

**Assessing the Effect of Nitrogen Sources, Rates and Time of applications on
Yield and Quality of Stockpiled Fescue and Tall Fescue Pastures**

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Thesis submitted to the faculty of the Virginia Polytechnic Institute and State University in
partial fulfillment of the requirements for the degree of

Master of Science

In

Crop and Soil Environmental Sciences

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August 1, 2008

Blacksburg, Virginia

Keywords: Nitrogen, Nitrogen rates, Nitrogen source, stockpiled fescue, pasture fertilization, tall

fescue

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Elizabeth L. Yarber

Abstract

In Virginia, tall fescue [(*Schedonorus phoenix* (Scop.) Holub,) formally known as *Festuca arundinacea* L.] can be found on more than 4 million ac of hay and pastureland. Two separate experiments were conducted at three different geographical locations over two growing seasons. The objective of Experiment 1 was to evaluate the influence of N sources and rates on yield and nutritive value of stockpiled tall fescue. Experiment 2 examined the effect of split spring and fall N applications at various rates on yield and nutritive value of tall fescue pastures. The first experiment was conducted at three locations (Blacksburg, Blackstone, and Steeles Tavern, VA) while the second experiment was conducted only at the Blacksburg and Steeles Tavern locations. In Experiment 1, the N sources included ammonium nitrate, ammonium sulfate, urea, urea + Agrotain[®], Environmentally Smart N[®] (ESN), Nutrisphere (NSN), Nitamin[®] (Blackstone only), pelleted biosolids (Blackstone only), and broiler litter (Steeles Tavern only) applied at 0, 28, 56, 84, and 112 kg plant available N (PAN) ha⁻¹. Plots were harvested in mid-December (Blacksburg and Steeles Tavern) and late January (Blackstone). The yield of the stockpiled tall fescue in 2006 ranged from 1,300 to 2,900, 1,700 to 3,000, and 2,600 to 3,300 kg DM ha⁻¹ for the Blacksburg, Steeles Tavern and Blackstone locations, respectively. In 2007, however, the yield response to N rate and sources was significantly less than that of 2006 due to low rainfall. At the Blacksburg location, ammonium sulfate and ESN resulted in higher CP concentrations, ranging from 11-14% and 12-20% for 2006 and 2007 growing seasons, respectively. Similar variation (12-20%) was observed for the Steeles Tavern location in 2006. In general, the ADF

and NDF content decreased as N rate increased from 0-112 kg ha⁻¹. Although the source and rate that resulted in high yield and nutritive value varied across location and years, N rates and sources improved the quality and yield of stockpiled fescue. Experiment 2 utilized urea which was applied in the fall at the rates of 0, 45, 90 or 135 kg N ha⁻¹ followed by spring application of 0, 45, 90 or 135 kg N ha⁻¹. A total of 16 treatment combinations per replication were used. Yields ranged from 1,900 to 3,600 kg DM ha⁻¹ and 700 to 2,500 kg DM ha⁻¹ in 2007 and 2008, respectively. At the Steeles Tavern location, yields ranged from 3,100 to 5,700 kg DM ha⁻¹ and 2,500 to 5,100 kg DM ha⁻¹, in 2007 and 2008, respectively. In both years CP increased with increasing N fertilization. On a dry matter basis, CP values ranged from 14 to 23% for both years. Treatments did not affect on NDF and ADF values. Split fall/spring N applications did not maximize yield of cool-season grass pastures in these experiments.

DEDICATION

I dedicate this thesis to my parents, David and JoEllen Yarber,
who have always been there to encourage me in whatever I pursue.

Thank you for the love and support!

ACKNOWLEDGEMENTS

I wish to thank all who have aided in this project. Below is a list, however, so many have helped and influenced me, it would be a hard chore to list them all.

Thank you!

David, JoEllen and Joseph Yarber

Dr. Ozzie Abaye

Dr. Mark Alley

Dr. Chris Teutsch

Dr. Guillerimo Scaglia

Steve Nagel

Mac Tilson

Matt Webb

Paul Le Bal

Katie Hurder

Agronomy Farm crew

Kentland Farm crew

Shenandoah Valley AREC crew

USDA-Forage Fed Beef Initiative

Agrotain Inc.

DCR

Agrium Inc.

Shenandoah Resource Conservation and Development Council

Southern States

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CHAPTER 1

INTRODUCTION

Tall fescue [(*Schedonorus phoenix* (Scop.) Holub,) formally known as *Festuca arundinacea* L.], is grown on more than 14.2 million hectares in the United States and over 1.32 million hectares in Virginia (NASS, 2002). Tall fescue is a cool season grass that produces flushes of growth in spring and fall under Virginia climatic conditions. The autumn growth flush of tall fescue is especially useful for stockpiling grass in the field to enable cattle to graze during the winter months, thus reducing hay costs. Management programs to optimize stockpiled tall fescue can potentially increase livestock productivity in Virginia and throughout the region.

However, decreased animal performance and disorders caused by the presence of the fungal endophyte *Neotyphodium coenophialum* (Scott *et al.*, 2007) in many fields reduces the suitability of tall fescue for many forage-livestock producers. A survey conducted by Ball *et al.* (1987) found over 90% of the fescue fields in the USA to be endophyte-infected. Ergot alkaloids produced by the endophytic fungus are toxic to livestock (Fritz and Collins, 1991). Broad ranges of other alkaloids are also produced by the endophyte, but ergopeptine alkaloids are most closely associated with animal toxicity (Hill *et al.*, 1991). The concentration of alkaloids begins decreasing after mid-December reducing the toxicity to animals during the winter months (Kallenbach *et al.*, 2003).

Utilizing stockpiled tall fescue during the winter months can reduce the cost of winter-feeding of livestock up to 35 percent (VCE, 2007). Although many types of forages can be used for stockpiling, tall fescue is the most productive because of its significant growth prior to the winter months. Crude protein and total digestible nutrients (TDN) values of stockpiled tall

fescue averaged 14.2 % and 68.1%, respectively in research conducted by Teutsch et al. (2005). Compared to the average Virginia hay nutritive values, stockpiled fescue has 35% more crude protein and 23% more energy (Stallings, 2005).

Agronomic factors that affect stockpiled tall fescue production were reviewed by Matches (1979) more than 25 years ago and more recently by Poore et al. (2000). A primary factor affecting yield is N fertilization. Response of tall fescue to autumn N applications is highly variable due to environmental conditions. In general, with moderate N inputs (62-124 kg N ha⁻¹), 4.5-9 kg of forage DM kg⁻¹ N can be produced (Poore et al., 2000). Applying N in late summer can also increase quality of stockpiled tall fescue (Singer, 2003). Rayburn et. al. (1979) found that applying 112 kg N ha⁻¹ increased yield from 880 to 1627 kg ha⁻¹. Crude protein values were 10.0 and 10.6% when no N and 112 kg N ha⁻¹ were applied, respectively. Singer (2003) and Collins and Balasko (1981) also found similar results of increasing CP and IVDMD concentrations with increasing N fertilization. While N fertilization positively impacts both the yield and quality of forages grown for ruminant livestock, it may not be profitable to apply N for stockpiling due to increasing fertilizer costs (Teutsch et al., 2005).

Typical N fertilization of pastures occurs during the early spring to promote growth for hay (Ball et. al., 2002). In addition to the spring N application, N in late fall can benefit the forage by promoting root growth, stand density, and winter survival (Turgeon, 2002). As temperatures become cooler, there is reduced top growth in cool season grass species but root growth remains active (Turgeon, 2002). By making fall N applications, root growth may increase and aid in water and nutrient uptake. The N also promotes spring growth and winter survival because of increased carbohydrate storage in the stem base (Smith et al., 2003).

The costs of N fertilizers are driven by the cost of natural gas, accounting for 90% of the cost of ammonia production (The Fertilizer Institute, 2007). These production costs have risen 172% from 1999 to 2005 (The Fertilizer Institute, 2007). In order for ruminant livestock producers to remain profitable, they need information on the most cost-effective N fertilization strategies for pastures in the transition zone of the US that are dominated by tall fescue. In the past, the most popular N source was ammonium nitrate. However the availability of this source is limited due to security concerns. The challenge now is determining which N source is the best substitute for ammonium nitrate, without increasing costs or decreasing productivity. Several alternative N sources such as urea, organic sources (manures and biosolids) and slow-release N fertilizers are available, but little is known about how these fertilizer sources affect yield and nutritive value of stockpiled fescue, as well as fescue pastures.

The overall objectives of the experiments reported in this thesis were to evaluate the effect of:

- Various N sources and rates on the biomass and nutritive value of stockpiled fescue for winter grazing; and
- Split spring and fall N applications at various rates on yield and nutritive value of tall fescue pastures.

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CHAPTER II

LITERATURE REVIEW

Tall Fescue

Tall fescue [*Schedonorus phoenix* (Scop.) Holub,] formally known as *Festuca arundinacea* L.], originated in Europe and introduced to North America, but the exact date of its arrival to North America is unknown. However, it is known that by the late 1800s, seed was being imported for pasture use and research on the various species of the *Festuca* genus. Tall and meadow fescue were originally given the same name, *Festuca elatior*. In 1771, tall fescue, was given the name *Festuca arundinacea* (Terrell, 1979). Tall fescue became a more prominent crop after the release of ‘Kentucky 31’ in 1943. Kentucky 31 was first found growing in Menifee County, Kentucky in 1931. Dr. E.N. Fergus collected and tested the seed and found this variety to be persistent, productive and widely adapted (Cowan, 1956). It rapidly became the main cool-season forage throughout the transitional zone of the United States and remains the most popular tall fescue variety in the United States (Ball et al., 1987; Sleper and West, 1996)).

The “transition climatic zone” is the area where the summers are too hot for cool-season grasses and the winters are too cold for warm-season grasses. The distribution of tall fescue is associated mainly with temperature with best growth occurring in regions where temperatures range between 20 to 25°C (Burns and Chamblee, 1979). New tillers can grow if temperature means are 4.4°C or above; the plant will become dormant when temperatures drop below 1.1°C (Templeton et al., 1961). Tall fescue requires at least 450 mm of rainfall in low lying areas and at least 900 mm of rainfall in upland areas (Buckner et al., 1979) and can persist in hot conditions as long as there is adequate moisture. Tall fescue can grow on very acidic (pH 4.7) to

alkaline (pH 9.5) soils (Cowan, 1962). An extensive root system allows tall fescue to survive in both droughty and wet soils. Due to the wide adaptations of tall fescue, it is able to grow on over 400,000 ha in Virginia and 14.2 million ha in the United States (Ball et al., 2002).

Tall fescue is a cool-season grass, which has most of its growth in the spring prior to relatively high summer temperatures. During the summer, it becomes dormant in most regions. Growth resumes in the fall and continues in the winter, where temperatures are mild (Sleper and West, 1996; Wolf et al., 1979). Vegetative growth begins in April, when temperatures begin to rise. In May, seed head development occurs followed by anthesis during early June. Stem elongation and flowering only occur in the spring and subsequent growth is vegetative (Wolf et al., 1979). Flowering tiller development requires a short day-long night photoperiod at low temperatures in order to induce bud primordia during late autumn and winter followed by a long day-short night period with cool temperatures during the spring. The majority of tall fescue's growth occurs during the spring (approximately 8 weeks) when about 45% of its annual dry matter production occurs (Wolf et al., 1979).

Tiller production under optimal conditions will increase exponentially, however under stress, buds will become dormant or die before a tiller can be formed (Templeton et al., 1961). Buds have been found on tall fescue in the summer in the southern Corn Belt, but tillering does not occur until autumn (Yeh et al., 1976). There is a negative correlation between tiller development and leaf area. As leaf area increases tiller production tends to decrease because the vegetative growth begins blocking the sunlight and water from the tillers, which require both to survive. Many of the practices that promote tiller growth tend to reduce dry matter production (Wolf et al., 1979).

Root development in tall fescue is interdependent with above ground growth. Thus defoliation of above ground growth can cause root growth to decline due to insufficient energy. Root growth tends to occur during the late fall when temperatures are cooler and less vegetative growth is occurring, allowing for excess metabolites to be available for root, tiller and rhizome growth (Sleper and West, 1996).

For Virginia, the primary forage base is endophyte-infected Kentucky 31 tall fescue. Most tall fescue plants are infected with the endophytic fungus *Neotyphodium coenophialum* (Scott et al., 2007). An endophytic fungus lives its entire life cycle in the plant and results in a mutualistic relationship with the plant. It is spread by the seed of tall fescue (Sleper and West, 1996). The endophyte affects both physiological and agronomic traits of the plant. The presence of the endophyte allows tall fescue to be more widely adapted, drought and pest resistant, competitive in stressful environments and tolerant to continuous stocking. The grass-endophyte interaction allows for the plant and the fungus to survive. Although the endophyte is beneficial for the plant, it tends to cause problems in livestock. The endophytic fungus produces ergot alkaloids that are toxic to livestock (Ball et al., 2002). A broad range of other alkaloids are also produced by the endophyte, but ergopeptine alkaloids are most closely associated with animal toxicity (Hill et al., 1991). Since alkaloids are produced by the endophytic fungus itself, endophyte-free (E-) tall fescue does not contain the toxic alkaloids that are produced in endophyte-infected (E+) fescue, and therefore does not negatively affect animals consuming it. However, when the endophyte is not present in the plant, the productivity decreases because the plant loses its tolerance to pests, drought and grazing tolerance. A survey conducted by Ball et al. (1987) found over 90% of the fescue field in the USA to be endophyte-infected.

Researchers in New Zealand have discovered an endophyte that is not toxic to animals because this newly discovered endophyte does not produce the toxic ergot alkaloids (Bouton et al. (2002.) This endophyte is commonly referred to as non-toxic or “novel”. A combination of characteristics between the two fescues (E+ and E-) has been found in novel endophyte infected fescue. Ball et al. (2002) explained that the novel endophyte infected fescue will have the persistence and hardiness of the E+, but without the toxic effects. “Max Q” tall fescue recently has been introduced as a “novel endophyte” tall fescue. This grass has an endophytic fungus that helps give it the positive agronomic characteristics commonly associated with varieties such as Kentucky 31 tall fescue (Andrae, 2003). However, the novel endophyte does not appear to cause the production of toxins found in other endophyte-infected tall fescue varieties. Moreover, initial investigations are positive, suggesting that animal performance will not be compromised by the presence of the novel endophyte (Bouton et al., 2002; Parish et al., 2003). Data are not available on differences, if any, for the response to N fertilizer applications on “novel endophyte” tall fescue compared to endophyte-infected fescue.

Uses and Management of Tall Fescue

The typical uses of tall fescue are pasture, hay, soil conservation and silage, with pasture being the most important. Two-thirds of tall fescue’s growth occurs during the spring and one-third of its growth occurs in the fall. In the fall, fescue can be managed for hay or stockpiled for later grazing. Stockpiling fescue is accomplished by clipping pastures in late summer, applying 67 to 90 kg N ha⁻¹ and allowing the growth to accumulate until December (NRCS, 2007; Ball et al, 2003).

Tall fescue maintains excellent autumn growth and quality following frost (Ball et al., 2002). This management alternative provides both a lower cost source of feedstuff and a higher quality feedstuff when compared to average quality hay and should improve the performance and profitability of the cowherd (Casler and Kallenbach, 1995). Ocumpaugh and Matches (1977) found that the factors most affecting autumn-winter yield were the environmental conditions, temperature and moisture. Following a killing frost, dry matter (DM), crude protein (CP), and in IVDMD decline, but tall fescue can still meet the nutritional requirements of beef cattle through most of the winter (Ocumpaugh and Matches, 1977). In addition, tall fescue generally maintains better nutritive value and quantity throughout winter grazing than most cool season grasses when stockpiled for winter grazing (Ball et al., 2002).

Many factors affect the productivity of a tall fescue stand including time of defoliation, frequency of defoliation, grazing or cutting height and N fertilization (Matches, 1979). Yields were reduced when tall fescue was cut at 2-wk intervals for hay production compared to being cut at 16-wk intervals; however an increase in tiller production occurred. Tiller production increased with the 2-wk interval cutting because sunlight was able to reach the growth occurring close to the soil surface (Matches, 1979). Templeton et al. (1965) observed differences in yield when tall fescue was cut at various times during development. Forage was harvested at boot stage and early bloom which yielded 5.6 metric ton ha⁻¹ and 8.0 metric ton ha⁻¹, respectively.

Nitrogen Fertilizer

Nitrogen gas (N₂) makes up 78% of the Earth's atmosphere, but is not available to plants until it is "fixed" into the ammonium (NH₄⁺) form. Plants can only use N in the form ammonium and nitrate (NO₃⁻) (Snyder and Leep, 1995). Nitrogen fixation from the atmosphere

can occur by several mechanisms: (1) microorganisms in the soil or on legume roots; (2) formation of N oxides through electrical discharges in the atmosphere; or (3) production of commercial N fertilizer (Havlin et al., 2005). For pure tall fescue swards, commercial N fertilizer is the most important N source. However, legumes such as white clover (*Trifolium repens*) in mixed legume – fescue swards can provide sufficient N for high yields. Legume percentages of the sward need to be at least 30% percent to provide adequate N for the grass (Follet and Wilkinson, 1995).

Nitrogen plays a major role in growth and development in plants. It is necessary for protein and amino acid synthesis and is an important component in chlorophyll. Adequate N results in an increase in photosynthetic activity, growth and dark green color of the plants. If N is deficient in plants, chlorosis occurs followed by necrosis at the leaf tip and down the midrib. Symptoms are first seen in the lower leaves (older growth) because N is a mobile nutrient within the plant, if deficiency worsens symptoms will be seen in top leaves (Whitehead, 2000)

Among the primary nutrients needed by plants, N is typically the most limiting nutrient. Organic or inorganic N fertilizers must be applied in order to supply adequate amounts of N (Snyder and Leep, 1995). Organic N fertilizers include manures, composts, biosolids, and legumes. These can provide N for the plants, however, the amount of N in manure is variable depending on animal diet, manure handling, timing of application and other factors such as soil properties (Havlin et al., 2005). The amount of N that is actually plant available from the organic sources is determined mainly by mineralization, which is the conversion of organic N to inorganic N. Volatilization also affects the amount of N in manures. Urea and uric acid present in manure can be quickly mineralized to NH_4^+ , and can then change to NH_3 , if conditions are warm and dry (PPI, 2003), and the manure is on the soil surface.

There are numerous N commercial fertilizers available; ammonium nitrate (34-0-0), urea (46-0-0) and ammonium sulfate (21-0-0-24S) are commonly used on forages. Ammonium nitrate is an effective source however it can be highly explosive if mixed with diesel fuel or other oxidizable C products. Worldwide use of ammonium nitrate has decreased and many agricultural suppliers are reluctant to sell this fertilizer due to security concerns (Havlin et al, 2005). Urea-based fertilizers are effective, but ammonia losses via volatilization can occur if hot, dry conditions exist shortly after surface applications of urea and urea-containing N fertilizers. Risks of volatilization losses are greatest during late spring and through the summer (Snyder and Leep, 1995). Ammonium sulfate (21% N) does not contain as much N as the other sources but does supply sulfur (S), which makes it a good N source if S also is needed by the plant. Volatilization losses of ammonia from ammonium sulfate are low. This results from the fact that dissolution of the ammonium sulfate granule results in NH_4^+ and SO_4^{2-} , which is the salt of a strong acid and thus the tendency is for the NH_4^+ to not shed a H^+ and be transformed into the gaseous NH_3 form (PPI, 2003).

Nitrogen Effect on Pastures and Stockpiled Fescue

Tall fescue, like other plants, requires adequate N to achieve maximum production. However, since tall fescue can be managed for spring and/or winter grazing, factors such as timing of N application(s), N rate and N fertilizer source can affect yield and nutritive values. Poore et al. (2000) reviewed agronomic factors including timing and rate of N fertilization, optimal initiation date and nutritional value of stockpiled fescue. After review, Poore et al. (2000) concluded that the main factor affecting yield and quality of stockpiled fescue was N

fertilization. When moderate N fertilizer is applied (64-127 kg N ha⁻¹) to tall fescue 5 to 9 kg of additional forage DM kg⁻¹ N is usually achieved.

Cherney and Cherney (2006) investigated the effect of N application timing on forage yield and quality of three perennial grasses. Tall fescue, orchardgrass and reed canarygrass each had N fertilizer treatments applied at i) 225 kg N ha⁻¹ in early spring, ii) 112 kg N ha⁻¹ in early spring with an additional 112 kg N ha⁻¹ following the first harvest or iii) 112 kg N ha⁻¹ in early spring with an additional 56 kg N ha⁻¹ following each harvest. Split N applications increased DM yields by 12% compared to the single N application in the spring. Split N applications also produced higher quality forage feed for lactating dairy cows (Cherney and Cherney, 2006).

Gerrish et al. (1994) tested the effects of initiation date and N fertilization date and rate on the yield and quality of stockpiled tall fescue in the Midwest. Tall fescue plots were fertilized at rates of 0, 46, 92, 138 kg N ha⁻¹ with ammonium nitrate then harvested on different dates during the winter months. Spring growth was also measured to observe any effect from the late summer N application for stockpiling. Tall fescue DM yield increased 30% when it was fertilized on August 1 vs. fertilized on August 29th. Yields increased by 22, 30 and 35% compared to the control when 46, 92 and 138 kg N ha⁻¹ were applied, respectively. Yield trends were similar to previous studies (Taylor and Templeton, 1976; Fribourg and Bell, 1984). Similar to Gerrish et al. (1994), Poore et al., (2000) also concluded that the initiation of the stockpiling as well as harvest date can influence the yield and nutritive value of stockpiled tall fescue.

A study conducted in Kentucky by Taylor and Templeton (1976) examined the effect of N fertilization on the quantity and quality of stockpiled Kentucky bluegrass and tall fescue for winter pastures. Kentucky bluegrass and tall fescue plots received N fertilizer at 0, 50 and 100 kg N ha⁻¹, in late summer. Plots were harvested during October, November, December or

February to determine which stockpiling period was optimal. Tall fescue yielded higher than Kentucky bluegrass each year of the study; however yearly growth was highly affected by the amount and distribution of precipitation. Growth accumulation was little for both species during October and November, however, tall fescue continued growing when fertilized with 100 kg N ha⁻¹ (Taylor and Templeton, 1976). In other similar studies that compared tall fescue to other cool-season grasses for stockpiling, tall fescue yields were up to 50 % higher (Reynolds, 1975; Archer and Decker, 1977). Crude protein concentrations increased with increasing N fertilization for both cool-season grasses, but began decreasing from December onward. For both forages, harvesting in November or December with moderate N fertilization produced the highest yield and nutritive value forage (Taylor and Templeton, 1976).

Tall fescue response to N and optimum harvest dates for yield and nutritive value of stockpiled forage was examined by Singer et al. (2003) in Iowa. Ammonium nitrate was applied at rates of 0, 28, 58, 115 kg N ha⁻¹ in mid-August, and harvested in mid-October, late October and mid-November. Additionally all plots were harvested in the spring to determine the effect of stockpiling on spring growth. Stockpiled tall fescue DM yield increased linearly with increasing N rate. Singer et al. (2003) conclude that harvesting stockpiled tall fescue beyond October under Iowa climatic conditions can reduce yield and nutritive value of the forage. Spring yields increased as the fall N fertilization increased. Yields the following spring were 787, 985, 1265 and 1533 kg DM ha⁻¹ for 0, 28, 58 and 115 kg N ha⁻¹ application rates, respectively.

Collins and Balasko (1981a, b) conducted two separate experiments to investigate the effect of cutting schedules and N fertilization on yield and nutritive value of stockpiled fescue. In the first study ammonium nitrate was applied at 0, 60, 120, and 180 kg N ha⁻¹ in split applications in March and August, and plots were harvested on various dates in the summer and

winter. Higher yields were achieved with two cuttings in early June and mid-July as compared to a single cutting in mid-June. Winter yields increased with increasing N fertilization up to 137 kg N ha⁻¹ when applied in mid-June for stockpiling (Collins and Balasko, 1981a). Crude protein concentrations were 7, 7.3, 8.6 and 10.1% with increasing N rates of 0, 60, 120, and 180 kg N ha⁻¹, respectively (Collins and Balasko, 1981b).

Collins and Balasko (1981a) fertilized tall fescue with ammonium nitrate at 0, 75, 150, and 225 kg N ha⁻¹ rates, following a late summer cutting. Forage was then harvested in late winter and the following summer. They concluded that yield and nutritive value depends on stockpiling initiation date and the N fertilization. The N fertilization rate should increase as the stockpiling initiation date is delayed.

Tall fescue can utilize large amounts of N (Cherney et al., 2002) but very high rates may not be economic or environmentally feasible. In 2003, Hall et al. (2003) conducted a study to examine the N rate on yield of cool-season grasses that optimizes economic return for Pennsylvania climate and soil conditions. These yields were 336, 432, and 257 kg N ha⁻¹ for orchardgrass, tall fescue and timothy, respectively. Economic return increased as the N rate increased up to 284, 368 and 299 kg N ha⁻¹ for orchardgrass, tall fescue and timothy respectively. Hall et al. (2003) concluded that the economic optimum N rate for orchardgrass, tall fescue and timothy for hay production was 26, 32, and 29 g N kg⁻¹, respectively.

A study comparing yield of orchardgrass and tall fescue using dairy manure and ammonium nitrate was conducted by Cherney et al. (2002) in New York. Manure was applied split at spring greenup and after the first harvest at rates of 55 and 110 kg N ha⁻¹. Ammonium nitrate was applied at a rate of 84 kg N ha⁻¹ at spring greenup and 56 kg N ha⁻¹ after spring harvest. Orchardgrass yielded 27% more than tall fescue during the first harvest but, tall fescue

yielded more during the regrowth harvests. Cherney et al. (2002) concluded that the lack of difference was due to a buildup of nutrients with consecutive manure applications. However, fescue fertilized with 55 kg N ha⁻¹ yielded significantly less dry matter than the other two treatments. Manure, as a source of N, can achieve similar yields as commercial N (ammonium nitrate) after multiple years of application as nutrient buildup occurs (Cherney et al., 2002).

A more recent study by Teutsch et al. (2005) investigated the effects of various N sources and rate on yield and nutritive value of stockpiled tall fescue. Nitrogen was applied in late summer at 0, 46, 92, 138 kg N ha⁻¹. N sources used were ammonium nitrate, ammonium sulfate, a complete fertilizer (18-9-9-12S), urea-ammonium nitrate, urea and broiler litter. Plots were allowed to accumulate growth until mid-December. Ammonium nitrate was shown to be the most effective N source for stockpiling and yielded approximately 1067 kg DM ha⁻¹ more than the urea-ammonium nitrate (UAN), which was the lowest yielding source. The N rate and N source did not have a significant effect on CP, ADF, NDF and TDN (Teutsch et al., 2005). With increasing N prices and the restriction on the availability of ammonium nitrate, new N sources and additives to reduce N losses and increase N availability from fertilizers have become available. The research by Teutsch et al. (2005) has provided some data on the effectiveness of several N fertilizers; however more research is needed to determine if these new N sources are a suitable replacement for ammonium nitrate.

Although several studies have been conducted, relative to the extensive areas of tall fescue production, and especially in Virginia, there has been minimal research to examine the effects of N fertilizer source on yield and nutritive value of tall fescue. Research is needed to address this issue, since the availability of ammonium nitrate which is commonly used for stockpiled fescue is uncertain and expensive.

Economic Analysis

According to the Fertilizer Institute (2008), global demand for N is up 14% from 2001 to 2006. As of April 2008, N fertilizer prices are 228% higher than January 2000. The increasing price of natural gas has caused 26 ammonia plants to close within the U.S. since 1999, which has increased the US's dependency on imported N (The Fertilizer Institute, 2008). Thus, the US now imports approximately 50% of needed N.

As N fertilizer prices rise, many producers question the value of N fertilization. Many variables must be considered before fertilizing tall fescues for winter or spring grazing. Major factors that must be considered are cattle prices and growth rates, N prices, hay prices and weather conditions. Dry conditions reduce forage yield response to N fertilization, which increases the forage production expenses. However, if moisture is adequate, an N response producing more forage will likely occur, reducing the cost per kg of DM produced. Managing tall fescue for winter grazing can lower the winter feed costs in beef production if hay prices are high and there is adequate moisture.

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CHAPTER III

Assessing Nitrogen Fertilizer Source and Rates on Biomass and Nutritive Value of Stockpiled Tall Fescue

ABSTRACT

Late summer nitrogen (N) fertilization is a primary factor affecting autumn yields of cool-season pastures allowed to accumulate herbage for deferred grazing. The current study evaluated the influence of N sources and rates on yield and nutritive values of stockpiled tall fescue [*Schedonorus phoenix* (Scop.) Holub.] formally known as *Festuca arundinacea* L.] Small plot experiments were established near Blacksburg, Blackstone, and Steeles Tavern, VA to evaluate the effectiveness of eight N sources each applied at five rates. The sources included ammonium nitrate, ammonium sulfate, urea, urea + Agrotain[®], Environmentally Smart N[®], Nitamin[®] (Blackstone only), pelleted biosolids (Blackstone only), and broiler litter (Steeles Tavern only) applied at 0, 28, 56, 84, and 112 kg plant available N (PAN) ha⁻¹. Plots were harvested in mid-December (Blacksburg and Steeles Tavern) and late January (Blackstone). Differences were observed among N rate, however, N sources had little effect. In 2006, the yield ranged from 1300 to 2900, 1700 to 3000, and 2600 to 3300 kg DM ha⁻¹ for the Blacksburg, Steeles Tavern and Blackstone locations, respectively. In 2007, the yield response to N rate and sources was significantly less than that of 2006. This was due to low rainfall conditions prior to and during the stockpiling period. At the Blacksburg location, ammonium sulfate and ESN resulted in higher CP concentrations, ranging from 11-14% and 12-20% for 2006 and 2007 growing seasons, respectively. Similar variation (12-20%) was observed for the Steeles Tavern location in 2006. In general, the ADF and NDF content decreased as N rate increased from 0-112 kg ha⁻¹. In 2006 at the Blacksburg location, ESN produced lower NDF (55%) than urea and

Agrotain® (56%) while the opposite was true in 2007 where NutriSphere treated urea and urea had lower NDF value than ESN. Although the source and rate that resulted in high yield and nutritive value varied across location and years, N rates and sources improved the quality and yield of stockpiled fescue.

INTRODUCTION

One of the greatest expenses for cow-calf producers is winter feed cost, which can account for 50% of the budget (VCE, 2007). Farm profitability is based on low feed costs; one way to lower costs associated with winter feed is to feed stockpiled forages during late fall, winter and early spring months. The practice of stockpiling grass forages for late fall and early winter grazing is a profitable forage management scheme in the southeast US (Taylor and Templeton, 1976; Ball et al., 2002; Burns and Chamblee, 2000, Poore et al., 2000). Stockpiled tall fescue is fall accumulated forage growth. It requires animals to be taken off fescue pastures/fields in mid to late August followed by a fall N ($45\text{-}90 \text{ kg N ha}^{-1}$) application. In addition, stockpiled fescue is a high-quality feed (Ball et al., 2002; Wolf et al., 1979)

Tall fescue response to N and optimum harvest dates for yield and quality of stockpiled forage was examined by Singer et al. (2003) in Iowa. Ammonium nitrate was applied at rates of 0, 28, 58, 115kg N ha⁻¹. Stockpiled tall fescue dry matter yield increased linearly with increasing N rate in the study. Singer et al. (2003) conclude that harvesting stockpiled tall fescue beyond October under Iowa climatic conditions can reduce yield and quality of the forage. Spring yields increased as the fall N fertilization increased. Similar results were obtained by Collins and Balasko (1981a) working on forage yield of stockpiled fescue in West Virginia.

Taylor and Templeton (1976) examined the effect of N fertilization on the quantity and quality of stockpiled Kentucky bluegrass and tall fescue for winter pastures. Growth accumulation was little for both species during October and November, however, tall fescue continued growing after the November harvest when fertilized with 100 kg N ha^{-1} (Taylor and Templeton, 1976). In similar studies, tall fescue yields were up to 50% higher compared to

orchardgrass for stockpiling (Reynolds, 1975; Archer and Decker, 1977). Crude protein concentrations increased with increasing N fertilization for both cool-season grasses, but began decreasing from December onward. For both forages, harvesting in November or December with moderate N fertilization produced the highest yield and quality forage (Taylor and Templeton, 1976).

A more recent study by Teutsch et al. (2005) investigated the effects of various N sources and rates on yield and quality of stockpiled tall fescue. Nitrogen sources used were ammonium nitrate, ammonium sulfate, a complete fertilizer (18-9-9-12S), urea-ammonium nitrate, urea and broiler litter. The most effective N source for stockpiling was ammonium nitrate, which yielded 1067 kg DM ha⁻¹ more dry matter. The N rate and N source did not have a significant effect on CP, ADF, NDF and TDN; however CP concentrations did increase with increasing N rate averaging 14.2% (Teutsch et al., 2005). With increasing N prices and restriction on the availability of ammonium nitrate, new N sources and additives have become available. Teutsch et al.'s (2005) research has provided some data on the effectiveness of several N fertilizers; however more research is needed to determine if these new N sources are a suitable, i.e. economic, replacement for ammonium nitrate. The objective of this study was to measure the influence of N sources and rates on biomass and quality of stockpiled tall fescue.

METHODS AND MATERIALS

Small plot experiments were conducted in 2006 and 2007 in Blacksburg, Steeles Tavern and Blackstone, VA (Figure 3-1) to evaluate the effectiveness of eight N sources applied at five N rates (0, 28, 56, 84, and 112 kg N/ha). The experimental design was a split-split plot design with four replicates. The main plots were N sources and sub-plots were N rates. The main plots

were 15 x 15 m and sub-plots were 3 x 3 m. Prior to fertilization, soil samples were taken randomly from each experimental location to determine soil-N (nitrate and ammonium), available phosphorus (P) and potassium (K), and soil pH. Nitrogen fertilizer was broadcasted across each plot. Plots at Steeles Tavern and Blacksburg were clipped to a stubble height of 7.5 to 10.0 cm prior to treatment application during both years. Plots at Blackstone were clipped to a stubble height of 15 and 10.0 centimeters, in 2006 and in 2007, respectively, prior to fertilizer treatment application.

Eight N sources (Table 3-1) were applied at rates of 0, 28, 56, 87 and 112 kg N ha⁻¹. Application and harvests dates are shown in Table 3-2 for all locations. Each plot was harvested for yield by clipping a swath through the center of each plot using a flail or sicklebar-type mechanical forage harvester. A subsample of fresh forage was collected from each plot for dry matter (DM), nutritive value and N content. Nitrogen uptake was calculated from DM yield and N content. Samples were dried in a forced air-oven (60° C) for at least 48 hours and ground to pass a 1-mm screen using a Wiley sample mill (Thomas Scientific, Swedesboro, NJ).

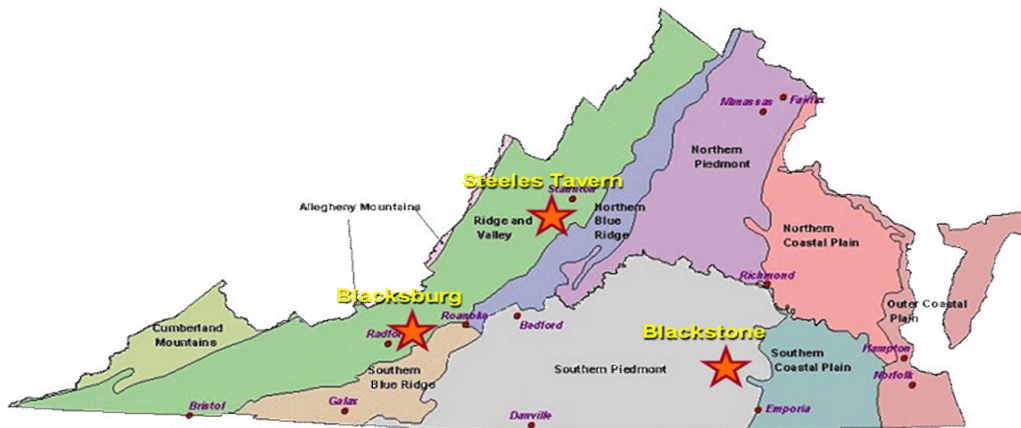


Figure 3-1. Experimental locations at Steeles Tavern, Blackstone and Blackburg during 2006 and 2007

Neutral detergent fiber (NDF), acid detergent fiber (ADF), and crude protein (CP) were estimated using near infrared spectroscopy (NIRS). WINISI II software was used to select a calibration data set for wet chemistry determination (Infrasoft International, Port Matilda, PA). Concentrations of NDF and ADF for calibration sets were determined using the ANKOM filter bag system (ANKOM Technologies, 2003). Total plant N was determined using a modified Dumas procedure (Elementar Americas, Cherry Hill, NJ). Crude protein was calculated as total N x 6.25. Prior to fertilization, soil samples were taken (10 cm deep) to determine soil-N, P and K. Routine soil test laboratory analyses of pH and Mehlich I (0.05M HCl and 0.0125 H₂SO₄)-extractable P and K were determined by the Virginia Cooperative Extension Soil Test Laboratory procedures (Donohue, 1992). Soil test results were used to maintain adequate levels of P and K for all locations.

Data were analyzed for all single effects and interactions using PROC GLM (SAS Institute, Cary, NC). Effect of treatment x rate, year and location were tested. Treatment, rate,

treatment x location, and treatment x rate x location were also tested. Regressions were performed using PROC REG (SAS Institute, Cary, NC). Significance was tested at the 10% level unless noted differently.

Table 3-1. Description of N sources to be used for the stockpiled tall fescue experiments conducted at three locations in Virginia.

N Source	Analysis (N-P-K)	Description
Ammonium Nitrate	34-0-0	Normally contains 34% N, half as NH_4^+ and half as NO_3^- . Not susceptible to volatilization when surface applied to pastures in late summer.
Ammonium Sulfate	21-0-0	In addition to 21% N, also contains 24% S making it a good N source when S is needed. Low risk of volatilization when applied in late summer. Results in greater soil acidification, requiring more lime per unit N applied.
Urea (granular)	46-0-0	Contains a relatively high concentration of N. Susceptible to volatilization when surface applied to pastures in late summer.
Urea (granular) + Agrotain	46-0-0	See above. The addition of Agrotain reduces N losses via volatilization.
Environmentally Smart N	44-0-0	Urea N that is encapsulated in polymer coating that results in a slow release N Source.
Nitamin	42-0-0	Slow release N source. This source is degraded to a plant available form by soil microbes over a 60-90 day period.
Pelleted Biosolids	6-3.5-0.5	Pelletized biosolids product that can be spread with conventional equipment. Approximately 60% of the total N is plant available (Teutsch and Tilson, 2006).
NutriSphere-N	46-0-0	Spray-on additive that is suggested to reduce volatilization and leaching losses

Table 3-2. N fertilizer applications and harvest dates for stockpiled fescue experiments in 2006 and 2007.

Year	N application date			Harvest dates		
	Blacksburg	Blackstone	Steeles Tavern	Blacksburg	Blackstone	Steeles Tavern
2006	August 15	Sept. 30	August 14	Dec. 14	Jan. 30	Dec. 18
2007	August 15	August 30	August 14	Dec. 19	n/a [†]	Dec. 18

[†] Unable to harvest due to lack of biomass

RESULTS AND DISCUSSION

Environmental Conditions

Blacksburg, Steeles Tavern and Blackstone locations

Fescue response to N fertilizer application is directly affected by available moisture and temperature conditions (Gerrish et al, 1994; Collins and Balasko, 1981, Poore et al., 2000).

Drought conditions and/or cold temperatures will reduce fescue growth and limit plant response, both yield and nutritive value, to applied N fertilizer. The Blackstone and Blacksburg locations both received rainfall greater than 0.25 cm within 5 days of N application, which is sufficient for incorporation of the surface applied water-soluble N fertilizers (Havlin, et. al., 2005). The first killing frost (28°F) occurred on 4 Nov 2006 at the Blackstone location and on 3 Nov 2006 at the Steeles Tavern and Blacksburg locations. In 2007, the first killing frost occurred on 29 October 2007 for both Steeles Tavern and Blacksburg.

At the Blacksburg location, total rainfall during the stockpiling period was lower for the 2007 growing season (435 mm) compared with the 2006 growing season (604 mm). The 55-yr average was 594 mm for the Blacksburg location. The total amount of rainfall for the 2006 stockpiling season (August-December) exceeded the 2007 rainfall total by 169 mm and was similar to the 55-yr average (Figure 3-2). At the Steeles Tavern location, total rainfall during the stockpiling period was lower for 2007 (323 mm) compared with 2006 (593 mm), and the 55-year average (565 mm) (Figure 3-3).

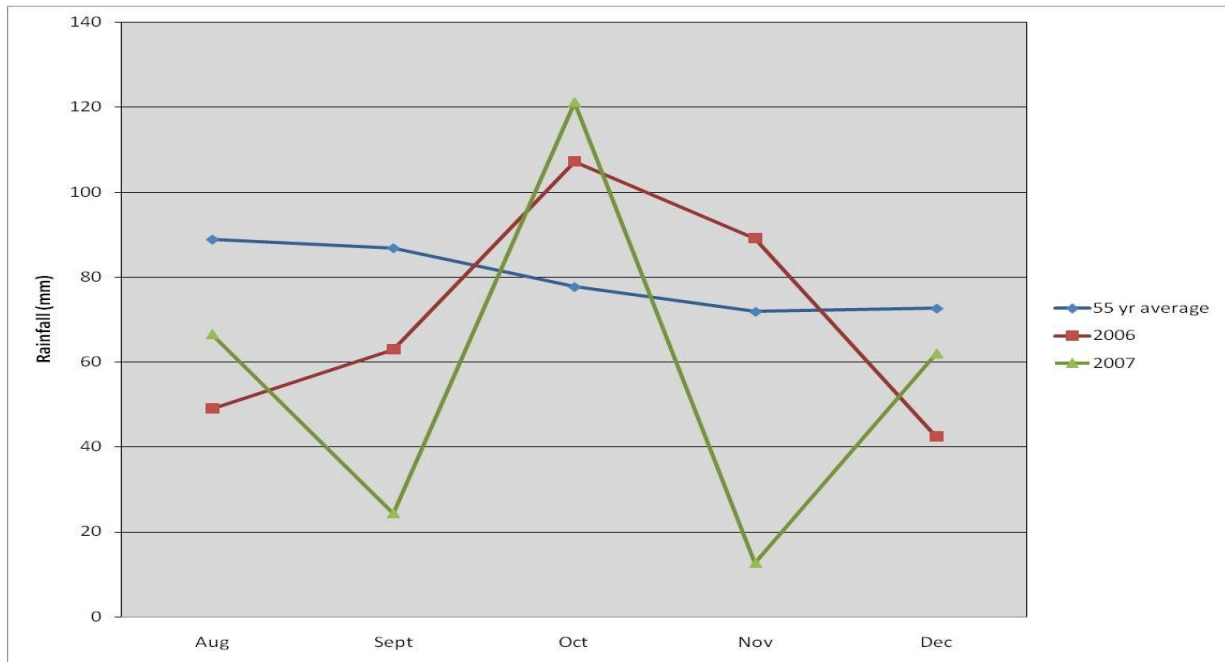


Figure 3-2. Monthly and the 55 yr average rainfall recorded in Blacksburg, VA during the 2006 and 2007 growing seasons.

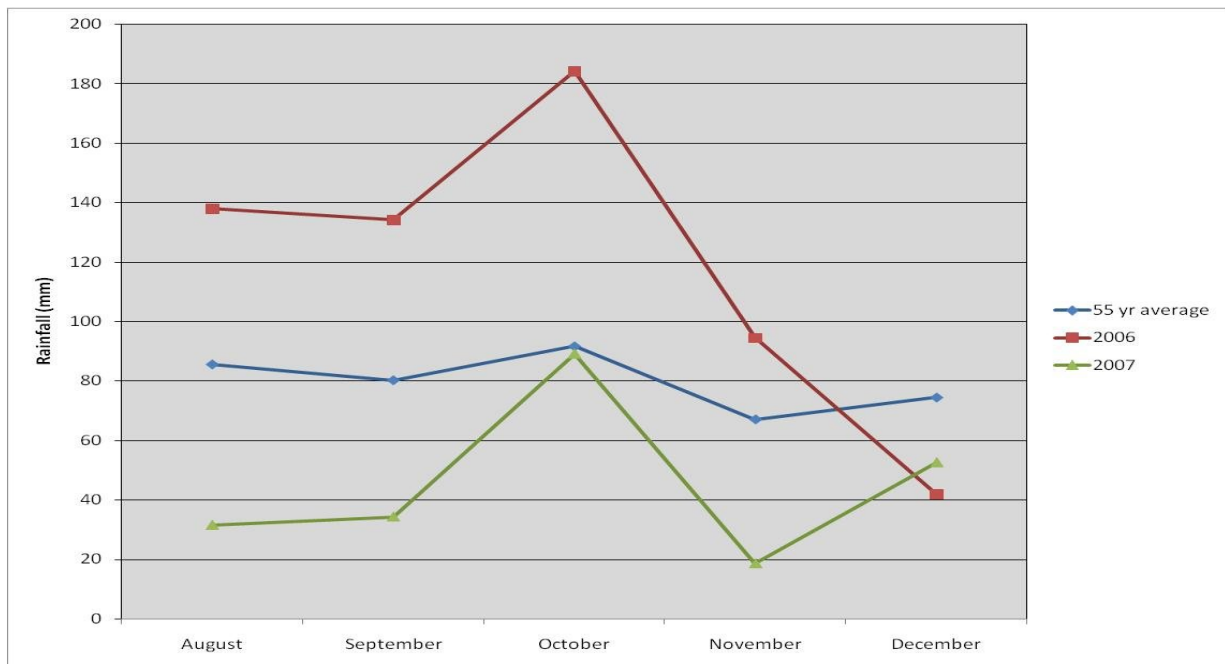


Figure 3-3. Monthly and the 55 yr average rainfall recorded in Steeles Tavern, VA during the 2006 and 2007 growing seasons

At the Blackstone location, total rainfall during the 2006 growing season exceeded the 50 yr average by 391 mm (Figure 3-4). However, during the 2007 growing season, rainfall was 587 mm, which is 154 mm lower than the 50 yr average. The lack of rainfall prior to the growing season and during the growing season greatly reduced forage growth. Due to little growth, plots in Blackstone in 2007 were not harvested and thus no data are reported.

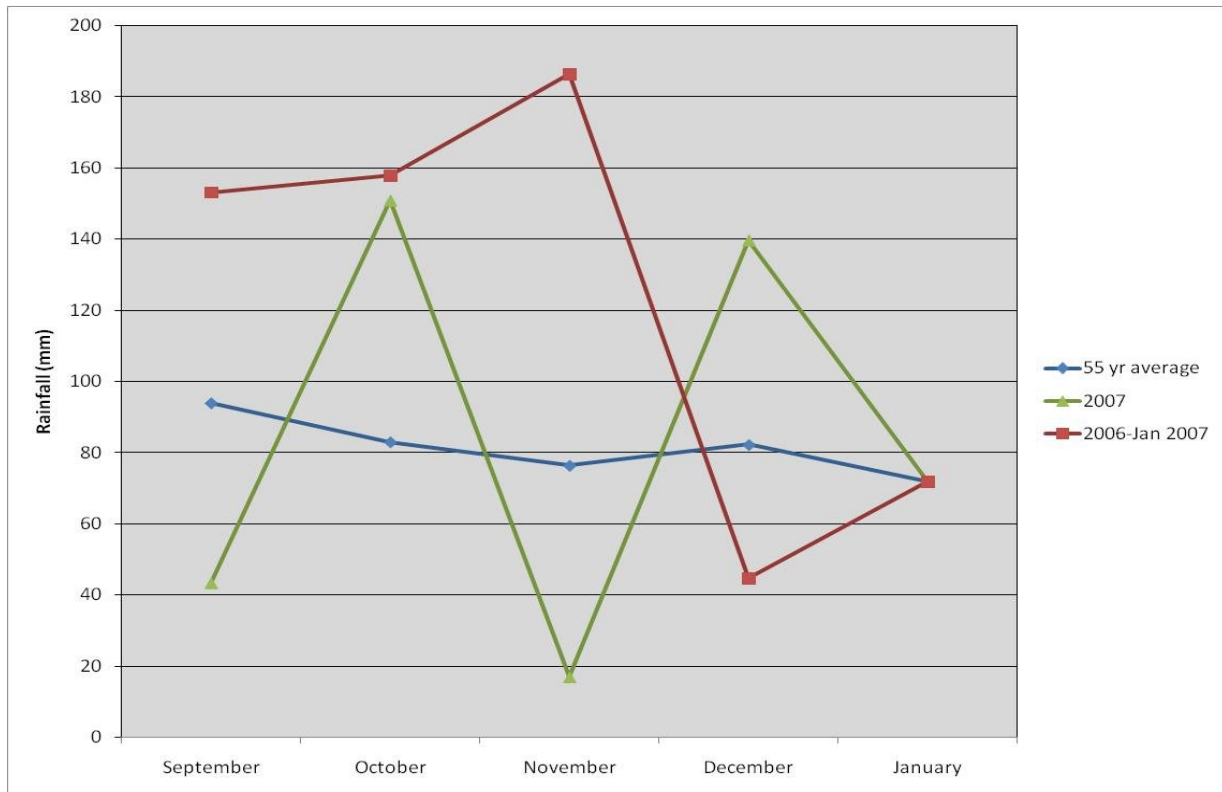


Figure 3-4. Monthly and the 55 yr average rainfall recorded in Blackstone, VA during the 2006 and 2007 growing seasons

Biomass Yields

Significant N rate x location ($P < 0.001$) and N source x location ($P < 0.05$) interactions were observed for dry matter yields. Therefore, data is presented by location. For each of the three locations, N rate x N source interactions were not present. Main effects of N rate and N source are presented for the yield data.

Blacksburg

At the Blacksburg location, biomass yield responses to N rates were quadratic and linear in 2006 and 2007, respectively. Yield ranged from 1300 to 3300 and 1100 to 1325 kg DM ha⁻¹ in 2006 and 2007, respectively (Figures 3-5 and 3-6). In 2006, yield increased quadratically with increasing N rate ($P < 0.01$) with N response beginning to decrease when rates reached 100 kg N ha⁻¹ (Figure 3-5). Taylor and Templeton (1976) reported that agronomic N use efficiency ranged from 15 to 24 kg DM kg⁻¹ applied N which is much higher than the N use efficiency of 8 to 10 kg DM/kg applied N reported by Rayburn et al. (1979). In 2007, yields increased linearly with increasing N rate (Figure 3-6) but the relationship was very poor ($R^2=0.02$) due to the low yields. Stockpiled yields increased at a rate of 1.9 kg DM kg⁻¹ applied N in 2007. The N response in 2007 was much lower than the 2006 yield due to the lack of rainfall prior to and during the stockpiling period. In 2006, the yield increase from 0 to 100 kg N was 2000 kg while in 2007 the difference between the 0 and 100 kg N rate was only 225 kg ha⁻¹. The difference in biomass yield between the two growing seasons can be attributed to the less than average rainfall received in 2007, which probably prevented the plant from utilizing the applied N. The yield response to applied N reported in 2007 was significantly less than previously reported. Taylor and Templeton (1976) reported tall fescue yields of 1887, 3086 and 3374 kg ha⁻¹ when fertilized with 0, 50 and 100 kg N ha⁻¹.

In 2006, the control treatment was significantly lower ($P > 0.001$) than all N sources. The difference between the control and the N sources was 1502 kg DM ha⁻¹. Lack of yield differences among N sources can be attributed to the rainfall (9.7 mm) received during the five days following N fertilization. Havlin et al. (2005) stated that if at least 2.5 mm is received within five days of N fertilization, the risk of volatilization is greatly reduced. In general,

biomass yield was significantly lower in 2007 compared to 2006. In terms of yield response to N sources there was no significant differences observed among treatments (Figure 3-8). This is likely due to the lack of rainfall received throughout the stockpiling season.

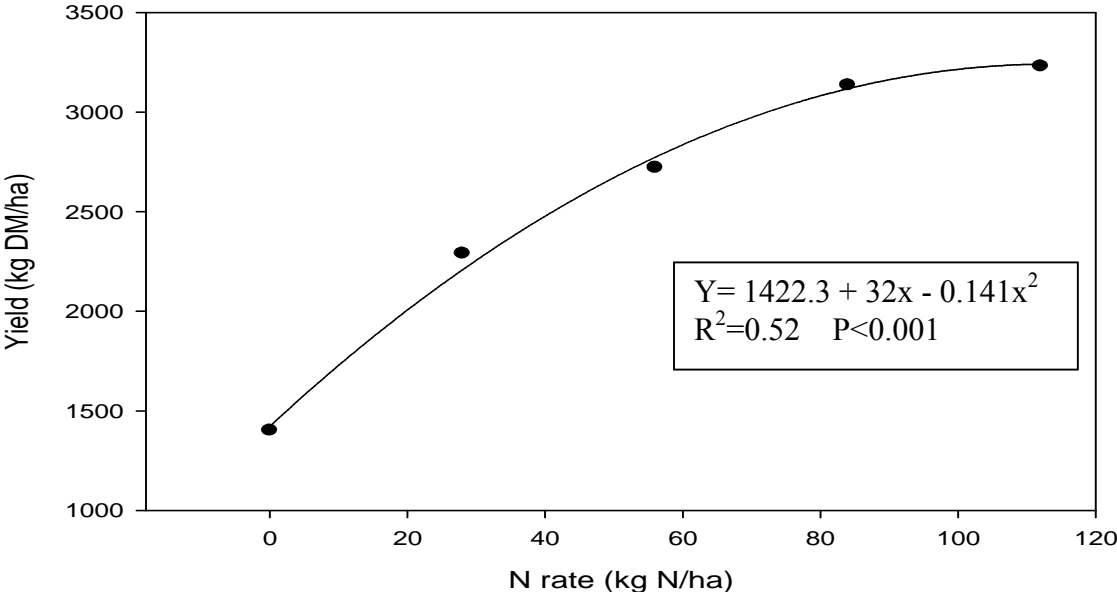


Figure 3-5. Averaged over all N sources, N rate influence on biomass yield for Blacksburg, 2006

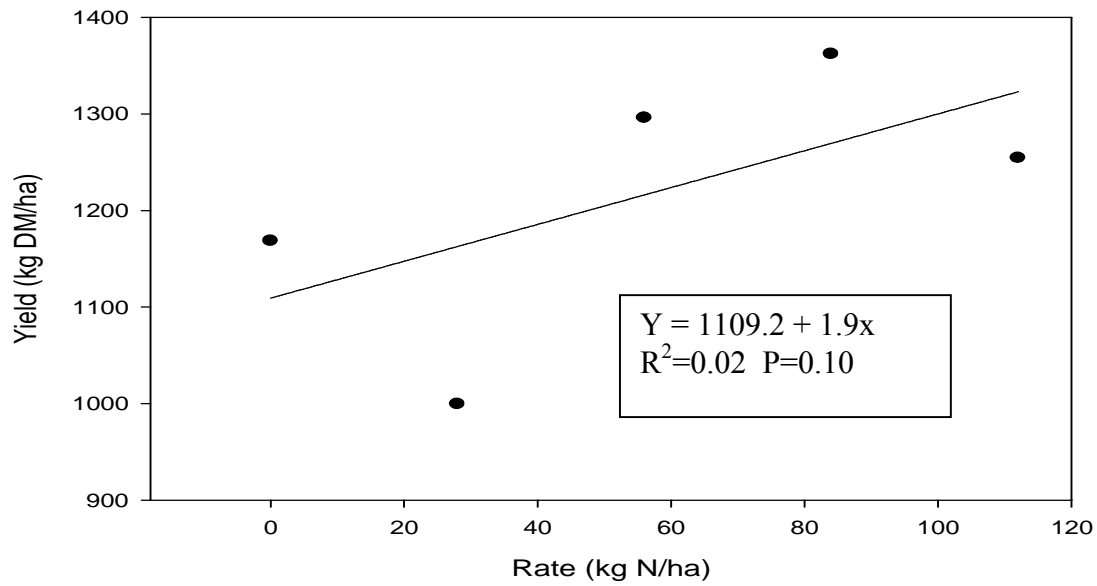


Figure 3-6. Averaged over all N sources, N rate influence on biomass yield for Blacksburg location, 2007.

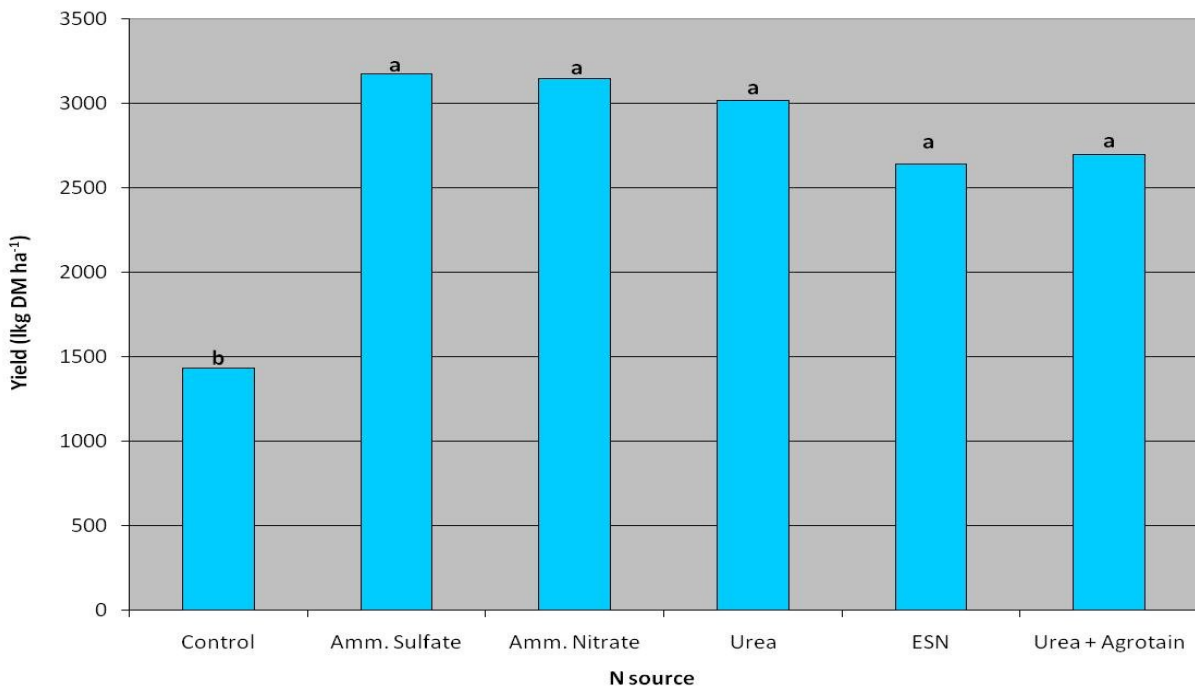


Figure 3-7. N source influence averaged over N rates on biomass yield for Blacksburg, 2006. Means for bars followed by the same letter are not significantly different according to Duncan's Multiple Range test ($P = 0.10$).

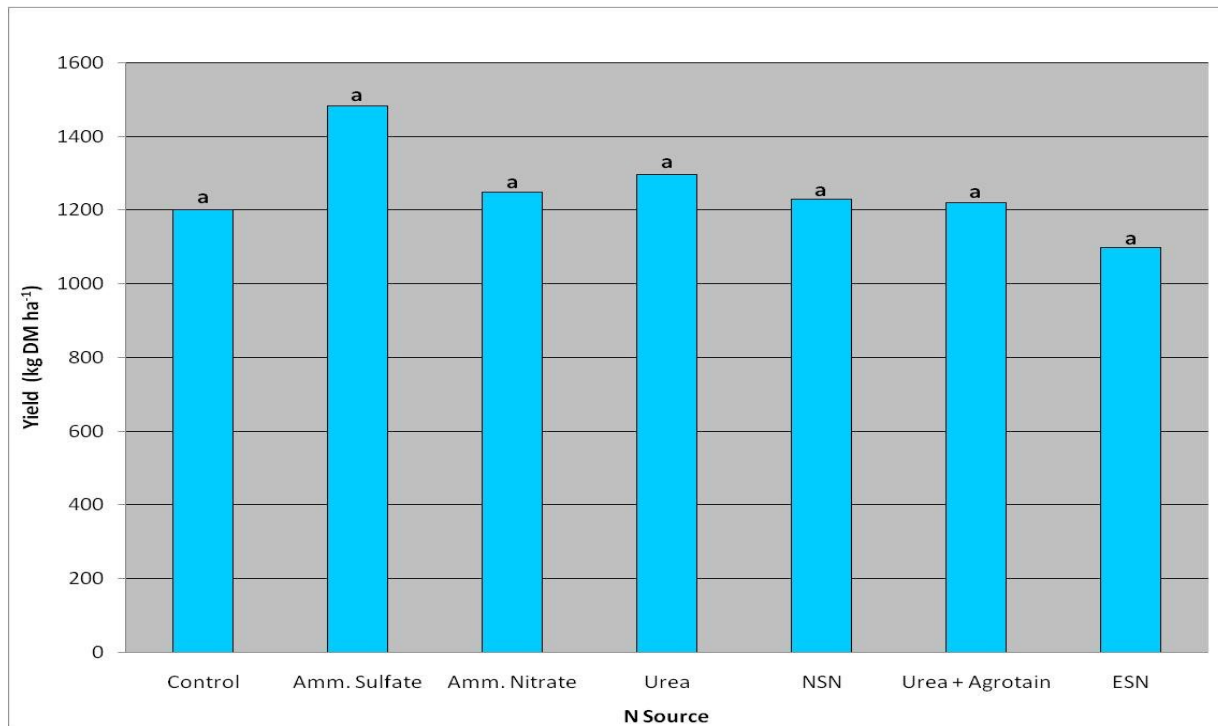


Figure 3-8. N source influence averaged over N rates on biomass yield for Blacksburg, 2007. Means for bars followed by the same letter are not significantly different according to Duncan's Multiple Range test ($P = 0.10$).

Steeles Tavern

At the Steeles Tavern location, yields ranged from 1700 to 3400 kg DM ha⁻¹ in 2006 (Figure 3-9). Stockpiled yields increased at a rate of 13.7 kg DM/kg applied N. Taylor and Templeton (1976) and Gerrish et al. (1994) both reported similar N responses of 15 to 24 kg DM kg⁻¹ applied N, while Rayburn et al. (1979) reported an N response of 8 to 10 kg DM kg⁻¹ applied N. In 2007, however, yields were significantly lower, ranging from 43 to 55 kg DM ha⁻¹. The extremely low yield response to N rates and source was due to the lack of precipitation during the stockpiling period and the management of plots prior to N application. In regard to grazing or clipping management prior to stockpiling, Berry and Hoveland (1969) reported that a summer rest period is needed in order to achieve maximum fall-winter growth. Berry and Hoveland (1969) stressed the importance of summer defoliation to stimulate tiller production but pointed out the negative effect on carbohydrate reserve which is needed for fall growth. The lack of

moisture and overgrazing may have attributed to depletion of the carbohydrates reserves, causing reduction in accumulated growth.

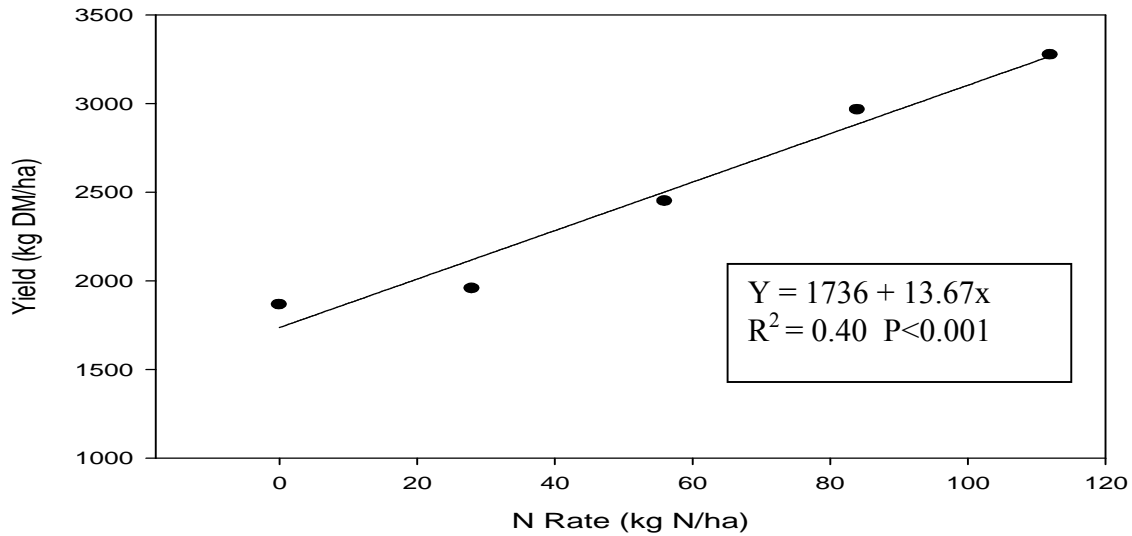


Figure 3-9. Averaged over N sources, the effect of N rates on biomass yield for Steeles Tavern, 2006

In 2006, ammonium nitrate and ammonium sulfate both yielded significantly higher than the control. Ammonium nitrate and ammonium sulfate increased yield 1125 and 1069 kg DM ha⁻¹, respectively versus the control. Similar to the Blacksburg location in 2006, lack of differences between N sources can be attributed to the timely rainfall that was received after N application.

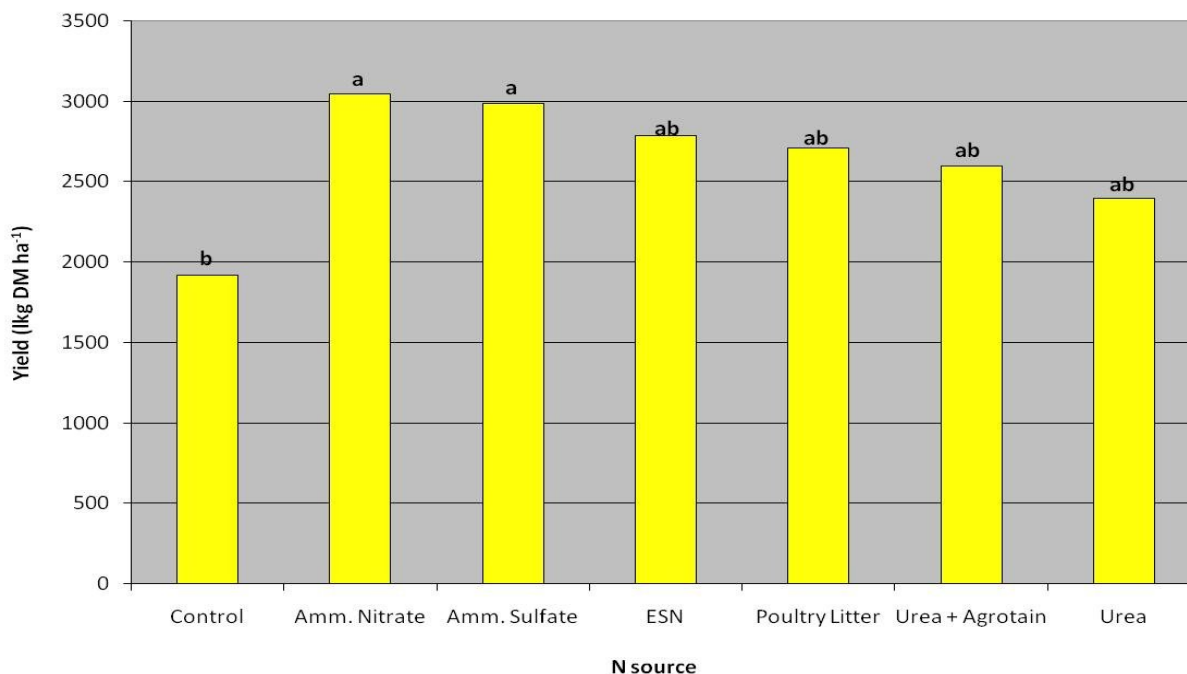


Figure 3-10. N sources influence averaged over all N rates on biomass yield for Steeles Tavern, 2006. Means for bars followed by the same letter are not significantly different according to Duncan's Multiple Range test ($P = 0.10$).

Blackstone

Yields in 2006 at the Blackstone location ranged from 3000 to 3700 kg DM ha⁻¹ and increased linearly with increasing N rate (Figure 3-11). Compared to the Steeles Tavern (1700 to 3400 kg DM ha⁻¹) and Blacksburg (1300-3300 kg DM ha⁻¹) locations, during 2006, Blackstone yields were much higher which may in part be due to a higher initial clipping height prior to stockpiling (15 cm for Blackstone versus 7.5 cm for the Steeles Tavern and Blacksburg locations). Stockpiled yield increased at a rate of 6.7 kg DM kg⁻¹ applied N. The N response observed at the Blackstone location was much lower than N response observed at the other two locations. This is likely related to the shorter stockpiling period. Burns and Chamblee (2000) reported that delaying stockpiling initiation date from June 1 to September 1 caused a linear decrease in biomass yield up to 282 kg ha⁻¹ for each week of delay. In a similar study where

both N rates and application date were investigated, Gerrish et al. (1994) reported varied yield response and N use efficiency when N was applied at the beginning of August vs. at the end of August. When N application date was August 1, N application at 45 kg N ha⁻¹ rate produced 1131 kg ha⁻¹ of biomass with N use rate of 14 to 25 kg DM kg⁻¹ applied N. However, when the N fertilization date was postponed until August 29 the N use rate was 6 to 9 kg DM kg⁻¹ applied N (Gerrish et al., 1994). At the Blackstone location, N was applied approximately one month later than the other two locations. Due to this shorter stockpiling period, the forage was not able to accumulate as much growth before the killing frost occurred. In a study conducted in North Carolina, yields were 4677, 3720, 3210 and 1660 kg ha⁻¹ when stockpiling initiation date began in June, July, August and September, respectively (Burns and Chamblee (2000)). Collins and Balasko (1981a) reported that yield and quality depends on stockpiling initiation date and the N fertilization rate.

At the Blackstone location, no yield differences were observed among the N sources and control treatment (Figure 3-12). The yield difference between the control and the seven N sources was 93 kg DM ha⁻¹. The overall averages among the N sources were higher at this location due to the difference in pre-stockpiling clipping height. This location was cut to 15 cm which is about 5 cm higher than the other two locations which resulted in more initial vegetation and higher overall yields. Due to lack of rainfall during the 2007 stockpiling season plots were not harvested because there was no harvestable growth during the stockpiling period.

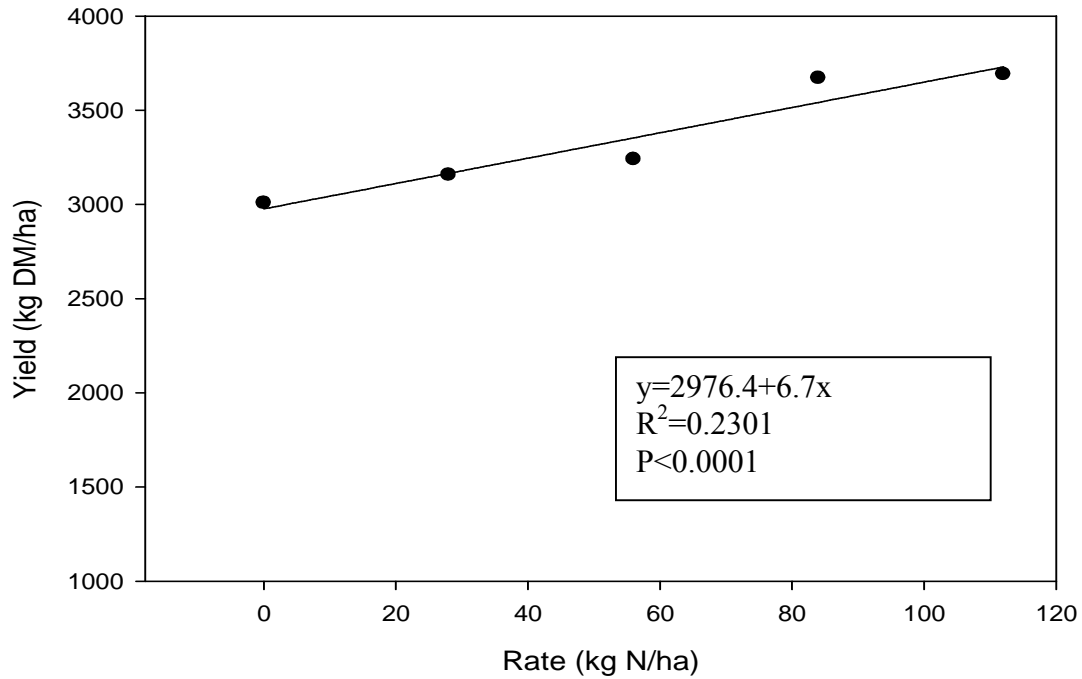


Figure 3-11. N rates influence averaged for all N sources on biomass yield for Blackstone, 2006.

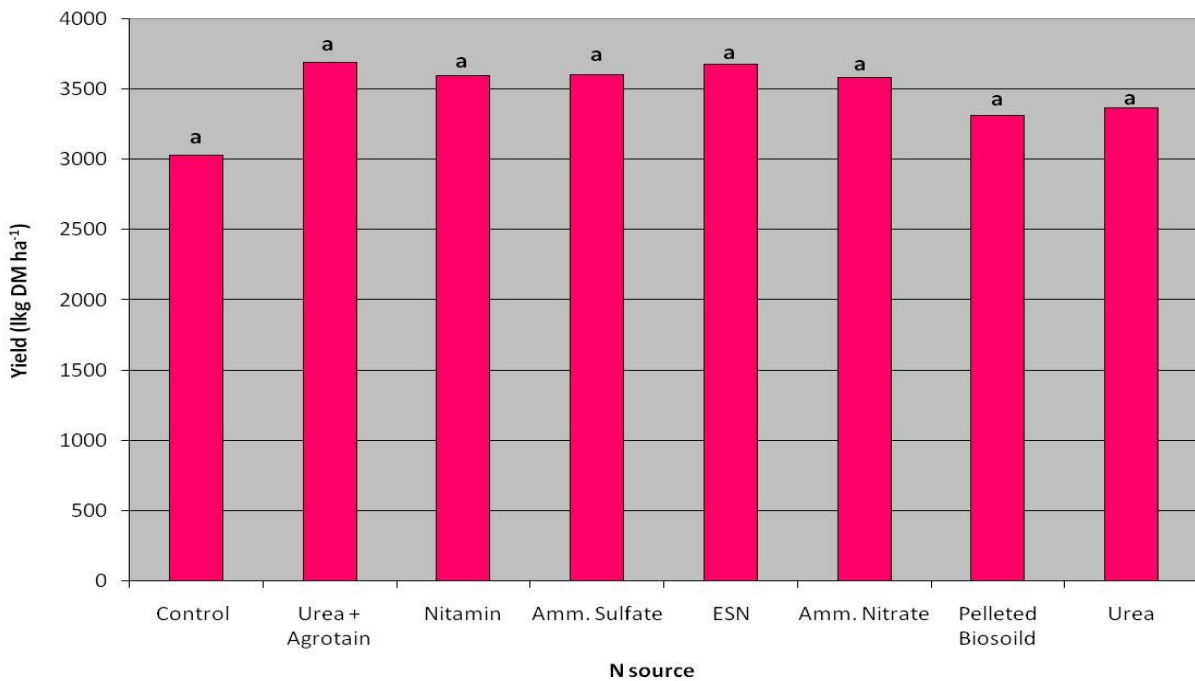


Figure 3-12. N sources influence averaged over all N rates on biomass yield for Blackstone, 2006. Means for bars followed by the same letter are not significantly different $P = 0.10$ (DMRT).

Effect on Nutritive Values

There were significant N rate and N source x location ($P < 0.007$) interactions for the crude protein (CP) concentrations. Therefore, data as presented for each year within a location.. There were significant N source x location ($P < 0.001$) interactions for both NDF and ADF. Therefore, data are presented by location. For Blacksburg and Steeles Tavern, N rate x N source interactions were not present for CP, NDF and ADF for both years ($P < 0.10$).

Blacksburg

Crude protein concentrations ranged from 11 to 15% and 13 to 21% in 2006 and 2007, respectively. In 2006, CP concentrations increased linearly with increasing N rate. The only difference between N sources that is observed is between ESN and urea. Urea was producing 11.5 kg DM kg N⁻¹ whereas ESN was producing 12.5 kg DM kg N⁻¹.

In 2007, there were not significant N rate N source interactions ($P > 0.47$) (Figure 3-14). CP concentrations increased quadratically for all the N sources except Agrotain, which increased linearly. This quadratic response which was observed is likely due to lack of rainfall, which limited the plant's use of N. Generally, in both 2006 and 2007, CP concentrations increased with increasing N rate (Figure 3-13 and 3-14).

Fiber concentrations (NDF and ADF) for all locations are shown in Tables 3-3 and 3-4. In most cases, values are within the acceptable range for all classes of animal production. Neutral Detergent Fiber and ADF concentrations decreased as N rate increased. In 2006, urea had a higher NDF concentration than the control ($P > 0.001$). In 2007, the control had a higher NDF concentration than all the N sources except ESN, which is likely attributed to less vegetative growth. Results for ADF were similar, the NDF concentration for urea was significantly higher than ESN, and control NDF concentrations were significantly higher than all

the other N sources in 2006 and 2007, respectively. Similar quality results were reported in previous studies (Burns and Chamblee, 2000; Teutsch et al., 2005; Poore et al., 2000; Taylor and Templeton, 1976; Archer and Decker, 1977; and Singer et al., 2003).

Table 3-3. N sources and N rates influence on NDF values for Blacksburg, 2006 and 2007 and Steeles Tavern, 2006.

N Source	Blacksburg		Steeles Tavern
	2006 NDF %	2007 NDF %	2006 NDF %
Amm. Nitrate	55.2ab	53.0b	57.7b
Amm. Sulfate	55ab	53.6b	58.6ab
AGRO	55.4ab	53.5b	58.6ab
ESN	54.0ab	55.0ab	58.3ab
Urea	56.2a	53.2b	59.2ab
Poultry Litter	†	†	58.5ab
NSN	‡	52.7b	‡
Control	55.4b	56.6a	60.1a
N Rate			
0	55.4ab	56.6a	60.0a
28	55.9a	54.4b	59.5ab
56	55.8a	53.7b	58.5abc
84	54.7ab	53.1b	58.4bc
112	54.2b	52.7b	57.8c

†Not applied at Blacksburg location; ‡Not applied in 2006; Data not presented for 2007 due to low yields

Table 3-4. N sources and N rates influence on ADF values for Blacksburg, 2006 and 2007 and Steeles Tavern, 2006.

N Source	Blacksburg		Steeles Tavern
	2006 ADF %	2007 ADF %	2006 ADF %
Amm. Nitrate	32.1ab	33.7b	34.5b
Amm. Sulfate	32.1ab	34.1b	35.1ab
AGRO	32.4ab	33.9b	35.1ab
ESN	31.5b	34.4b	35.0ab
Urea	32.9a	34.1b	35.3ab
Poultry Litter	†	†	34.8ab
NSN	‡	33.5b	‡
Control	32.2ab	35.8a	35.9a
N Rate			
0	32.2	35.8a	35.8a
28	32.4	34.7b	35.3ab
56	32.6	34.4b	34.8b
84	32.0	33.7bc	35.1ab
112	32.0	32.9c	34.8b

†Not applied at Blacksburg location; ‡Not applied in 2006; Data not presented for 2007 due to low yields

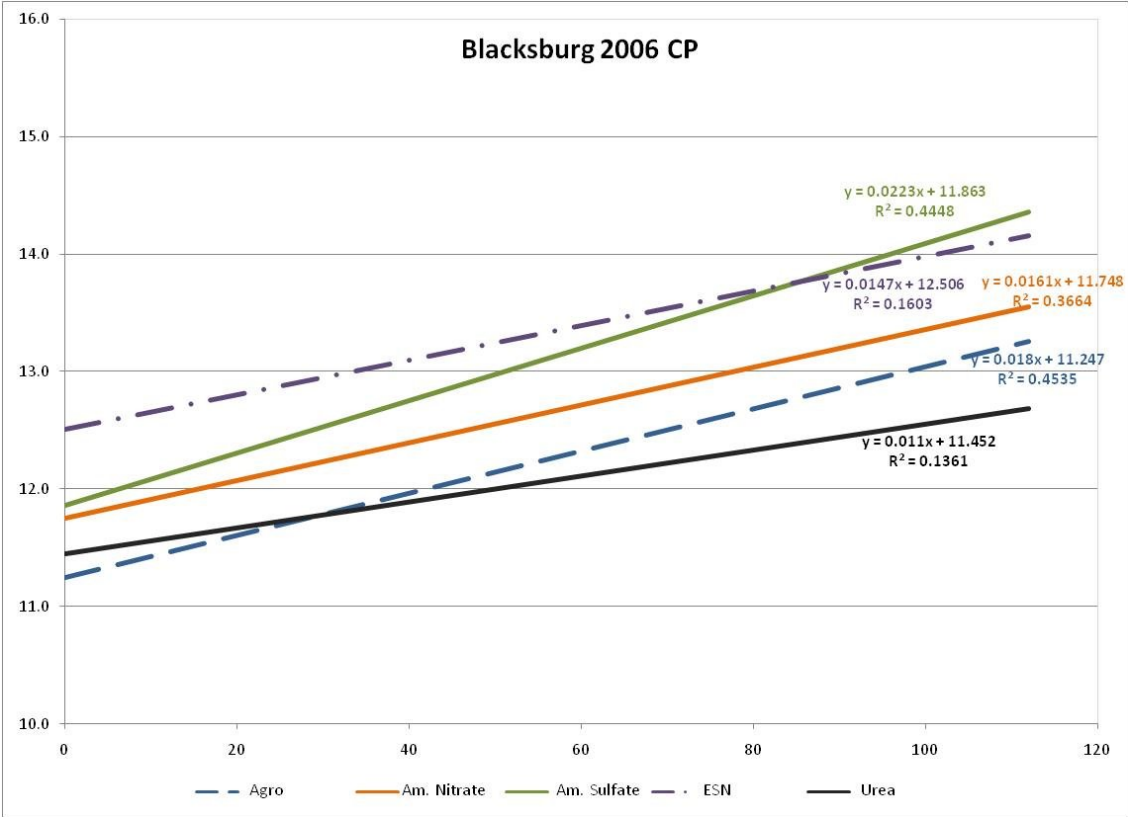


Figure 3-13. Influence of N rate and source on CP in Blacksburg, 2006.

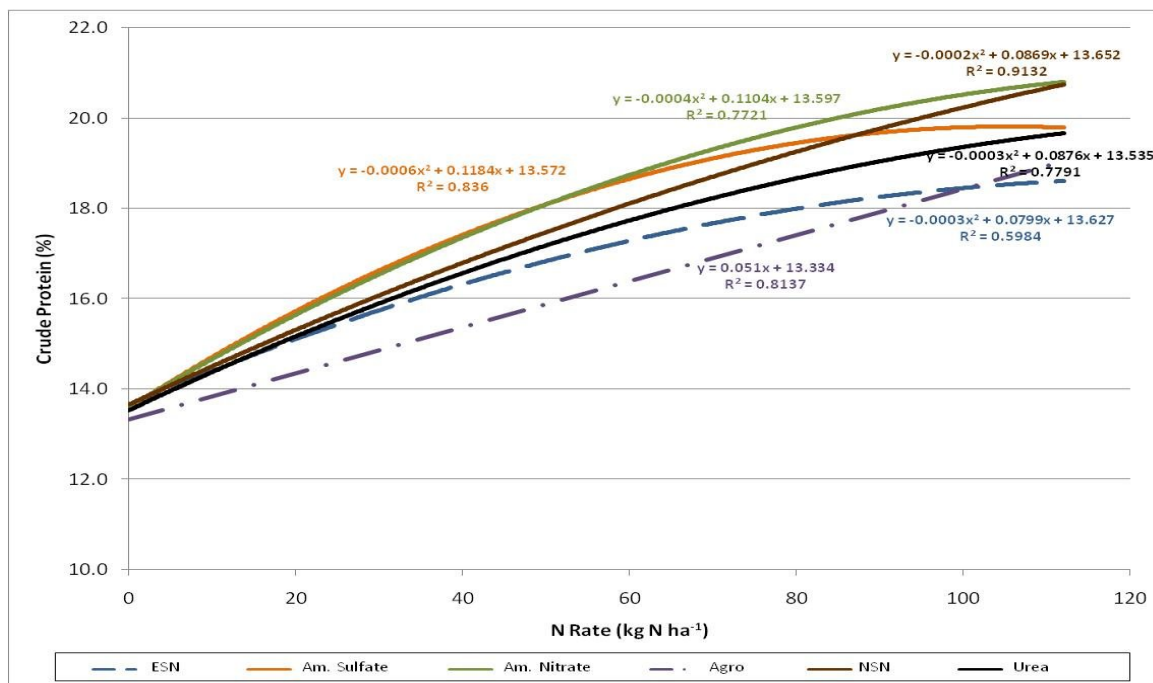


Figure 3-14. Influence of N rate and N source on CP in Blacksburg, 2007.

Steeles Tavern

Crude protein concentrations of fescue ranged from 10-14% in 2006. In 2006, there were differences among N sources ($P < 0.001$). There were no significant N rate x N source interactions observed ($P > 0.4670$). Crude Protein concentration of fescue fertilized with ESN was 12.6% which was significantly higher than the CP concentrations for fescue fertilized with urea (11.1%) and the control (10.6). All CP concentrations among N sources, except urea were higher than the control. There were differences among N rates, that is, as N rate increased CP concentrations also increased (Figure 3-15). Similar quality results were reported in previous studies (Burns and Chamblee, 2000; Teutsch et al., 2005; Poore et al., 2000; Taylor and Templeton, 1976; Archer and Decker, 1977; and Singer et al., 2003). In 2007, yields were negligible due to severe drought preventing any meaningful discussion of nutritive values. Table 3-3 and Table 3-4 show NDF and ADF results for all locations. All values are within the acceptable range required for all classes of livestock. The N rate was significant for both years.

Generally, as N rate increased, NDF and ADF decreased. For 2006 this can be attributed to the high leaf to stem ratio during the stockpiling period due to increased vegetative growth.

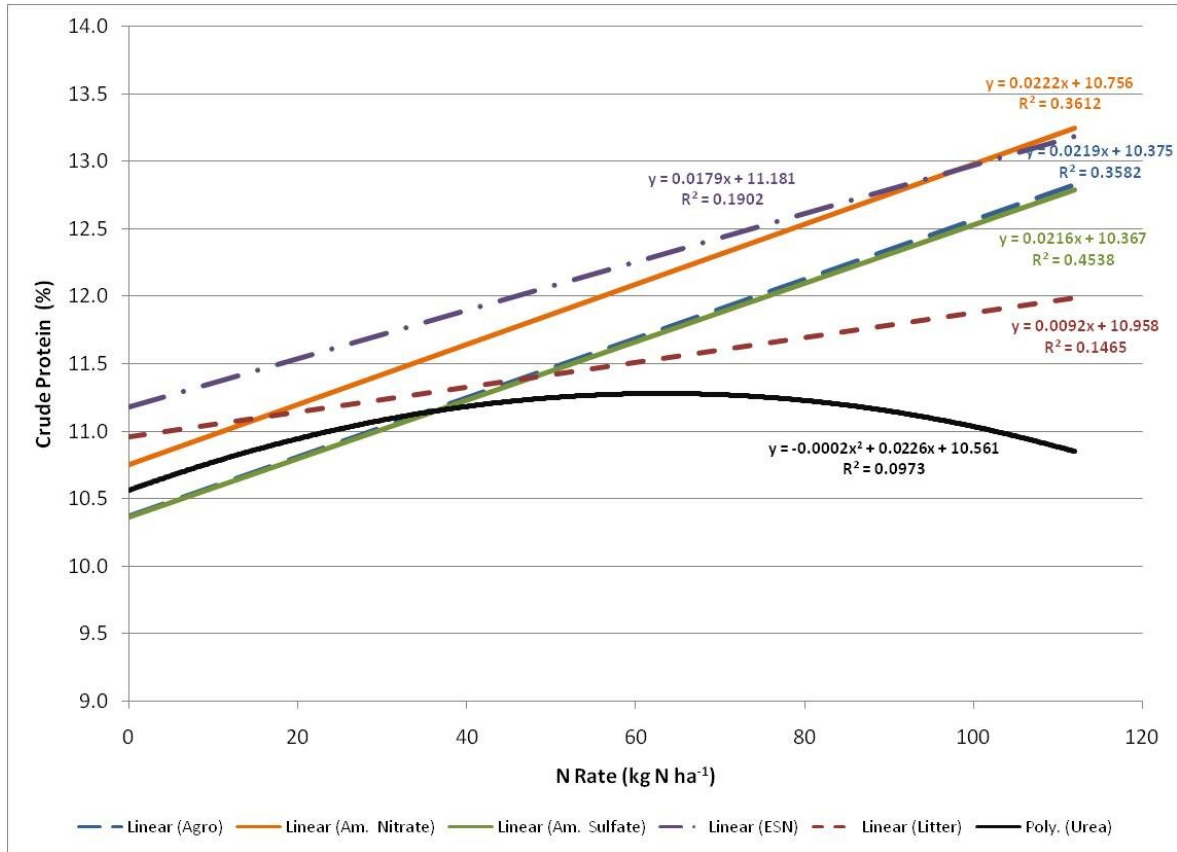


Figure 3-15. Influence of N rate and N source on CP in Steeles Tavern, 2006

SUMMARY AND CONCLUSION

At the Blacksburg and Steeles Tavern locations in 2006, the environmental conditions were favorable for fall biomass production during stockpiling. As a result the biomass yield response to N rates ranged from 1400 to 3300 kg DM ha⁻¹ at 0 and 112 kg N ha⁻¹, respectively. In terms of N source, at the Blacksburg location, there were similar yield responses among all N sources applied. At the Steeles Tavern location, overall, the effect of N source on biomass yield was similar to the results obtained at the Blacksburg location in 2006 with the exception that DM yields from both ammonium nitrate and ammonium sulfate were significantly higher than the control yields. At the Blackstone location, the yield response to N rates varied from 3000 to 3700 kg DM ha⁻¹ for 0 and 112 kg N ha⁻¹, respectively. This response to N rate was significantly less than the other two locations during the 2006 growing season. The difference in yield response to N rate and sources at this location can be attributed to the late stockpiling initiation date and clipping height prior to application.

Overall, for all locations over the two experimental years, percent CP increased with increasing N rate. The single and combined effect of N rate and source resulted in the CP content acceptable to meet the CP requirements of non-lactating animals. In general, percent NDF and ADF decreased with increasing N rate. The percent ADF and NDF values ranged from 31 to 36% and 53 to 60%, respectively. Generally, the quality of the stockpiled fescue, regardless of N rates and sources resulted in CP, ADF and NDF levels acceptable to support all classes of livestock beyond maintenance level.

Among temperate grasses adapted to the region, tall fescue is the most desirable grass to stockpile for late fall and winter grazing. During the fall and winter months, the stocked forage provides good quality feed to animals having varied production levels. The stockpiled forage is

very palatable and maintains high quality throughout the winter season (Poore et al., 2000; Burns and Chamblee, 2000). The quality of the stockpiled forage is maintained at the high level throughout the winter period due to the maintenance of green leaf with minimum amount of decay and deterioration associated with the stockpiled forage.

Based on our research we recommend that when choosing an N source and rate for N fertilization of stockpiled fescue, it should be based on current fertilizer prices and the amount of DM needed for livestock production. The prices of various N sources will vary, however based on our research there is little to no difference between N sources when it came to yield and quality. The amount of DM needed for livestock production will vary among livestock operations; a small cow-calf operation may not be able to utilize the amount of DM 60 kg N ha^{-1} produces, so a lower rate may be more applicable whereas a larger operation may be able to utilize that amount of DM. We recommend that stockpiled fescue pastures be fertilized with N during normal rainfall conditions. Proper pasture management should be maintained prior to N fertilization of stockpiled fescue. This would include proper clipping height (3-4") and also applying N at the correct time. As seen in this study, in a normal rainfall year, a large yield increase was seen when N was applied, however, in a drought year, N fertilization may not be beneficial. In a year, where a drought is expected, N fertilization should be reduced or eliminated. Based on our research, the N rate for stockpiled fescue pastures should continue to be between $45\text{-}90 \text{ kg DM ha}^{-1}$. Fertilizer prices and rainfall are the two main factors that will likely affect which N source and N rate that will be applied.

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CHAPTER IV

The Influence of Split Spring and Fall N Applications at Various Rates on Biomass Yield and Nutritive Value of Tall fescue Pastures.

ABSTRACT

Nitrogen fertilization is a major factor in determining the productivity of tall fescue [(*Schedonorus phoenix* (Scop.) Holub,) formally known as *Festuca arundinacea* L.] pastures. Factors such as timing of N application, rate and type of fertilizer can affect yield and nutritive values of tall fescue. As N fertilizer costs continue to increase, it has become crucial to optimize N use efficiency. Small plot experiments were conducted in 2007 and 2008 in Blacksburg and Steeles Tavern, VA to evaluate the effectiveness of split fall and spring N applications on the yield and nutritive values of tall fescue pastures. The experimental design was a randomized complete block design with four replications. There were 16 treatments of split fall-spring N applications with urea at rates of 0, 45, 90, or 135 kg N ha⁻¹ at each application time. At the Blacksburg location, there were significant yield differences among treatments. Yields ranged from 1,900 to 3,600 kg DM ha⁻¹ and 700 to 2,500 kg DM ha⁻¹ in 2007 and 2008, respectively. At the Steeles Tavern location, yields ranged from 3,100 to 5,700 kg DM ha⁻¹ and 2,500 to 5,100 kg DM ha⁻¹, in 2007 and 2008, respectively. In both years CP increased with increasing N fertilization. On a dry matter basis, CP values ranged from 14 to 23% for both years. Treatments did not affect on NDF and ADF values. Split fall/spring N applications did not maximize yield of cool-season grass pastures in these experiments.

INTRODUCTION

In terms of acreage, forages are the number one crop in Virginia. The backbone of these forages has long been tall fescue [(*Schedonorus phoenix* (Scop.) Holub,) formally known as *Festuca arundinacea* L.] Studies have shown that nitrogen (N), phosphorus (P) and potassium (K) fertilization have positive effects on swards production (Kohler et al., 2004; Niczyporuk and Jankowska-Huflejt, 1995; Samuel, 1998). Nitrogen fertilization is a major factor in determining the productivity of tall fescue pastures. Factors such as timing of N application, rate and fertilizer type can affect quantity and nutritive values of tall fescue (Poore et al., 2002). It is typically recommended to split apply N in the spring, one prior to the first cutting and then again following each hay cutting (Ball et al., 2002). Cherney and Cherney (2006) investigated the effect of N application timing on forage yield and nutritive value of three perennial grasses, tall fescue, orchardgrass (*Dactylis glomerata* L.), and reed canarygrass (*Phalaris arundinacea* L.). Each had N fertilizer treatments applied at 1) 225 kg N ha⁻¹ in early spring, 2) 112 kg N ha⁻¹ in early spring with an additional 112 kg N ha⁻¹ following the first harvest or 3) 112 kg N ha⁻¹ in early spring with an additional 56 kg N ha⁻¹ following each harvest. Split N applications increased DM yields by 12% compared to the single N application in the spring. Split N applications also produced higher quality forage feed to that met lactating dairy cows' requirements (Cherney and Cherney, 2006).

Hall et al. (2003) conducted a study to examine the N rate on three cool-season grasses that optimized economic return for Pennsylvania climate and soil conditions. Yield response began to decrease at 336, 432, and 357 kg N ha⁻¹ for orchardgrass, tall fescue and timothy (*Phleum pratense* L.), respectively. It was also reported that economic return increased as the N

rate increased up to 284, 368, and 299 kg N ha⁻¹ for orchardgrass, tall fescue, and timothy, respectively. Hall et al. (2003) concluded that the economic optimum N rate for orchardgrass, tall fescue, and timothy for hay production was 26, 32, and 29 kg N Mg⁻¹, respectively.

In turfgrass management, researchers have recommended two N applications, one occurring in the spring and the other during late fall (mid-October to mid-November) (Turgeon, 2002; Christians, 1998). A late fall N application allows for earlier spring greenup, reducing the amount of N needed in the spring and this is due to increasing stored carbohydrates from the late fall fertilization. When the late fall N is applied air temperatures are beginning to decline reducing shoot production (Christians, 1998). The ideal air temperature for shoot growth is between 18 and 24°C, while most root growth occurs when soil temperatures are between 14 and 18°C. In the fall, air temperatures decline quickly, while soil temperatures decline slowly. Once air temperatures decline soil temperatures are still within the ideal range. Thus, the justification of late fall application is that the plant is still producing carbohydrates; however they are not being used for shoot production. The carbohydrates are translocated to the stems and roots, where they are used for growth until soil temperatures decline or are stored for spring growth following winter dormancy (Christians, 1998).

Limited information is available comparing single vs. split N fall-spring applications on the effects of yield and nutritive values of tall fescue pastures. The objective of this study was to determine the effect of split fall and spring N fertilizer applications at various rates on yield and nutritive value of tall fescue pastures.

METHODS AND MATERIALS

Small plot experiments were conducted in 2007 and 2008 in Blacksburg and Steeles Tavern, VA to evaluate the effectiveness of split fall and spring N applications on the yield and nutritive values of tall fescue pastures. The experimental design was a randomized complete block design with four replications per site. There were sixteen treatments (Table 4-1) per replication. The experimental unit was the plot. Each plot was 3 x 3 m. Prior to fertilization, soil samples were taken (10 cm deep) to determine soil-N, P and K. Routine soil test laboratory analyses of pH and Mehlich I (0.05M HCl and 0.0125 H₂SO₄)-extractable P and K were determined by the Virginia Cooperative Extension Soil Test Laboratory procedures (Donohue, 1992). Soil test results were used to maintain adequate levels of P and K for all locations. All plots were clipped to 7.6 to 10.2 cm before fertilization. The weather data was obtained from Kentland Farm for the Blacksburg location and Steeles Tavern AREC for the Steeles Tavern location.

In the fall, plots were fertilized with urea at rates of 0, 45, 90 or 135 kg N ha⁻¹ (Table 4-2). The following spring plot received another N application at 0, 45, 90 or 135 kg N ha⁻¹. Harvesting occurred once forage reached late boot growth stage during the spring (Table 4-2).

For the determination of biomass yield, each plot was harvested by clipping a swatch through the center of each plot using mechanical forage harvester (Swift Machine and Welding Ltd, Swift Current, SK). A subsample (200 g) of fresh forage was collected from each plot for DM, and nutritive value determinations. Samples were dried in a forced air-oven 60° C for at least 48 h and then ground to pass a 1mm screen using a Wiley sample mill (Thomas Scientific, Swedesboro, NJ).

Table 4-1. Nitrogen treatments applied at varied rates over two seasons (Fall and Spring) at two Virginia locations.

Treatment ID	Fall N Rate (kg N ha ⁻¹)	Spring N Rate (kg N ha ⁻¹)
0-0	0	0
45-0	45	0
90-0	90	0
135-0	135	0
0-45	0	45
45-45	45	45
90-45	90	45
135-45	135	45
0-90	0	90
45-90	45	90
90-90	90	90
135-90	135	90
0-135	0	135
45-135	45	135
90-135	90	135
135-135	135	135

Table 4-2. Nitrogen application dates over two seasons and harvest dates for the years 2006-2007 and 2007-2008 at two Virginia locations.

Year	N application date				Harvest date	
	Blacksburg		Steeles Tavern		Blacksburg	Steeles Tavern
	Fall	Spring	Fall	Spring		
2006-2007	Nov 2	Mar 20	Nov 3	Mar 19	May 14	May 15
2007-2008	Nov 12	Mar 25	Nov 13	Mar 20	May 13	May 14

Neutral detergent fiber (NDF), acid detergent fiber (ADF), and crude protein (CP) were estimated using near infrared spectroscopy (NIRS) (FOSS, St. Paul, MN). WINISI II software was used to select a calibration data set for wet chemistry determination (Infrasoft International, Port Matilda, PA). Concentrations of NDF and ADF for calibration sets were determined using the ANKOM filter bag system (ANKOM Technologies, 2003). Total N was determined using the Dumas procedure (CNS analyzer, Elementar America, Cherry Hill, NJ). Crude protein was calculated as total N x 6.25.

Data were analyzed for all single effects and interactions using PROC GLM (v. 9.1, SAS Institute, Inc. 2002-2003) with a Tukey's adjustment. Effect of split fall and spring application, year, rep and location were tested. Year*N treatment, location*N treatment and location*year*N treatment interactions were tested. Significance was tested at the $P \geq 0.10\%$ level unless noted differently.

RESULTS AND DISCUSSION

Environmental Conditions

Blacksburg and Steeles Tavern locations

The first killing frost (-2°C) occurred on 3 Nov 2006 and 1 Nov 2007 at the Blacksburg and Steeles Tavern locations, respectively. Starting in June, at the Blacksburg location, total rainfall during 2007 was below normal (Figure 4-1). The below normal rainfall greatly affected the biomass produced during the 2008 season. The lack of rainfall affects biomass growth because the plant requires water in order to carry out photosynthesis and rainfall is needed for N uptake to occur. During the time between the first N application and harvesting, rainfall was 426 and 331 mm for 2006 and 2007, respectively. During 2006, rainfall amounts were normal for November however,

for both locations in December rainfall amounts were below normal. In 2007, rainfall amounts were below normal for both locations; however Blacksburg received more rainfall than Steeles Tavern. At Steeles Tavern, rainfall during July, August and September, rainfall was far below normal.

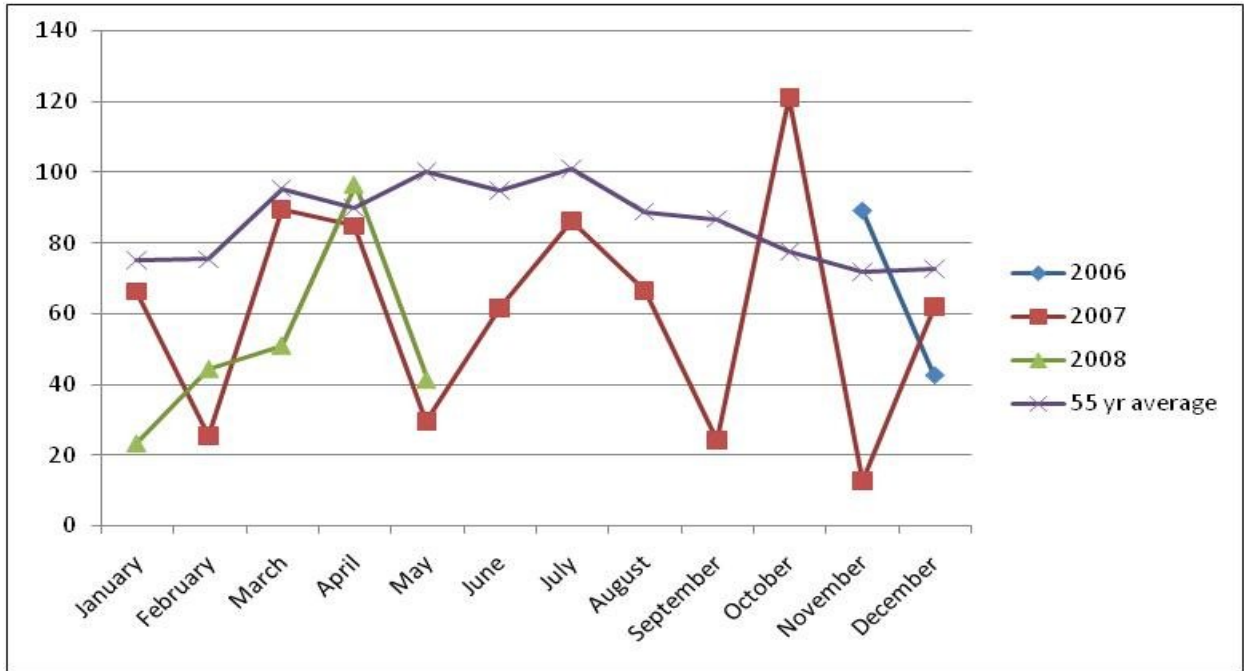


Figure 4-1. Monthly and the 55 year average rainfall recorded in Blacksburg, VA during the study.

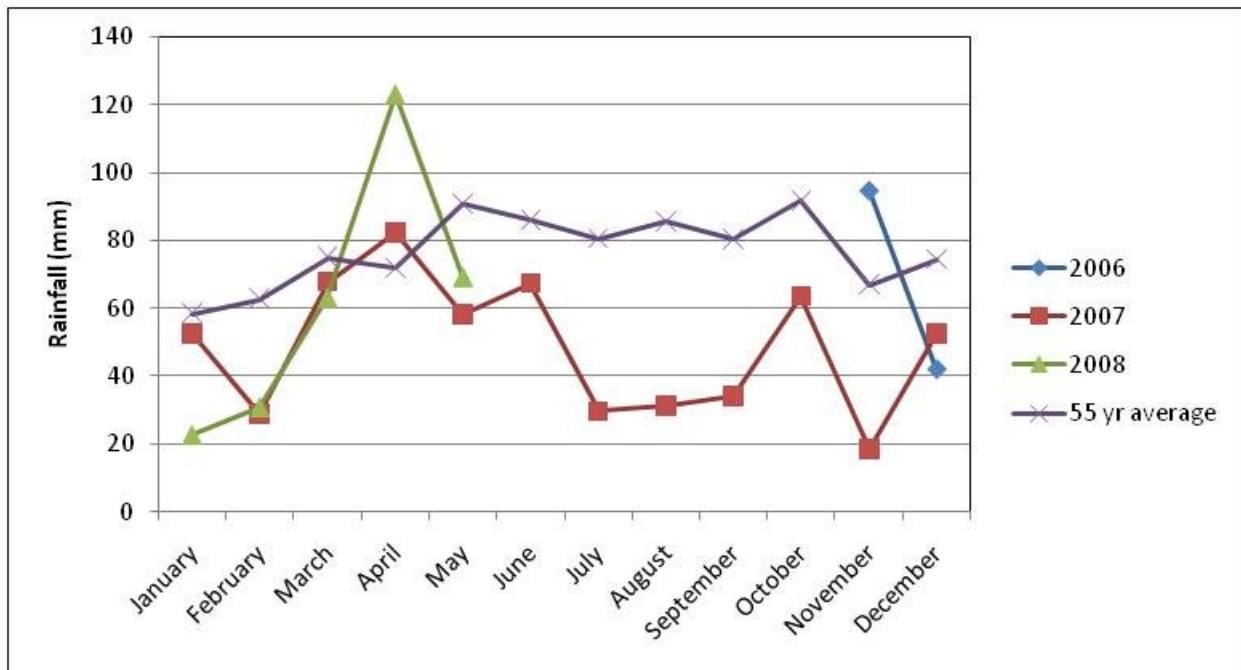


Figure 4-2. Monthly and the 55 year average rainfall recorded in Steeles Tavern, VA during the study.

Effect on Biomass

Blacksburg

Yields ranged from 1,900 to 3,600 kg DM ha⁻¹ and 700 to 2,900 kg DM ha⁻¹ in 2007 and 2008, respectively (Table 4-3). Yields in 2008 were lower than the previous year likely due to severe drought that occurred during the last six months of 2007. Generally, in both years yield increased with increasing N fertilization.

In 2007 at the Blacksburg location, yields when only fall N was applied increased with increasing N rate up to 45 kg N ha⁻¹ then began to decline (Figure 4-3A), however when only fall N was applied no differences were observed between rates (Table 4-3). The yield difference between the control and the 135/135 split fall/spring application was 1,731 kg ha⁻¹ which was a 90% yield increase (Table 4-3). In 2008, fall N applications increased yield up to an N rate of 90 kg N ha⁻¹. Applying 90 kg N ha⁻¹ in the fall produced a yield of 2,276 kg DM ha⁻¹, which was higher than the control and the 45/0 split fall/spring N application (Figure 4-3B). The 135/135 and the 90/90 split fall/spring N application yields were 2,714 and 2,936 kg DM ha⁻¹, respectively. The yield difference between these treatments (135/135 and 90/90 vs. 45/0 and control) was 1,732 kg DM ha⁻¹. Similarly, Cherney and Cherney (2006) reported yields of 6,454 and 7,134 kg DM ha⁻¹ when single and split spring N applications were made, respectively.

Steeles Tavern

At the Steeles Tavern location, yields ranged from 3,100 to 5,700 kg DM ha⁻¹ and 2,500 to 5,100 kg DM ha⁻¹, in 2007 and 2008, respectively. There was no difference between the control and single fall N applications of 45-135 kg N ha⁻¹ (Figure 4-4A). In 2007, a significant yield increase was observed for the 45/45 split fall/spring N applications as well as the 90/45, 135/45, 45/90, 90/90, 0/135, 45/135 and 135/135 treatments when compared to the control. The

yield advantage over the control for these treatments were 2,067, 1,983, 2,127, 2,544, 2,455, 1,961, 2,311 and 2,521 for the single and split applications of 45/45, 90/45, 135/45, 45/90, 90/90, 0/135, 45/135 and 135/135, respectively. The percentage yield increase over the control for these treatments ranged from 62 to 80%. The highest percentage yield increase was observed for the 0/90 and 135/135 split fall/spring applications. In 2008, fall applications of 45 and 135 kg ha⁻¹ resulted in a yield increase of 1,776 and 1,841 kg DM ha⁻¹, respectively over the control which was 70 and 72% yield increase, respectively (Table 4-3 and Figures 4-3-A, B, 4-4 A, B). The highest yield increase was observed for 135/135 split fall/spring N applications which was 2,554 kg DM ha⁻¹ over the control (100% yield increase).

Table 4-3. The effect on dry matter yields of varying N rates split applied in Fall and Spring at two locations over two growing seasons

Fall-Spring N (kg N ha ⁻¹)	Blacksburg		Steeles Tavern	
	2007 (kg DM ha ⁻¹)	2008 (kg DM ha ⁻¹)	2007 (kg DM ha ⁻¹)	2008 (kg DM ha ⁻¹)
0-0	1,906b	733c	3,168b	2,545c
45-0	2,723ab	1,454bc	4,858ab	4,321ab
90-0	2,486ab	2,276ab	4,303ab	3,482bc
135-0	2,421ab	1,970ab	4,704ab	4,386ab
0-45	2,745ab	1,737abc	4,374ab	3,661abc
45-45	2,610ab	1,762abc	5,236a	4,042abc
90-45	3,023ab	2,579ab	5,151a	4,086abc
135-45	3,212ab	2,185ab	5,294a	4,381ab
0-90	2,874ab	2,098ab	4,685ab	4,153ab
45-90	2,755ab	2,371ab	5,712a	4,616ab
90-90	3,563ab	2,936a	5,622a	5,064ab
135-90	3,325ab	2,423ab	4,877ab	4,828ab
0-135	3,076ab	1,991ab	5,129a	4,481ab
45-135	2,377ab	1,991ab	5,478a	4,605ab
90-135	3,002ab	2,584ab	4,965ab	4,218ab
135-135	3,631a	2,714a	5,688a	5,099a

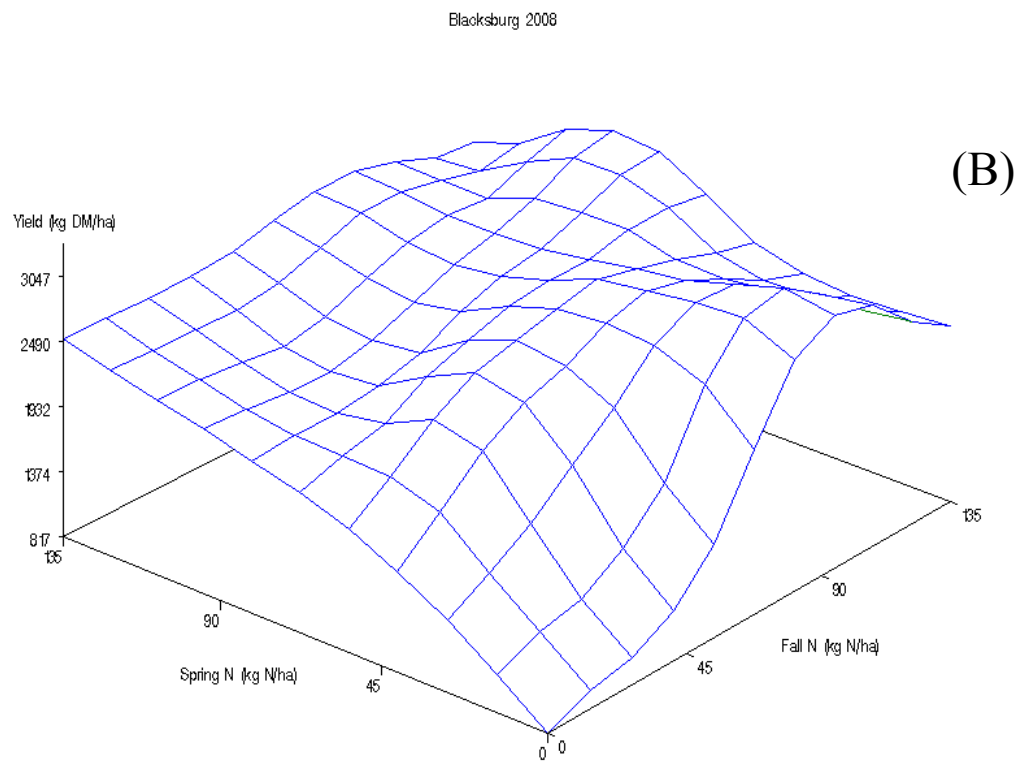
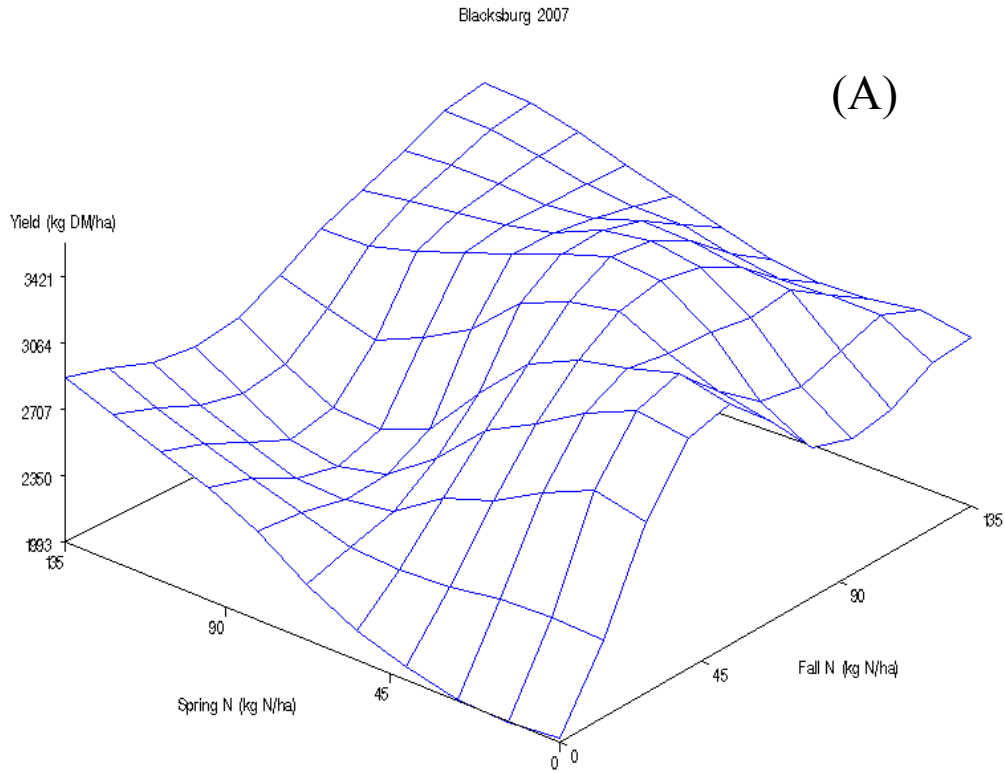


Figure 4-3. Effect of split fall and spring N applications on yield for Blacksburg, 2007 (A) and 2008 (B)

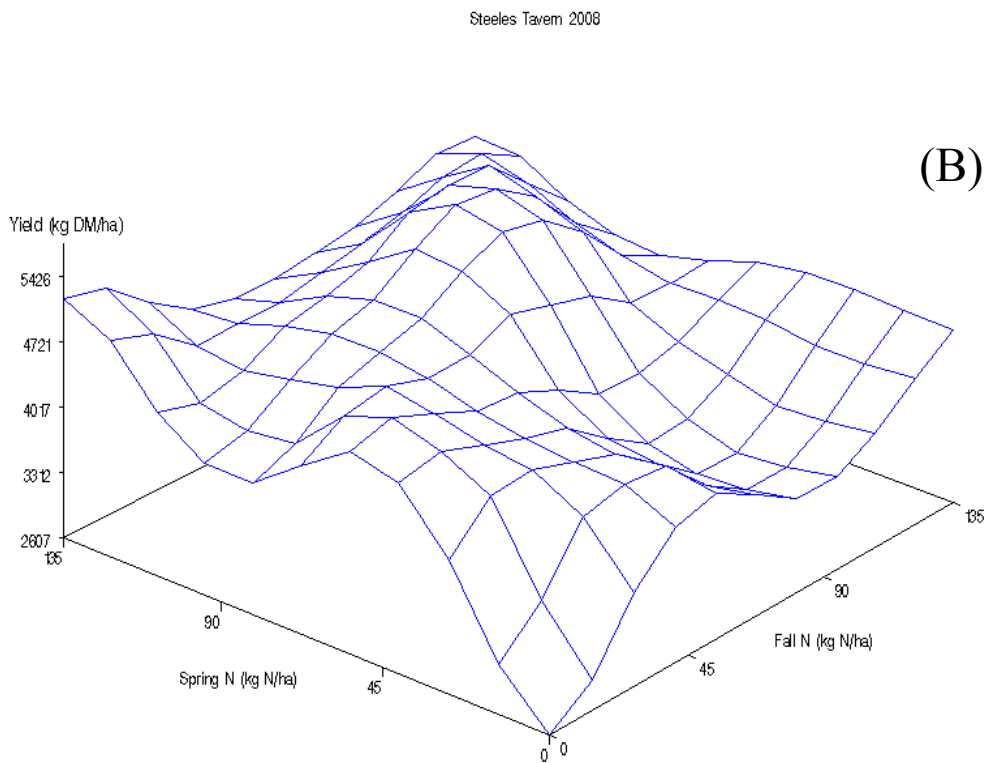
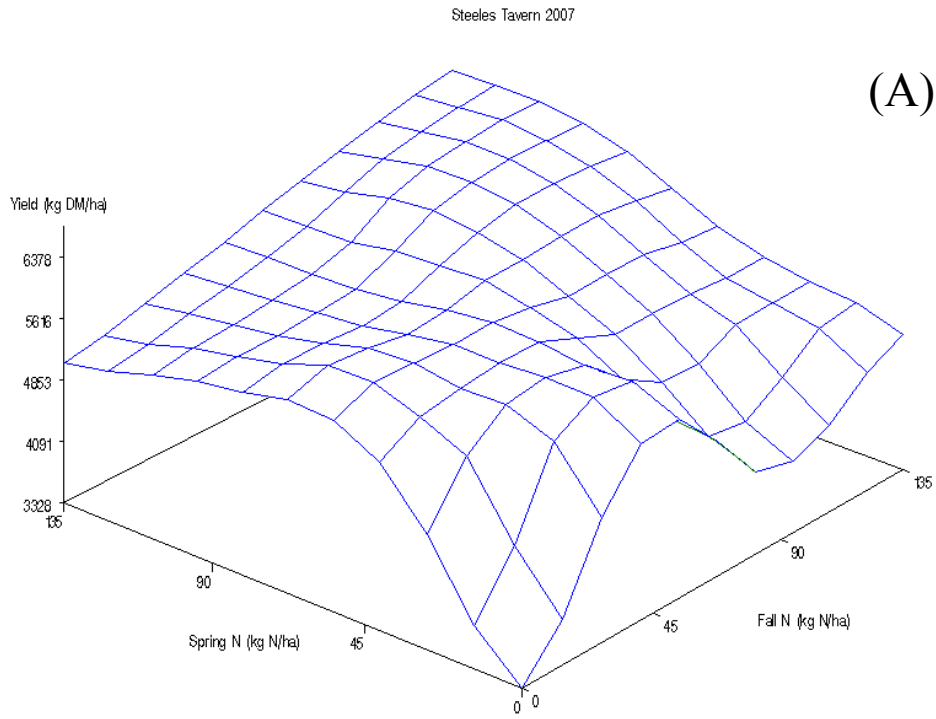


Figure 4-4. Effect of split fall and spring N applications on yield for Steeles Tavern, 2007 (A) and 2008 (B)

Forage Quality

For percent CP, there were significant differences among locations ($P < 0.001$). There was no year effect on CP at Blacksburg ($P < 0.994$) and Steeles Tavern ($P < 0.15$). There was also no year x treatment interaction for CP at either location. However, there were year x location ($P < 0.02$) and location x treatment ($P < 0.02$) interactions for ADF. Thus data for NDF and ADF are presented by location and year.

Blacksburg

In both years of the study, CP values ranged from 14 to 23% (Figure 4-5). There were differences among treatments ($P < 0.0001$). Crude protein increased with increasing N fertilization. Although there are significant differences among treatments, all values are within the acceptable range for all classes of animal production (Ball et al., 2002). The concentration of CP in the control treatment was 14% which is 35% higher than typical grass hay in Virginia (Stallings, 2005).

There were no differences between treatments for ADF and NDF concentrations. In 2007 and 2008, NDF values ranged from 49 to 60% and 59 to 63%, respectively (Table 4-4). The ADF concentrations ranged from 34 to 42% and 33 to 35%, for 2007 and 2008, respectively (Table 4-5).

Steeles Tavern

Crude protein concentration ranged from 13 to 21% for both years (Figure 4-6). There were differences among N treatments. However, all values are within the acceptable ranges for all livestock. Similar to the other locations, CP increased with increasing N fertilization. Treatments did not have an effect on NDF and ADF values. Values for NDF ranged from 54 to

57% and 59 to 62% in 2007 and 2008, respectively. The ADF values averaged 34.1 and 33.8% in 2007 and 2008, respectively.

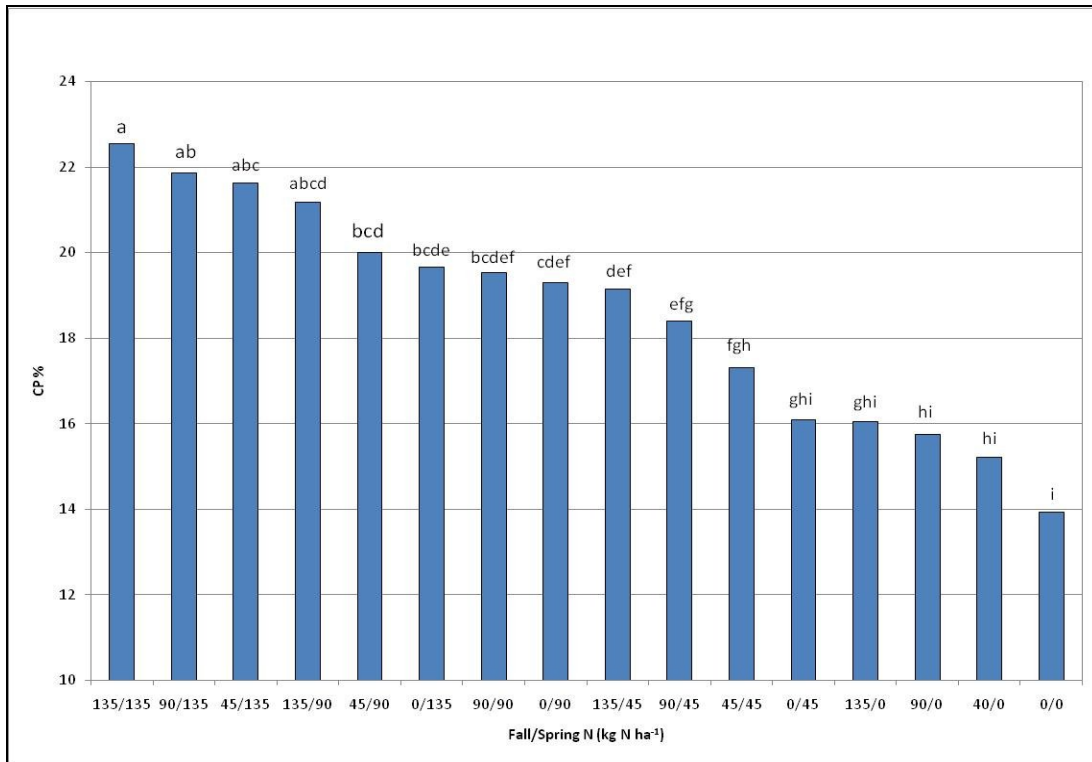


Figure 4-5. The effect of split fall and spring N applications on CP over a two-year period at Blacksburg.

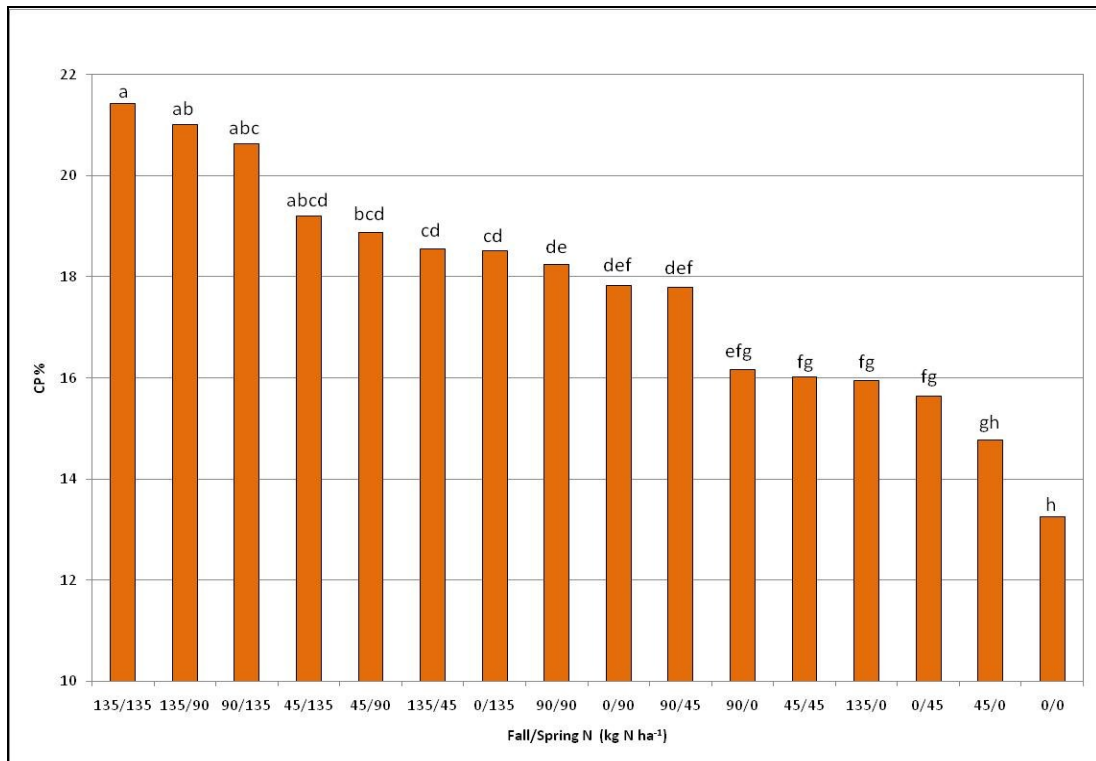


Figure 4-6. The effect of split fall and spring N applications on CP over a two-year period at Steeles Tavern

Table 4-4. Influence of Split Fall and Spring N fertilization on NDF for Blacksburg and Steeles Tavern.

Fall-Spring N (kg N ha ⁻¹)	Blacksburg		Steeles Tavern	
	2007 NDF (%)	2008 NDF (%)	2007 NDF (%)	2008 NDF (%)
0-0	60.7	63.2	55.0	60.8
45-0	59.9	64.0	56.4	61.7
90-0	49.7	64.0	54.7	60.0
135-0	46.6	63.1	55.4	61.2
0-45	61.0	60.5	56.2	59.7
45-45	59.6	63.2	56.4	61.8
90-45	56.9	61.8	56.6	60.9
135-45	59.9	62.2	55.8	60.6
0-90	55.9	59.7	55.8	59.7
45-90	56.5	61.5	56.3	61.1
90-90	57.2	60.6	57.1	60.6
135-90	58.8	62.3	56.7	60.6
0-135	59.2	61.2	56.1	60.9
45-135	57.2	61.5	57.0	60.9
90-135	59.5	61.1	56.1	60.1
135-135	55.9	62.2	56.7	60.6

Table 4-5. Influence of Split Fall and Spring N fertilization on ADF for Blacksburg and Steeles Tavern.

Fall-Spring N (kg N ha ⁻¹)	Blacksburg		Steeles Tavern	
	2007 ADF (%)	2008 ADF (%)	2007 ADF (%)	2008 ADF (%)
0-0	35.8	35.2	33.5	34.2
45-0	36.8	35.6	34.0	34.8
90-0	42.4	35.6	33.5	33.3
135-0	42.3	35.7	33.6	34.6
0-45	36.0	33.7	34.2	33.3
45-45	36.2	35.0	34.4	34.2
90-45	35.1	35.3	34.1	33.8
135-45	36.1	33.9	34.3	33.7
0-90	34.7	33.0	34.8	33.1
45-90	34.5	34.1	34.4	33.6
90-90	34.2	34.0	34.5	33.6
135-90	34.9	34.4	34.2	33.3
0-135	34.8	33.9	33.4	34.4
45-135	34.9	34.5	34.6	33.6
90-135	34.8	34.3	34.4	34.0
135-135	34.9	34.5	34.2	33.6

SUMMARY AND CONCLUSION

The amount of rainfall during the two experimental years varied widely. At the Blacksburg location, in 2007, yield response to single and/or split application of N was minimal. The only difference in yield was observed between the control and 135/135 split fall/spring N application. The yield difference between the two extreme rates was 1,725 kg/ha which resulted in a 91% yield increase. In 2008, however, yield increases for a number of N rates and time of application treatment combinations were observed. The yield increase for the various N rates and application times ranged from 1,247-2,202 kg DM ha⁻¹ with the percentage yield increase of 169-200%. The percent yield response observed in 2008 at the Blacksburg location was much higher

than that reported by Cherney and Cherney (2006). Cherney and Cherney (2006) reported a 12% yield increase when N was split applied in the spring with 225 kg N ha⁻¹.

In 2007, at the Steeles Tavern location several treatment combinations resulted in yields higher than the control treatment. The 45/45, 90/45, 135/45, 45/90, 90/90, 0/135 and 45/135 split fall/spring application yielded higher than the control. The yield advantages of these split N rates applied fall/spring or spring-only over the untreated control were 2,068, 1,983, 2,454, 1,517, 1,961, 2,310, 2,520 kg DM ha⁻¹, for the 45/45, 90/45, 135/45, 45/90, 90/90, 0/135/ and 45/135 split fall/spring rates, respectively. Over all locations and years, it appeared that the 90/90 split application resulted in yield increases from 77-300% across locations and years. Generally, percent CP increased with increasing N rates. The effect of N rate and application dates on percent ADF and NDF was minimal.

Pasture can dramatically respond to N fertilization with measured yield increase up to 400% as reported previously. However because of climate, the plant species, and location the actual N used by the plant may vary from 0 to over 200 kg ha⁻¹ year⁻¹. Unlike fertilization of field crops the decision as to how much and when to fertilize pastures are largely dependent on the individual goals. Our data show that split applications of N will not necessarily maximize yields. Our research also shows that generally there is no difference between applying N in the fall or spring as long as rainfall is sufficient. Factors such as forage production needed for livestock, time that this forage is needed, and economic return to the investment on fertilizer all must be considered when fertilizing pastures.

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CHAPTER V

SUMMARY AND CONCLUSION

In Virginia, tall fescue is the best adapted cool-season grass for forage production. Winter feeding costs can account for more than 50% of cow-calf expenses. Utilization of stockpiled tall fescue could reduce winter feeding costs by more than 35%. Nitrogen fertilization is a major factor in determining the productivity of tall fescue pastures. Factors such as timing of N application, N rate and N fertilizer can affect yield and quality of tall fescue. Even though N fertilizer costs are decreasing from recent record highs, it is crucial to optimize N use efficiency because N fertilizer is still a major expense.

The results from our stockpiled study showed that N rates affect the yield and nutritive values of stockpiled fescue, however little differences were seen among N sources. Generally, yield increased with increasing N rate. At two of the locations for one year, all N sources yielded higher than the control, however at one location no difference was observed. The effectiveness of N sources in improving crude protein did have some differences however; NDF and ADF concentrations did not differ. Ammonium nitrate is the most commonly used N source for stockpiled fescue and has been shown in previous research to be the most effective nitrogen source. However, the future availability of this source is uncertain. Global use of ammonium nitrate has decreased and many agricultural suppliers are reluctant to carry it due to security concerns. Our experiment showed that depending on location, and rainfall, in the absence of ammonium nitrate, N sources including ESN, ammonium sulfate, poultry litter, NSN, Nitamin and urea can be effectively used to stockpile fescue, especially when significant rainfall occurs

shortly after application. Therefore the decision to what and how much N to apply should be based on forage need, climatic condition (concerning N loss through volatilization) and N cost.

Experiment 2 dealt with the effect of single and/or split application of urea on yield and nutritive values of tall fescue pastures. The results showed that N rates and timing of fertilization can greatly affect the yield and nutritive values of the forage. Overall, N fertilization increased yield from 62 to 300% over the untreated control. However, the results from this study showed no difference between applying N in the fall or spring and that splitting N applications between fall and spring will not necessarily maximize tall fescue yields. Pasture fertilization, as our research has shown, can dramatically increase yield and CP values, however fertilizing at high rates may not be economically feasible. A producer should consider factors such as animal need, production level (maintenance vs. meat and milk production), timing of forage need, amount of hay in the storage, the price and quality of purchased hay, and economic return when determining N rate and timing of application.