. This new design offered greater statistical power to examine the effects of P fertilization.

In both years, tall fescue leaf nutrient concentrations of Ca, Mg, and P exhibited similar patterns across the seasons as previous studies (Blevins et al. 2004). By having monthly harvests across the entire year, our study will give further insight into the nutrient dynamics of tall fescue leaves when managed for forage and baleage than previous studies. During the 2015-2016 field study, no statistically significant effects of P fertilizer yield and leaf Ca and Mg were observed. However, leaf P was increased with the highest level of P fertilization, and there was a trend of increasing leaf P with increasing P fertilizer treatments. Measurements will continue with soil tests and monthly leaf harvests through the spring of 2016. Additionally, leaf K was not measured due to laboratory equipment failure, however leaf K will be determined on these samples as well as future samples. These data will then be used to determine if the Grass Tetany Ratio was improved with treatments.

This study will also be replicated the following year (2016-2017), and these additional results should further elucidate any responses of P fertilizer to soil, leaf, and baleage measurements in this production system.

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