Management and Nutritional Quality of Tall Fescue and Alfalfa Grown in Combination, Compared to Tall Fescue Fertilized with Nitrogen.

by

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(ABSTRACT)

'Kentucky 31' endophyte-free tall fescue fertilized with 160 kg N $ha^{-1}yr^{-1}$ was compared to similar fescue grown with 'Cimarron' alfalfa in a randomized block pasture experiment with four replications. Quality and yield of stockpiled forages and performance and serum minerals of grazing steers were investigated during 1991-92 and 1992-93. Effects of grazing and timing of initiation of stockpiling forages were investigated during autumn of 1992. Rate and extent of release of Ca, Mg, P, S, Cu, and Fe from stockpiled forages were determined in a dacron bag study in 1992-93. In 1991-92, stockpiled N-fertilized fescue improved steer performance over stockpiled fescue-alfalfa ($P<0.05$); in 1992-93, this result was reversed ($P<0.05$) due to forage availability. Blood urea nitrogen was higher ($P<0.07$) and serum Ca and S were higher ($P<0.05$) in steers which grazed stockpiled fescue-alfalfa. September stockpiling of fescue-alfalfa improved botanical composition, yield, and forage quality, compared to August stockpiling. September stockpiling of N-fertilized fescue improved quality but lowered yield, compared to August stockpiling. Fescue-alfalfa had higher ($P<0.05$) yield and improved botanical composition when grazing occurred. Nitrogen-

fertilized fescue had higher ($P<0.05$) yield when mechanically harvested. Alfalfa released P. Ca, Mg, S, and Fe to a greater extent and rate than either type of fescue at 24 h and P, Mg, S, and Fe at 72 h ($P<0.05$). Fescue grown with alfalfa released S to a greater extent and rate than N-fertilized fescue. Fescue-alfalfa produces animal performance as good or better than N-fertilized tall fescue, while eliminating need for N-fertilization.

Dedication

This thesis is dedicated to my

Best Friend,

who knows who *HE IS*.

It is furthermore dedicated

to my family and other friends,

who know who they are, too.

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I would like to express my appreciation for the help

I have received during this project from

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Chapter 1

Introduction

Agriculture is one of the largest industries in the United States. United States farmers produce approximately 50% of the world's soybeans, 40% of the maize, and 25% of the grain sorghum. Today, one farmer feeds about 115 people (USDA, 1990). Such high productivity has been the benefit of almost completely mechanized farming systems dependent upon purchased inputs. These inputs include fuel, fertilizers, and pesticides, all derived largely from fossil fuel, a non-renewable resource. In some areas of the United States, water is naturally limiting to production, but is provided at enormous expense and long-term insecurity. The industry has created erosion and pollution problems in the efforts to feed the world. United States agriculture is not inexpensive.

Many people believe that agricultural methods must change from high-input systems, or "conventional" systems, which tend to produce benefits mostly in the short term. New systems must be able to use fewer non-renewable resources in order to keep productivity high in the long term: new systems must be "sustainable". Such systems, including ones called organic, biological, or regenerative, are generally known by the blanket term "alternative systems" (NRC, 1989).

Alternative systems usually have the goals of reducing manufactured inputs and protecting human and environmental health. "Sustainable systems" usually are considered to be systems which could remain productive indefinitely without disturbing the environment or using up non-renewable resources. Harwood (1990) defines sustainable systems as those which "can evolve indefinitely toward greater human utility, greater efficiency of resource use, and a balance with the environment which is favorable both to humans and to most other species."

Alternative systems attempt to take advantage of naturally-occurring ecological interactions so that inputs not natural to the system may be reduced while productivity remains high. Some very common practices in alternative systems are crop rotation, integrated pest management and biological pest control, covercropping, use of pest-resistant crop varieties, conservation tillage, and especially diversification of enterprise. Creating systems from these production methods often means that the new systems require a higher level of management than those which depend upon purchased inputs to compensate for low soil fertility or pest problems.

"Low input" does not necessarily imply "low output." NRC (1989) concluded that alternative systems are often productive and profitable, even without the aid of commodity income and price support programs. One of the goals of conventional systems has been to provide the very highest yields possible, even if the cost of producing such yields reduced profit. Alternative systems seek to maximize the profit margin. Sometimes yields in alternative systems do not reach their maximum potential; if production costs have fallen accordingly because purchased inputs have been reduced, lowered yield is acceptable since the profit margin has been maintained.

One factor common to many sustainable systems is diversification of enterprise. Many conventional systems use only one or two commodities, such as the classic corn-andsoybean rotation. Many years of raising the same crops, especially row crops, can damage soil fertility and perpetuate pest and disease problems. Producers who wish to implement alternative systems generally need to consider different crops or products so that techniques such as crop rotation and cover-cropping may be used. Also, since productivity of one enterprise may be reduced by the use of alternative practices, another enterprise can compensate.

The use of livestock in diversification of enterprise is often considered essential in alternative systems (Harwood, 1990; King, 1990). Livestock can utilize nutrients which humans cannot, return these nutrients in a form usable to humans, and aid in nutrient cycling. Forages form a necessary part of livestock enterprises, particularly those which seek to reduce off-farm input such as bought feed. Forages provide inexpensive feed for animals, and can often be a part of some other enterprise, such as grain production or cover-cropping. Forages which are adapted to an area will generally not require supplementary water or pesticides and do not need soil cultivation except during establishment. Carefully-managed forage stands can often resist weed- and disease-invasion without chemical treatment.

In addition to their utility in providing low-cost feed for animals, forages are usefull in soil conservation and improvement. Properly-chosen forages can be productively grown on land which is too fragile, erodable, or otherwise unsuitable for other crops. Forage covers provide much organic matter, with all its attendant benefits, to soil (Cardon, 1948). Sod crops, in rotation or in permanent culture, increase permeability and water-holding capacity of soil, and may improve soil fertility, especially if legumes are present (Heath and Kaiser, 1985). Mixing grasses and legumes reduces the need for fertilizers in pastures.

If United States agriculture is to be able to produce food in the future, operations must become less resource-costly, less damaging to the environment, and remain profitable. The use of forage-livestock systems within sustainable operations can help farmers to achieve these goals. Pastures and rangelands are ecosystems, and as such, can be managed within the bounds of nature, reducing unnatural inputs and losses while maintaining productivity for many years.

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Chapter 2

Literature Review

Tall fescue

Introduction. Tall fescue (*Festuca arundinacea* Schreb.) is a cool season perennial bunch-type grass with rhizomes, which allow it to form a thick sod if it is mowed or grazed frequently (Buckner, 1985). The leaves are about 0.5 cm wide, dark green, with very pronounced veins and rough edges. The culms are round, erect, and reach a maximum height of about 2 m (Terrell, 1979). The inflorescences are compressed panicles.

Tall fescue originated in Europe, which remains the center for variation of the tribe Festuceae. The exact date of introduction to the United States is unknown, but Terrell (1979) reported the earliest known specimen to have been found in New Jersey in 1879. Fergus and Buckner (1972) reported that the cultivar 'KY 31' had been recognized as early as 1875, in Menifee County, KY. It was collected in 1931, and released by the Kentucky Agricultural Experiment Station as a variety in 1942. By the early 1940's, tall fescue had become a prominent forage in the southeastern United States. In 1973, 12 to 14 million ha grew in the United States, ranging from Florida to Canada (Buckner et al., 1979).

Adaptability. Tall fescue is best adapted to cool humid temperate regions, but will survive a wide range of adverse conditions. It will tolerate both droughty and wet soils (Smith, 1986), but its response to high temperatures depends upon moisture availability: it does not do well in droughty soils in hot areas (Buckner, 1985; Burns and Chamblee, 1979). Tall fescue will survive a wide range of pH, from 4.7 to 9.5 (Cowan, 1956) (as cited by Buckner, 1985) but thrives at pH from 5.3-5.5 (Burns and Chamblee, 1979). It will persist under low fertility, but responds well to N-fertilization (Smith, 1986). Tall fescue is considered a fairly aggressive pasture grass (Blaser et al., 1956), second only to perennial and annual ryegrasses (*Lolium* spp.) in aggressiveness of cool-season grasses.

Management. Tall fescue has a typical cool-season growth curve, with an increase of growth in spring, a lag in summer, and a small increase of growth in autumn. Tall fescue is a useful crop in that its management can be quite flexible. It may be continuously or rotationally grazed, cut for hay, or stockpiled for autumn and winter grazing. Grazing must be managed so that a sufficient amount of leaf area remains to carry on photosynthesis and to allow plants to replenish total nonstructural carbohydrates (TNC) (Smith et al., 1986); close defoliation must be infrequent (Booysen and Nelson, 1975). Austenson (1963) recommends leaving an 8-cm stubble for continuous grazing. Keeping the residual leaf area high maintains a high relative growth rate (Booysen and Nelson, 1975).

Spring production depends very much upon the previous autumn's management. Annual production, in turn, depends heavily upon spring management. Baker et al. (1988) found that total spring production and annual production were increased by grazing the previous autumn, possibly due to the influence of excreta. Early spring grazing lowered spring hay yield and annual production, compared to two hay cuts and no grazing, possibly because grazing often removes more forage than haying does and early grazing removes tillers which are then unavailable for hay production (Baker et al., 1988). Austenson (1963) found that first-cut hay yields rose rapidly up until full bloom, but that aftermath yields dropped quickly as harvest was delayed. Fescue quality and palatability dropped as harvest was delayed, as well (Smith, 1986). While total annual forage production was highest in a no-grazing system for Baker et al. (1988), metabolizable energy/acre for spring- and fall-grazed systems were comparable to all-hay treatments. The choice of haying or grazing must be made on an individual basis, since fescue will tolerate either management strategy.

Forage quality. Fescue, when managed properly and grazed at the correct times of year, is a high-quality forage in relation to chemical composition, suitable for finishing animals, lactating animals, and other high-production animals (Moss et al., 1988; Hoveland et al., 1979). Since fescue is a cool season grass, it does not have stems after first clipping in early spring. It produces lush leafy growth in spring and autumn. Fescue is highest in quality in autumn, intermediate in spring, and lowest in summer (Bagley et al., 1983; Buckner, 1985). Buckner et al. (1967) found that average protein values were 22%, 18%, and 19% in spring, summer, and autumn, respectively. Carbohydrates averaged 9%, 8%, and 18% in spring, summer, and autumn. Increasing carbohydrates often increases voluntary intake (Bagley et al., 1983). Digestibility averaged 69%, 66%, and 73% over these seasons. Digestibility declines with age of forage (Brown et al., 1963).

Fertility has an effect on nutritional quality of fescue. Collins (1991) found that N fertilization up to 150 kg N^{-1} ha increased N-levels in fescue, as well as increasing yields.

These results agree with those of Burmester and Adams (1984) who determined that the most economic level of N-fertilization for fescue is 150 lbs N^{-1} ha, since at that level of N, fescue had 18.7% crude protein and was as digestible as at higher levels of N.

Fescue has a unique relationship with the endophyte *Acremonium coenophalium*. The endophyte lives in leaf sheaths and seeds of fescue, relying on the grass for housing and nutrients. During vegetative periods, the endophyte moves to meristem tissue and crowns as well. The endophyte spreads among fescue stands when infected seeds germinate. Fescue benefits from the endophyte's presence by increased drought resistance, pest and disease resistance, and increased survivability under other stresses, compared to fescue without endophyte infection (Bacon and Siegel, 1988). Unfortunately, the endophyte, or possibly the infected grass, produces alkaloids and other substances which are toxic to grazing animals, although the endophyte does not affect digestibility and chemical composition of tall fescue (Fritz and Collins, 1991).

Endophyte toxicity may manifest itself in several ways, and usually depresses animal performance along with other symptoms. Animals usually have lowered intake on toxic fescue (Stuedemann and Hoveland, 1988). Summer syndrome, fescue foot, and fat necrosis are common problems in beef cattle which graze infected fescue. Dairy cows experience lowered milk production. Mares which have grazed toxic fescue during the latter part of pregnancy may have prolonged gestation, abortion, retained placenta, agalactia, and may die (Ball et al., 1991).

Stockpiling tall fescue

Stockpiling of tall fescue has been widely practiced in the southern United States since the late 1940's (Taylor and Templeton, 1976). Mays and Washko (1960) define stockpiling as "The practice of allowing forage to accumulate in the field until it is needed for grazing." A similar definition is now generally accepted: "To allow forage [of any kind] to accumulate for grazing at a later period" (FGTC, 1991).

Usually, stockpiling is practiced in autumn so that accumulated forage is available for winter grazing. Stockpiling reduces the need for winter hay-feeding: 1 ha of stockpiled tall fescue can support 2.5 beef cows for approximately 120 days (White, 1977). Stockpiled tall fescue is a high-quality forage which can easily support dry beef cows or even maintain stocker steers throughout a significant part of winter in Virginia (White, 1974; Allen et al., 1992).

The accepted method of stockpiling fescue in Virginia is to clip or graze fescue in the beginning of August. Approximately 80 kg N^{-1} ha are applied at that time. Forage is allowed to accumulate until grazing begins in early November (Brown et al., 1963; White, 1977; Bagley et al., 1983). Nitrogen supply and precipitation during the stockpiling period are the main factors in determining how long grazing can last. With adequate precipitation and approximately 100 kg N^{-1} ha, fescue will continue to grow into November (Taylor and Templeton, 1976). Stockpiled fescue can be grazed until January or February, but forage quality and yield drop drastically by the end of December (Taylor and Templeton, 1976; Ocumpaugh and Matches, 1977; Rayburn et al., 1979; Bagley et al., 1983), probably due to weathering and increasing amounts of dead forage.

Quality of stockpiled tall fescue is high in Virginia. During the cooler days of September and October, photosynthesis occurs at a higher rate than respiration. This process allows total nonstructural carbohydrates to accumulate in the grass, which is why stockpiling usually begins in August (Brown et al., 1963). Rayburn et al. (1979) stockpiled fescue with accumulation initiated in June, July, August, and September. Sampling occurred in December. They found that forage quality of stockpiled tall fescue was better with a shorter period of accumulation, since forage was less mature when sampled. Having a short accumulation period did lower forage yield.

Taylor and Templeton (1976) found that stockpiled fescue had a nutritive value index (Donefer et al., 1966) as high or higher than that of good alfalfa. Stockpiled tall fescue had higher TNC, lower fiber content, and lower crude protein content than stockpiled orchardgrass when both were sampled in November (Sheehan et al., 1985). Bagley et al. (1983) found that stockpiled fescue, harvested in mid-November, had 10.6% crude protein and 15.9% TNC. Crude fiber was 32.2%. White (1977) observed similar values.

Alfalfa

Introduction. Alfalfa (*Medicago sativa* L.) is a cool-season perennial legume. It has a deep taproot which may grow to be more than 9 m long. Nodules on the roots house rhizobium bacteria which allow alfalfa to convert atmospheric N to plant-available forms. Leafy branches arise from a crown and may grow to be 60 to 90 cm tall (Barnes and Sheaffer, 1985). Leaves are pinnately trifoliate. Raceme-type flowers on long peduncles rise from leaf axils; flowerets are purple to white and quite fragrant.

Alfalfa is the oldest known crop grown solely for forage. It originated in the mountainous regions east of the Mediterranean and was recognized as early as 700 BC (Smith, 1986). It was introduced into Greece in 490 BC; the Romans carried it from Greece into Europe (Smith, 1986). The Spaniards introduced it into the Americas in the 1500's. In 1736, colonists introduced alfalfa to the eastern United States, but acidic eastern soils did not support the plant well (Barnes and Sheaffer, 1985). Alfalfa reached California from Spanish sources in 1840 and spread rapidly across North America (Smith, 1986). Winter-hardy varieties were developed and now alfalfa ranges from Alaska to Florida (Barnes and Sheaffer, 1985).

Adaptability. Alfalfa is best adapted to the cool temperate regions of the world but will survive temperatures from -25°C to 50°C, provided that water is not limiting in hot climates (Barnes and Sheaffer, 1985). It is highly drought-tolerant, owing to its taproot; it will go dormant for up to 2 years during prolonged and severe drought. Irrigation allows alfalfa to grow very well in the dry, fertile, slightly basic soils of the western United States (Barnes and Sheaffer, 1985). Alfalfa thrives on slightly alkaline and calcareous soils; it is sensitive to acid soils because low pH causes Al to be toxic and Ca and Mg to be unavailable (Morris et al., 1992). Alfalfa's winter-hardiness depends upon its degree of autumn dormancy; winter-hardy cultivars do not grow tall and lush after an early fall cutting or grazing (Smith, 1986).

Management. Alfalfa is a cool season plant which follows the cool season growth curve, but it does not experience a severe hiatus of growth in summer as some cool season plants, such as bluegrass (*Poa pratensis*), do. Alfalfa stores reserve carbohydrates in the taproot. Plants rely mostly upon reserves, rather than leaf area, for regrowth (Barnes and Sheaffer, 1985; Smith, 1986).

Alfalfa is often managed as hay, since good alfalfa hay is a high-value cash crop, especially for the horse and dairy industries. Grazing has long been considered detrimental to alfalfa stands. Properly managed, grazing is <u>not</u> harmful to alfalfa stands, but grazing may not be economically viable for alfalfa if a market exists for hay. Grazing-tolerant cultivars which will persist under frequent defoliation due to their ability to store TNC are being developed (Brummer and Bouton, 1992).

Some work has shown that alfalfa may be continuously grazed for up to 6 wk in spring (Allen et al., 1986). First hay cut will then be delayed by about the same length of time that the stand was grazed. Alfalfa may be rotationally grazed in mid to late summer at early bloom (Allen et al., 1986). Van Keuren and Matches (1988) suggest that grazing is not harmful to alfalfa as long as adequate recovery time is allowed; 7 to 10 grazing days require about 30 to 40 days of recovery.

Timing of hay cuts and grazing periods is important to obtain high-quality forage and high seasonal yields without compromising stand persistence. Robinson and Massengale (1968) found that stage of growth at harvest was more important to stand density and production than stubble height left from the previous harvest. In other words, alfalfa should be cut closely but not often. Smith (1986) and Latheef et al. (1988) suggested that the best stand survivability and seasonal yield can be obtained by cutting hay close to full bloom; this management allows plants to have enough TNC in late bloom stage. Cutting at more frequent intervals will lessen survivability and integrity of the stand if the practice is followed for more than two or three years. Latheef et al. (1988) also found that a variable first harvest had little influence on stand longevity if the alfalfa was not in late bloom stage and if subsequent cuts were taken at 10% to 30% bloom.

Autumn management. Autumn management of alfalfa must depend upon a number of factors, including location, overall health of the stand, and other yearly management practices. A number of studies have shown that cutting alfalfa from September to mid-October may reduce stand vigor and persistence (Sheaffer, 1988). An equal number have shown that autumn cutting does not harm stands (Sheaffer, 1988). In general, timely autumn cutting will not harm a healthy, winter-hardy variety growing on a fertile site (Sheaffer et al., 1988).

Stockpiling of alfalfa is not a common technique and little research has been done on the subject. Allen et al. (1992) stockpiled tall fescue and alfalfa together in Virginia, by taking a last hay harvest in early September and allowing forage to grow until grazing began October 31. They found that cattle which grazed stockpiled tall fescue-alfalfa had improved daily gains, total gains, and final weights over cattle grazing stockpiled N-fertilized fescue. Using stockpiled fescue-alfalfa required more hay-feeding than stockpiled fescue alone.

Quality. Alfalfa is considered to be one of the highest-quality forage crops, owing to its high protein, mineral, and vitamin contents, high digestibility, and high yields (Barnes and Sheaffer, 1985). Alfalfa produces more protein per hectare than grain or oil seed crops (Barnes and Sheaffer, 1985). In comparison with other legumes, such as birdsfoot trefoil

(*Lotus corniculatus*), cicer milkvetch (*Astragalus cicer* L.), and red clover (*Trifolium pratense*), alfalfa under drought conditions still produces more forage mass and more nutrients per hectare (Peterson et al., 1992). Alfalfa is more digestible than some other legumes such as sericea lespedeza (*Lespedeza cuneata*); Schmidt et al. (1987) found that rotationally grazed alfalfa had 69% digestibility while sericea had only 39% at comparable dry matter.

Fescue-legume mixtures

Introduction. Growing legumes with fescue is a long-practiced method of increasing forage yield, extending the grazing season, supplying high-quality forage to animals, and reducing need for N-fertilizer. The management of grass-legume mixtures can be problematic. Care must be taken to ensure that proper grazing techniques (Aiken et al., 1991) and fertilization regimes (Baker, 1980) are used to maintain both the grass and the legume in the mix.

Legumes can often supply adequate N to fescue (Groffman et al., 1987; Varco et al., 1987). Researchers have reported that soil N-losses from legumes may be greater or less than loss from fertilizers (Groffman et al., 1987; Varco et al., 1987) depending upon weather conditions, the companion legume, and the overall growth of the sward.

Yields. Fescue-legume stands often have seasonal forage yields as high or higher than N-fertilized fescue stands. Fescue-ladino and fescue-red clover are well-known and often-used mixes. The use of either of these legumes with fescue raises overall pasture yields by two-to three-fold (Dobson et al., 1976). Offutt and McKee (1973) found that fescue-alfalfa, fescue-red clover, and fescue-white clover (*Trifolium repens* L.) yielded 30%, 14%, and 8% more, respectively, than N-fertilized fescue.

In addition to raising seasonal yields, using legumes with fescue may extend the grazing season. Johnsons and Nichols (1969) found that fescue-alfalfa cut twice during the growing season produced 60% of its total yield at the first cut and 40% at the second; pure fescue produced 72% and 28% at the two respective cuts under the same management regime. Total yields of the two types of forages were similar, but the more even yield distribution of fescue-alfalfa had the potential to provide flexibility in the management of the mix, as well as reducing the need for supplemental feeding.

Quality. Fescue-legume mixes can have higher forage quality than pure fescue stands, or even pure legume stands. The different forage types in mixes compensate for antiquality factors or supply nutrients that the other forage does not. For example, Burns et al. (1973) found that fescue-ladino (*Trifolium repens* L.) pastures produced feeder steers which graded higher and gained 30% more than cattle grazing straight fescue fertilized with N. Blaser et al. (1969) found that average daily gain and total gain per hectare were greater for steers grazing fescue-ladino clover than for steers grazing N-fertilized fescue. Hoveland et al. (1981) agreed with Blaser's conclusions.

Nitrogen-supplemented grasses have often been found to have higher CP percentages than the same grasses without N-supplementation, whether extra N comes from legumes or N-fertilizer. Some work has refined this conclusion to state that grass-legume mixtures have more CP than N-fertilized grasses. Rayburn et al. (1980) found that fescue-legume mixtures have greater CP and lower crude fiber (CF) than the weighted means of the components, indicating that diversity is the important factor in these pastures. Johnson and Nichols (1969) found that tall fescue grown with alfalfa had higher CP than N-fertilized fescue in a year with plentiful rainfall, but that N-fertilized fescue had more CP in a dryer year. Fescue-alfalfa mixes produce greater CP, digestible dry matter (DDM), and total yield than ladino and red clover mixes (Offutt and McKee, 1973).

Mixing fescue with legumes can help to reduce the potential toxicity of fescue and bloat problems of legumes. Several researchers have suggested that a mix with 40% to 60% legume will lessen both antiquality factors and provide adequate N for the grass (Jackobs, 1963; Wilkinson and Mays, 1969; Chessmore, 1979) and high quality forage for the animals (Chessmore, 1979). Hamilton et al. (1969), working with orchardgrass (*Dactylis glomerata* L.), timothy (*Phleum pratense* L.), and smooth bromegrass (*Bromus inermis* L.) mixed with alfalfa, found that lethal bloat occurred only when alfalfa reached 90% in the pasture.

Fescue lessens the effects of bloat, but legumes can help to mitigate the toxicity of endophyte-infected fescue. Fribourg et al. (1991) discovered that, in a ladino (*Trifolium repens* L.)-fescue mix, the endophyte effects became visible at about 22% infection. Stuedemann and Hoveland (1988) estimate that for every 10% infection, there is a .22 kg reduction in average daily gain of beef steers, so the fact that endophyte toxicity did not manifest under 22% infection in ladino-fescue pastures is significant.

Management. Some legumes, such as milkvetch (Morris, et al., 1992; Dobson et al., 1976), are unable to compete with fescue, which is an aggressive grass (Blaser, 1956), unless pasture management favors the legume. Burger et al. (1958) found that ladino clover declined in fescue pastures when pastures were clipped at an enigmatic "pasture frequency", but would persist when pastures were clipped more often. Weeds encroached on pastures when legumes other than ladino were used.

Fescue-alfalfa. Alfalfa may be even more compatible with fescue than other legumes, due to its morphology, perennial nature, and tolerance of drought and hot weather (Kalton and Wilsie, 1953; Barnes and Sheaffer, 1985). Alfalfa must be rotationally grazed, except in spring conditions; fescue will tolerate this management (Booysen and Nelson, 1975; Van Keuren and Matches, 1988). Alfalfa is more competetive than other legumes (Blaser, 1956) and so may survive better than they against hardy fescue.

Hay cuts and grazing events must be timed so that both fescue and alfalfa are in appropriate stages of maturity; waiting until the fescue has gone to late seed will favor the alfalfa so much that the fescue will disappear (Smith et al., 1973). Burger et al. (1958) found that taking three hay cuts per year gave the highest total sward yields and also maintained an acceptable percentage of legume in the sward. They found that the legume was favored as stubble height was lowered, possibly because that alfalfa regrows from stored TNC more readily than fescue does.

Sulfur nutrition of plants and animals

Forms of soil sulfur. The earth's crust has, on average, 0.06% to 0.10% sulfur (Tisdale et al, 1985). Ninety percent or more of the sulfur in arable lands is organic, but these forms are not readily available to higher plants. Inert organic sulfur makes up the difference (Freney, 1986). Inert organic sulfur is especially resistant to any degradation or chemical changes (Tisdale et al, 1985). Higher plants must have mineralized sulfur, which can be limiting for plant growth (Sulphur Institute, 1982). Usually they obtain sulfur as dissolved sulfate, which moves through soil solution by diffusion and mass flow. Many soils tend to be deficient in this form of sulfur; a deficient soil may have less than 5 ppm SO_4 (Tisdale et al, 1985). Highly weathered soils with low organic matter tend to be naturally deficient in S (Jordan and Ensminger, 1956).

Sulfate in surface horizons in soil solution is vulnerable to leaching, especially in humid regions (Jones et al., 1968). Elemental S is not subject to leaching until it is mineralized (Burns, 1958). Because of leaching, sulfate accumulates deep in the subsoil, where it may be adsorbed by clay particles, especially kaolin, or hydrous oxides of aluminum and iron (Burns, 1958; Jordan and Ensminger, 1958).

Several factors affect the adsorption of sulfate in soil. First, as pH falls, sulfate adsorption increases (Kamprath et al., 1956; Burns, 1958; Chang and Thomas, 1963), due to increases in anion exchange capacity and specific adsorption sites. Second, the more sulfate that is in solution, the more is adsorbed (Kamprath et al., 1956; Burns, 1958). Third, other anions affect the adsorption of sulfate, notably phosphate; as phosphate levels increase, sulfate adsorption decreases, particularly in surface horizons (Kamprath et al., 1956). Sulfate adsorption increases over time, given fixed sulfate concentration and pH (Chang and Thomas, 1963). Organic matter also adsorbs sulfate (Barrow, 1961), and as organic matter decomposes, sulfate is released (Jordan and Ensminger, 1958).

The sulfur cycle - inputs and losses. Sulfur may enter soil in several ways, and undergoes transformations between organic and inorganic forms in soil. Some sulfur is inherently present in soil. Sulfur may be added to soil through animal manures, other soil amendments, or by atmospheric deposition from coal combustion or other industries (Terman, 1978). In many places, atmospheric deposition is still the major source of S. Sulfur is a component of many N, P, and K fertilizers, such as superphosphate and ammonium sulfate, but these fertilizers are no longer widely used (Fertilizer Institute, 1982). If S-fertilization is needed, gypsum is a convenient source (Sulphur Institute, 1982). Some pesticides contain S. Sulfur deficiencies for crop production have been occurring for many years as atmospheric deposition decreases, S-containing fertilizers are no longer in common use, and crop demands have increased (Sulfur Institute, 1982).

Sulfur may leach as sulfate, or volatilize as hydrogen sulfide. Volatilization is a minor method of soil sulfur loss which occurs only in highly organic or waterlogged soils (Tisdale et al., 1985). Other losses include plant removal by animals or harvest, especially if animal or plant residues are not returned to the soil; and erosion.

Loss of plant-available sulfate may occur through transformations to organic forms, the tendency of sulfate to accumulate deep in the soil profile, and through liming. Limed soils do not retain S very well; as pH rises from 4 to 7, adsorbed sulfate levels fall (Bohn et al., 1986) and mineralization of organic S slows (Tabatai and Al-Khafaji, 1980). If the C:S ratio of a soil is more than about 200:1, then sulfur will become unavailable (Tisdale et al., 1985). Care must be taken not to exceed this ratio when organic residues are added to soils.

Plant response to sulfur. Sulfur is an essential plant nutrient; it is often considered a macronutrient, since plants require approximately as much S as they do Ca or P (Tisdale, 1986). Sulfur is involved in low-energy bonding and protein synthesis in plants, is a constituent of several amino acids, vitamins, and coenzymes, activates enzymes, and may have a role in hardening off seedlings to cold or drought (Beaton et al., 1971; Metson, 1973; Gardner et al., 1985). Sulfur fertilization produces both yield and quality response in crops when S is limiting in soil (Beaton et al., 1971).

The amount of S required varies considerably among crop plants, with such crops as sugar cane, okra, and cotton requiring twice as much as corn and soybeans (Gardner, 1985). Soybeans in the southeastern United States responded when S was less than 4 mg kg^{-1} in soil (Kamprath and Jones, 1986). Corn in the southeastern United States responded when S was less than 3 mg kg^{-1} (Reneau and Hawkins, 1980). Buttrey et al. (1987) found that S fertilization increased weight of corn plants and grain by 7% over non-S-fertilized corn.

Sulfur requirements of forage crops are not well known, although Metson (1973) estimated that grasses require 0.30% S in tissue for maximum yields. Brogan and Murphy (1980) estimated that total S levels less than .2% or an N:S ratio of 15:1 indicate S deficiency. Grasses accumulate S more vigorously than legumes, and may have a considerably greater S content than legumes growing in the same location (Metson, 1973). Legumes may have a greater response to S-fertilization than grasses (Wilkinson and Mays, 1979). Tall fescue responded to 56 kg S ha^{-1} by doubling yields of second, third, and fourth hay cuts (Wilkinson and Mays, 1979).

Sulfur fertilization can enhance forage quality, particularly on sites where soil S is low. Such improvements include increase in vitamin A, chlorophyll, and protein content; decrease in non-protein N content and nitrate content; increase in protein quality; and increase in digestibility (Tisdale, 1977). Forage crops grown on land deficient in S for plant requirements will certainly not supply enough S for animal requirements (Rendig, 1986). Jones et al. (1982) found that a feed:gain ratio of 48:1 was required for lambs fed ryegrass not fertilized with S, grown on S-deficient soil. Lambs fed ryegrass fertilized with 90 kg S ha^{-1} needed a feed:gain ratio of only 18:1.

Sulfur-deficient plants display stunting, yellowing of leaves, and thin stems. Firing of lower leaves does not occur because S is not very mobile in plants (Gardner, 1985). Plants low in S do not produce optimum yields, and may also accumulate non-protein N in forms such as nitrates and nitrites, which are toxic to animals. This phenomenon occurs because S is not available to synthesize proteins, so N simply takes other forms (Tisdale, 1985). Sulfur status of plants does not appear to affect the amount of N that plants accumulate, only the forms in which N appears (Buttrey et al., 1987).

Plants have various mechanisms for absorbing S. Some plant species absorb more S than others. Different plants also store S in different parts. For example, Barney et al. (1984), using ^{35}S solution, found that high pH decreased S absorption by alfalfa, but had no effect upon S absorption by orchardgrass or fescue, indicating that alfalfa has a different S-carrier or absorption site than the grasses. These researchers also found that alfalfa absorbed more total S than either grass. Fescue absorbed more S than orchardgrass, and orchardgrass accumulated more S in roots, rather than in aerial parts. Obviously, S in roots is unavailable to animals.

Different forages may supply different amounts of S to animals. For example, Kentucky researchers Glenn et al. (1981) found that S was more available in the rumen from tall fescue than from orchardgrass under high N-fertilization. Even though S is more available from fescue than from orchardgrass, S from orchardgrass is more likely to be converted into protein in the rumen. Glenn et al. (1981) concluded that the metabolism of fescue differs from that of orchardgrass.

Animal response to sulfur. Sulfur is a critical mineral in animal nutrition for several reasons. Several amino acids and amino acid derivatives contain S, including the essential amino acid methionine, which performs various structural and metabolic functions. Methionine is a particularly important compound, since all other sulfur compounds needed for bodily functions - with the exceptions of thiamine and biotin - can be synthesized from methionine (NRC, 1984). Bodily functions which involve S include protein synthesis and metabolism, fat and carbohydrate metabolism, blood-clotting, endocrine system function, and intra- and extra-cellular fluid acid-base balance (NRC, 1980; NRC, 1984). Sulfur aids in nitrogen retention and utilization (Starks et al., 1954; Bull and Vandersall, 1973; Kahlon et al., 1975; Buttrey et al., 1985). Sulfur is also a component of wool or hair, collagen, some enzymes, hemoglobin, and some hormones (NRC, 1980; NRC, 1984). Since S is such a pervasive mineral in the body, consideration must be given to S in the diet.

Sulfur requirements for sheep and dairy cattle are well-documented. These animals produce products with high S content. Wool production is quite sensitive to S in sheep diets. Generally, a N:S ratio of 10:1 has been reported as necessary in sheep diets; this ratio is approximately .14% to .18% for mature ewes and .18% to .26% for young lambs. Both estimates are on dry matter basis (NRC, 1985).

Requirements for beef cattle are less well-known. The total S content of the body of a beef bovine is about .15% (NRC, 1984). Muscle tissue has a fairly constant N:S ratio of about 15.3:1 (NRC, 1984). Usually adequate levels of S are present in beef cattle diets, but S-supplementation may be beneficial for high-production cattle such as finishing steers or lactating dams. Cattle on high-grain diets with nonprotein-N supplementation responded to elemental S supplementation). Some grass diets may be improved with either supplemented S or fertilizer S (Rees et al., 1974; NRC, 1984). Buttrey et al. (1987) found that S supplementation of corn silage diets to an N:S ratio of 45:1 resulted in as much improvement in dry matter digestibility as supplementation to 12:1.

Sulfur-deficient animals perform very poorly. Symptoms of S deficiency include reduced appetite, weight loss, apathy, emaciation, watery eyes, and death in extreme cases (Starks et al., 1954; Bull and Vandersall, 1973; Kahlon et al., 1975). Sulfur deficiency damages rumen microbial ability to synthesize protein, so animals exhibit protein deficiency.

Many forms of S exist, but some are more biologically available to animals than others. Rumen microbes have the ability to convert inorganic S to organic forms, so supplementation of ruminants with inorganic S is possible. Non-ruminants require organic S (NRC, 1980). Most supplementation is given in inorganic forms, since these are less expensive to buy than organic ones. Generally, researchers have found that organic forms of S, such as methionine, are more available and provide better animal performance than inorganic forms such as elemental S, even for ruminants.

Kahlon et al. (1975) ranked several forms of S from most to least available to rumen microbes: L-methionine was most available, followed by calcium sulfate, ammonium sulfate, DL-methionine, sodium sulfate, sodium sulfide, elemental S, and finally by hydroxy analog of methionine. The trials of Starks et al. (1954) agreed that methionine is the most biologically available form of S, even when diets contain more N than is generally recommended: Starks' methionine diet had an N:S ratio of 20:1, while the other diets had ratios of 15:1.

Sulfur may make diets more digestible and N more available. Akin and Hogan (1983) found that S-fertilization of *Digitaria pentzii* increased voluntary intake and digestibility of this warm-season grass, compared to S-supplementation of sheep which had non-fertilized *Digitaria*, possibly by enhacing the fiber-digesting capabilities of rumen microbes. Rees et al. (1974) had similar results with pangola grass (*Digitaria decumbens*). Buttrey et al. (1987) found that N was more digestible from corn silage when S was supplied either as a supplement to sheep or as fertilizer to the corn. Apparent absorption of N was greater for S-fertilized corn silage than for the S-supplemented diet.

Kahlon et al. (1975) and Starks et al. (1954) found that sulfur aided in N-retention and utilization, especially when N was present as urea. Sulfur did not affect apparent N-digestibility when expressed as a percentage of N-intake, but S-supplemented animals consumed more N. Sulfur lowered urine N content, indicating higher N retention. Buttrey et al. (1987), as well, found that S aided in N-retention, and they further discovered that S-fertilized corn silage aided in N-retention more than did S-supplementation. Bull and Vandersall (1973) found that methionine analog aided in ADF digestibility, DMD, and absorption and retention of N.

Sulfur interacts with other minerals in the body, most notably with copper (Cu). Certain forms of S, such as ferric sulfide, can cause Cu deficiency by forming insoluble copper sulfides (Church and Pond, 1988). Sheep, as they age, produce increased levels of sulfide in the rumen, and Cu availability is reduced by the formation of CuS (Little, 1981).

Nitrogen

The nitrogen cycle. Nitrogen comprises about 78% to 79% of the earth's atmosphere (Tisdale et al., 1985). The N-cycle centers in soil. Atmospheric N can enter soil and become available to plants by four major methods: free-living soil bacteria; symbiotic bacteria in conjunction with host legumes; fertilizer manufacture; and, a minor occurrence, electrical charges in the atmosphere (Stevenson, 1982; Tisdale et al., 1985). Fertilizers and legumes are responsible for most N-fixation, which is a very energy-expensive process. Some N also falls as NO_3, NO_2, and organic forms in acid precipitation, but the amount of N which reaches soil by this route is not usually important in agriculture (Stevenson, 1982). Plants add N to soil as they decompose; animals add N to soil in excreta or as their bodies decompose (Smith and Peterson, 1982).

Nitrogen can leave soil by several routes (Stevenson, 1982). Harvest of crops, or of animals who have eaten plants, removes N and other nutrients. Erosion, especially of heavily-fertilized soils, removes much N and usually puts this N in dangerous and inconvenient places, such as major rivers and the Chesapeake Bay. Nitrogen occurs in several forms in soil, and these forms leave soil by different routes. Nitrate can leach away, often entering groundwater. Alternately, NO_2 and NO_3 can undergo chemical transformation in soil to N_2 or NH_3 and volatilize. Volatilization and leaching losses that occur as a result of transformation of N in soil represent loss of costly inputs; such losses are therefore undesirable to producers and can be very expensive to correct.

Nitrogen in the soil. Nitrogen has a complex relationship in soil. Many N transformations can take place, depending upon soil moisture, temperature, pH, microbiology, and aeration. Mineralization, immobilization, ammonification, nitrification, and denitrification are common reactions of N in soil. Microorganisms cause most of these transformations.

Legumes and N-supply. Plants cannot use atmospheric N; the only plant-available forms of N are NH_4 and NO_3. Legumes have a symbiotic association with bacteria of the genus *Rhizobium*. These bacteria are able to change atmospheric N_2 to usable forms of N, through the use of nitrogenases. Often they can supply enough N for their plant hosts as well (Havelka et al., 1982). An enormous amount of N is fixed each year by these creatures; Hardy and Holsten (1972) estimated that 90×10^6 T N yr^{-1} are made available to plants (as cited by Havelka et al., 1982).

Most legumes, with their associated rhizobia, can "fix" about 75% of their required N; a deficit must be made up by soil N or some other source of N. Some can supply much more than that (Tisdale et al., 1985). Alfalfa, clovers, and lupines supply more N than beans and peas. Extra N is available to supply other plants. The transfer of N from legumes to other plants takes place slowly, over a matter of days, through root exudates, sloughed-off root cells, decaying leaves or other legume parts. Animals can help to speed the transfer by consuming legumes: some N is converted to body tissue and some is excreted in urine or feces and is immediately available to other plants.

Conditions which aid photosynthesis will encourage N-fixation, since fixation is energy-expensive. Proper soil pH, good soil physical properties, and presence of other necessary nutrients are essential for fixation to take place at a maximum rate (Stevenson, 1982). If N is applied to soil as fertilizer or animal waste, N-fixation will be discouraged, since adequate N will already be available to plants; plants will grow without sending carbohydrates to roots (Stevenson, 1982).

Chapter 3

Stockpiling of N-fertilized tall fescue vs tall fescue grown with alfalfa: I. Effects of forage on animal performance, blood urea nitrogen, and serum minerals. II. Effects of timing of stockpiling on forage quality of N-fertilized tall fescue and mixed tall fescue-alfalfa.

Abstract

Stockpiling of tall fescue (*Festuca arundinacea* Schreb.) is a common management technique in forage-livestock systems in Virginia. Stockpiled fescue grown with alfalfa may improve animal performance over stockpiled N-fertilized fescue. Nitrogen-fertilized fescue is stockpiled starting at the beginning of August. When fescue is grown with alfalfa rather than being fertilized with N, stockpiling in August may cause loss of alfalfa. Animal performance, blood urea nitrogen (BUN) levels and serum mineral concentrations, were investigated for cattle grazing stockpiled N-fertilized tall fescue or stockpiled fescue-alfalfa, in a randomized block design with four replications. Yield, botanical composition, and forage quality of N-fertilized tall fescue and fescue-alfalfa, stockpiled in August or September, were measured. Forage samples were taken at initiation of grazing of stockpiled forage in early

November. Steers grazing stockpiled fescue-alfalfa performed better ($P<0.05$) than steers grazing stockpiled N-fertilized fescue in yr 2 but not in yr 1, due to forage availability. Averaged over year, serum mineral levels of S and Ca were higher ($P<0.05$) in steers grazing stockpiled fescue-alfalfa than those grazing N-fertilized fescue at the end of the grazing period, but P, Mg, Cu, and Fe did not differ. Averaged over year, BUN levels tended to be higher ($P<0.07$) in steers grazing stockpiled fescue-alfalfa. Fescue-alfalfa stockpiled in August yielded less ($P<0.05$), had higher ($P<0.05$) fiber concentrations and lower ($P<0.05$) CP concentration than fescue-alfalfa stockpiled in September. Fescue-alfalfa stockpiled in August yielded less than N-fertilized fescue stockpiled in August or fescue-alfalfa stockpiled in September. Based on these results, fescue-alfalfa should be stockpiled beginning in early September to optimize yield and quality.

Introduction

Tall fescue is grown primarily throughout the southeastern United States, but its range extends north into Canada and west to the eastern part of the Great Plains (Buckner, 1985). Approximately 14 million ha were grown in 1979 in the United States (Buckner et al., 1979). Fescue is an aggressive cool season grass which will persist and produce under very poor environmental conditions (Blaser et al., 1956; Buckner, 1985; Smith, 1986). Fescue is the basis of many forage-livestock systems in Virginia and can be a high-quality, palatable forage when managed correctly (Buckner, 1985).

Alfalfa (*Medicago sativa* L.) is one of the few crops to be grown in every state of the contiguous United States. In the mid-1970's, approximately 11 million ha were grown throughout the United States (Barnes and Sheaffer, 1985). Alfalfa is an aggressive, drought-tolerant crop whose high nutritional quality and high yields under stress have made it an important forage in the southeastern United States.

Growing tall fescue and alfalfa in combination is not common, but can be advantageous for several reasons. Mixing the two forages can increase seasonal yields, extend the grazing season farther into the summer (Johnson and Nichols, 1979), raise forage quality (Hamilton et al., 1969; Allen et al., 1992), and reduce or eliminate the need for N-fertilization of fescue (Allen et al., 1992). Usually 40 to 60% legume in the mix is used for maximum benefit (Jackobs, 1963; Wilkinson and Mays, 1969; Chessmore, 1979).

Stockpiling of tall fescue is an often-practiced management technique in Virginia. Stockpiled tall fescue is a high-quality forage which can support beef cows or maintain stocker steers throughout a significant part of the winter in Virginia without supplemental hay feeding (White, 1977; Allen et al., 1992). The accepted method in Virginia is to graze the forage until about August 10, when extra forage is clipped or grazed. If management permits, hay may be harvested at this time. About 80 kg N ha^{-1} are applied, and the fescue is allowed to accumulate until grazing begins, usually in early November, depending upon precipitation during the stockpiling period (Brown et al., 1963; White, 1977; Bagley et al., 1983). Grazing of stockpiled fescue can usually last until January or February, although quality declines rapidly after December (Taylor and Templeton, 1976; Ocumpaugh and Matches, 1977; Rayburn et al., 1980; Bagley et al., 1983).

Stockpiled fescue is of high nutritive value (Buckner, 1985) because total nonstructural carbohydrates (TNC) increase while fiber components remain stable during the cool days of August and September (Brown et al., 1963). Stockpiling fescue and alfalfa together results in an even higher quality forage. Allen et al. (1992) found that steers which grazed stockpiled tall fescue-alfalfa had higher daily gain and total gain than steers which grazed N-fertilized fescue alone. The improved performance of fescue-alfalfa steers continued on feedlot, where these animals gained faster and more than steers which had grazed N-fertilized fescue the previous winter.

Allen et al. (1992) stockpiled fescue-alfalfa in September because alfalfa stockpiled in August may deteriorate due to maturity by the time grazing begins in November. The yield of fescue-alfalfa stockpiled forage might not be as high as August-stockpiled N-fertilized tall fescue, but improved animal performance may offset this disadvantage. These studies were designed to investigate the effects of stockpiled fescue-alfalfa on forage quality and animal performance as compared to stockpiled N-fertilized fescue; and the effects of timing of stockpiling on forage quality, yield, and stand persistence of fescue-alfalfa and N-fertilized fescue. A further objective was to investigate the influence of the different forages and harvest methods on soil fertility and bulk density.

Materials and Methods

'Kentucky 31' endophyte-free tall fescue and similar fescue grown in mixture with 'Cimmarron' alfalfa were established in 1988 for use in a long-term grazing and farm systems research study at the Whitethorne-Kentland Virginia Agricultural Research Station in Montgomery County, Virginia. The present study was a complete randomized block design with four field replications. Pastures were 1.6 ha each and were established on Shottower soils (Typic Hapludults, fine-loamy, mixed, mesic, with river cobbles in the surface). Lime, P, and K were applied according to soil test recommendations at the time of establishment. Thereafter, N was applied in split application at 160 kg ha^{-1} yr^{-1} to tall fescue. Ammonium nitrate N solution containing 34% N was used. Times of application were early spring and early August. Mixed tall fescue-alfalfa received no N fertilizer, but was fertilized with 65 kg P ha^{-1} yr^{-1} and 140 kg K ha^{-1} yr^{-1} according to soil test recommendations. Applications were made in early spring. Six Angus steers were blocked according to initial weight and randomized to treatment (N-fertilized fescue vs fescue-alfalfa) for each replication (24 steers per treatment).

Experiment 1. The study was conducted during the 1991-1992 and the 1992-1993 stockpiling seasons. In both years, N-fertilized tall fescue was clipped and fertilized with 80 kg N ha^{-1} at the beginning of August, in preparation for accumulation of forage. Tall fescue-alfalfa pastures were clipped at the beginning of September. No fertilizer was applied. Both types of forage were allowed to accumulate until 25 Nov. 1991 (yr 1); and 1 Nov. 1992 (yr 2). At these dates, six weanling Angus steers, approximately 205 kg, began grazing each pasture replicate, for a total of 24 steers per treatment. The delay in initiation of grazing in 1991 was due to a severe drought during the preceding summer and autumn. In 1991, hay feeding for fescue-alfalfa steers began on 23 Dec. In 1992, hay feeding of fescue-alfalfa steers began 28 Dec. Thus, there were 28 and 53 grazing days prior to hay feeding in yr 1 and yr 2, respectively.

Initial blood samples were taken by venapuncture from each steer at the time grazing of stockpiled forages began. Initial steer weights were obtained at this time as well. Additional blood samples and animal weights were obtained at 28-d intervals. When hay feeding began on the fescue-alfalfa, final blood samples and weights were taken. In both years, 28-d intervals coincided with final sampling dates.

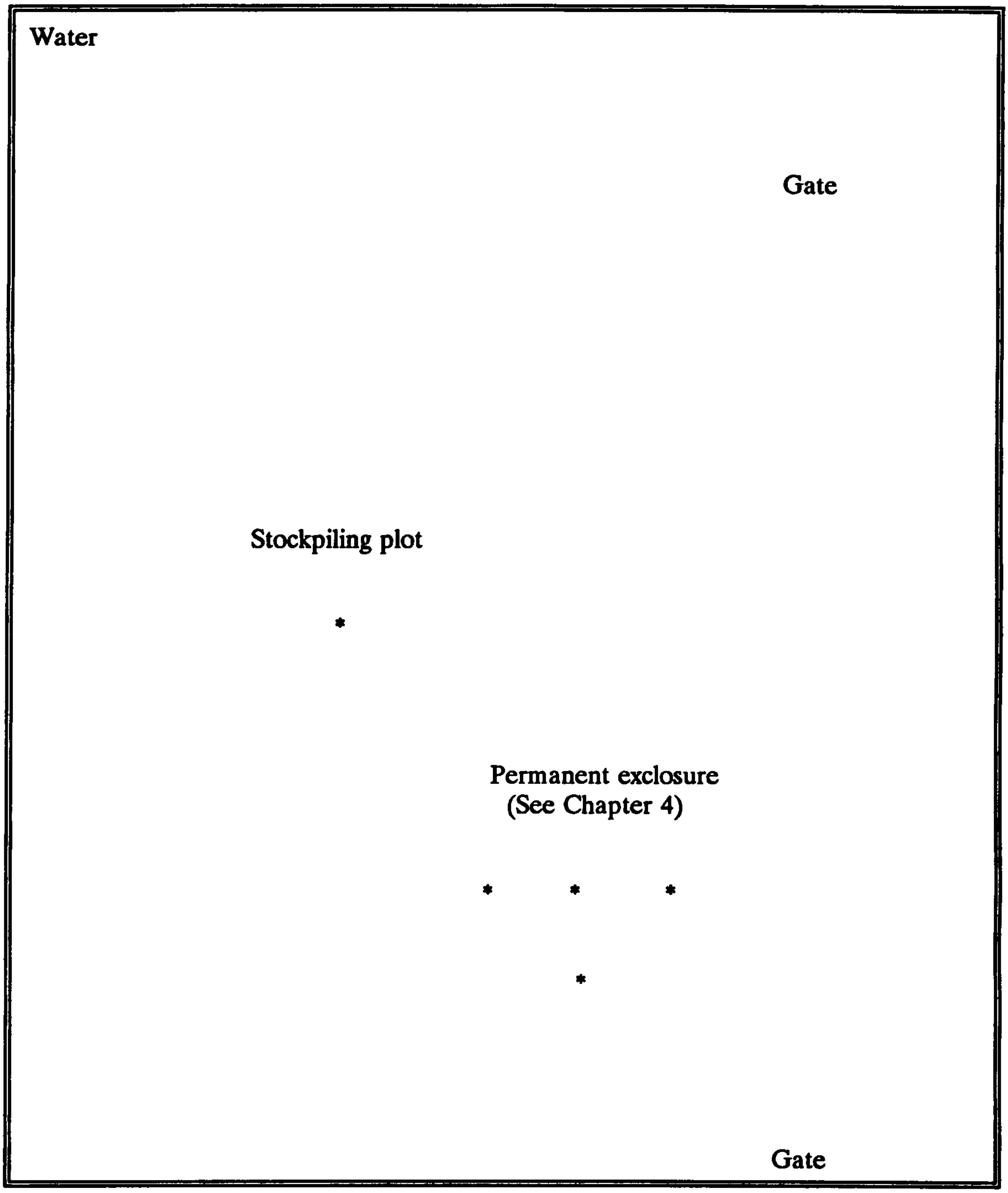
Blood samples were centrifuged at 45,000 rpm for 15 min. Serum was frozen for later analysis. Serum was diluted to 1 ml serum:9 ml .1 molar HCl for analysis of mineral content by inductively-coupled plasma spectrophotometry (ICP). Minerals determined included P, Ca, Mg, S, Cu, and Fe. Blood urea N content of undiluted serum was determined by use of Union Carbide Centrifichem 500 auto-analyzer in conjunction with Baker Instruments Pipetter 2000. Sigma diagnostic BUN Rate 10 kit (Sigma Diagnostics, St. Louis, MO 63178) was used for this procedure.

Data were analyzed as a complete randomized block (SAS, 1990) using a model that tested treatment and time effects and interactions.

Experiment 2. This study was conducted during the 1992-1993 stockpiling season. Pastures were treated as described in Experiment 1. In addition, one small plot, approximately 6 m^2, was located in each pasture to investigate effects of timing of stockpiling (Fig. 1).

Samples were taken for determination of forage quality at initiation of grazing of stockpiled forage from each pasture on 1 Nov. 1991. Samples were obtained by criss-crossing pastures and clipping forage at 5 cm every 20 paces. These samples were collected in order to estimate quality of forage cattle grazed. In fescue-alfalfa pastures, fescue and alfalfa were collected separately. Samples were dried at 55°C and ground in a stainless steel Wiley mill through a 1-mm mesh screen. Dry matter was determined by drying subsamples at 110°C. Forages were analyzed for neutral detergent fiber (NDF), acid detergent fiber (ADF), lignin, and cellulose (Goering and Van Soest, 1970). Forages were wet-ashed with nitric acid and

Figure 1. General map of N-fertilized fescue and fescue-alfalfa pastures at Whitethorne-Kentland Farm, Montgomery County, VA.



* Samples taken for yield and quality analysis.

perchloric acid for mineral analysis by ICP (Muchovej, 1986). Residue was diluted to 50 ml with distilled deionized water.

Forage heights were measured with a diskmeter apparatus on 25 Nov. 1991. This measurement was changed to extended plant height for 1 Nov. 1992 so that fescue and alfalfa could be evaluated separately. Also, Aiken and Bransby (1992) found that diskmeter readings varied so much among observers that the measurement was of limited use if different observers took the measurement, which was the case in this study. Ten measurements of each forage were taken randomly in each pasture.

In 1991, forage yield was estimated by cutting two 6-m strips with a Gravely mower. The cutter bar was 91 cm wide, for a total area of each strip of 5.46 m^2. Forage was collected, dried at 55°C, and weighed to estimate yield in kg ha^{-1}. Dry matter was considered to be that of criss-cross samples. In 1992, forage stands in fescue-alfalfa pastures were so thick that the Gravely could not get in without damaging too much forage. Yield was therefore estimated by cutting three .25 m^2 quadrats in each pasture, within a 6-m radius of permanent plots which were located in pastures for use in a grazing study described in Chapter 4 (Fig. 1). Forage was collected, dried at 55°C and weighed to estimate yield in kg ha^{-1}. Forages from these quadrats were analyzed for fiber components, crude protein, and mineral concentrations for use in the grazing study and to compare to samples from different stockpiling dates in this study.

Botanical composition of each pasture was visually estimated at initiation of grazing of stockpiled forages in both 1991 and 1992, by the modified Double DAFOR Scale (Abaye, 1991). The same three people performed these evaluations each time. In N-fertilized fescue pastures, small plots were clipped in early August both years, when the rest of the pasture was clipped in preparation for stockpiling. In 1992, this took place on 4 Aug. In 1993, this occurred on 12 Aug. Small plots were covered with plastic to prevent N from reaching forage when pastures were fertilized. Small plots were clipped and raked in August to remove dead forage and weeds. Small plots were clipped and raked again when stockpiling was initiated for fescue-alfalfa pastures. In 1992, this occurred 29 Aug. Small plots were fertilized by hand with 80 kg N ha^{-1} (80 g) ammonium nitrate after clipping. Quadrat samples, plant heights, and botanical composition observations were obtained when grazing of stockpiled forages began 1 Nov. 1992.

In fescue-alfalfa pastures, small plots were located as well (Fig. 1). These small plots were clipped and raked 4 Aug. 1992. Small plots were not fertilized, but left to grow until grazing began 1 Nov. 1992. Quadrat samples, plant height, and botanical composition observations were taken at that time. Fescue and alfalfa were separated in the field for later analysis.

Small plot quadrat samples from each pasture were analyzed for fiber concentration, crude protein concentration, and mineral concentration. They were compared to quadrat samples which had received normal stockpiling treatment (N-fertilized fescue stockpiled in August; fescue-alfalfa stockpiled in September).

Data were analyzed as a complete randomized block (SAS, 1990), using a model that tested effects of forage, block, time of stockpiling, and all two- and three-way interactions. Differences among forages in chemical composition were further tested by orthogonal contrasts (SAS, 1990) to compare 1) alfalfa vs fescue and 2) N-fertilized fescue vs fescue grown with alfalfa.

Results and Discussion

Experiment 1. Data on animal performance is presented in Table 1. Results are not combined over years because growing conditions were so different for the two years and year-by-system interactions occurred. Steers began grazing stockpiled N-fertilized fescue and fescue-alfalfa pastures 25 Nov. 1991 (yr 1) and 1 Nov. 1992 (yr 2). In yr 1, steers grazing fescue-alfalfa were fed hay beginning 23 Dec. At that date, weights of steers grazing different forages did not differ (Table 1).

In yr 2, steers were heavier ($P<0.05$) entering the grazing period than in yr 1. Hay-feeding in fescue-alfalfa pastures began on 29 Dec. 1992. At this time, steers grazing fescue-alfalfa were significantly heavier ($P<0.05$) and had higher total gain and daily gain ($P<0.05$) during the 2 mo than steers grazing N-fertilized fescue.

Performance of cattle grazing fescue-alfalfa was less than cattle grazing N-fertilized fescue in yr 1, possibly due to the severe drought in the summer and early autumn of 1991, which depressed growth and quality of fescue-alfalfa pastures, particularly alfalfa (see Table 7). Forage available for animal consumption was very brown and of poor quality (see Experiment 2). Alfalfa was 20% to 50% of the forage, according to visual evaluation, and was very stemmy, with little leaf within reach of grazing cattle. Although total forage mass, as measured by yield strips, was similar in N-fertilized fescue and fescue-alfalfa pastures, the presence of stemmy, poor-quality alfalfa in the mix reduced the amount of forage actually available for fescue-alfalfa steers to eat. Since N-fertilized fescue pastures had no alfalfa, more forage was available for grazing.

Results for yr 2 were in accordance with Allen et al. (1992). Year 2 had adequate

Table 1. Animal performance of steers grazing stockpiled N-fertilized fescue (conventional) or stockpiled fescue-alfalfa (alternative).

Item	Year	System: Conventional	System: Alternative	SE
		kg		
Initial wt.	'91-'92	203	203	4
Nov. 25-Dec. 23, 1991				
Total gain		18	14	2
Daily gain		.67	.52	.1
Final wt.		221	217	4
Initial wt.	'92-'93	214	214	3
Oct. 28-Dec. 29, 1992				
Total gain†		44	53	2
Daily gain†		.71	.87	.1
Final wt.†		258	267	4

† Systems differ ($P<0.05$).

rainfall and near ideal temperatures for fescue and alfalfa growth, so forage was available for consumption (see Table 7). In yr 2, fescue-alfalfa pastures had approximately 50% fescue and 50% alfalfa, while N-fertilized fescue pastures had 90% to 100% fescue, with little weed invasion, according to visual evaluation.

Legume-grass mixtures can allow animals to perform 20 to 25% better than pure grass stands, according to Thomson (1978), who reviewed literature of experiments on animal performance on mixed pastures and pure grass stands. Intake of legumes is higher than that of grasses, and animals use metabolizable energy from some legumes, such as white clover (*Trifolium repens* L.), more efficiently than from grasses, such as ryegrass (*Lolium* spp.) (Joyce and Newth, 1967; Rattray and Joyce, 1969). Having alfalfa mixed with fescue was probably partially responsible for the better performance of steers grazing fescue-alfalfa compared to those grazing N-fertilized fescue. A second factor in the performance of the fescue-alfalfa steers was that fescue-alfalfa was not stockpiled until 1 Sept. Nitrogen-fertilized fescue was stockpiled 1 Aug., so that this forage was at a more advanced stage of maturity and therefore of lesser quality than stockpiled fescue-alfalfa.

Serum samples were taken when cattle began grazing stockpiled forages and when hay-feeding began, in order to measure only the effects of the different stockpiled forages on serum minerals and BUN, without measuring any effects of hay. Initial concentrations of serum P, Mg, S, Cu, and BUN differed ($P<0.05$) between years, as expected, since the cattle were from entirely different lots (Table 2).

Phosphorus, Mg, Cu, and Fe did not differ among cattle grazing different forages when hay-feeding began. Calcium decreased ($P<0.05$) in cattle of both systems from initial to final dates in yr 1, probably because plants could not take up Ca due to lack of water and

Table 2. Mineral and blood urea nitrogen concentrations of serum from steers grazing stockpiled N-fertilized fescue (conventional) or stockpiled fescue-alfalfa (alternative).

Time	System	Year	Mineral						
			P†‡	Ca‡§	Mg†‡	S†§	Cu†‡	Fe‡	BUN†¶#
			mg dl⁻¹						
11-25-91	Conventional	1	8.9	9.4	1.7	79.6	0.070	0.26	11.8
	Alternative		9.4	10.0	1.7	84.6	0.073	0.21	11.5
	SE		0.3	0.2	0.1	0.2	0.004	0.02	0.5
12-23-91	Conventional		9.7	8.6	1.5	78.5	0.064	0.15	15.0
	Alternative		10.0	8.9	1.6	81.6	0.067	0.14	20.6
	SE		0.3	0.2	0.1	1.4	0.004	0.04	0.5
11-1-92	Conventional	2	11.6	9.5	1.9	85.6	0.086	0.20	15.3
	Alternative		11.8	9.5	1.8	86.0	0.093	0.19	15.6
	SE		0.3	0.2	0.1	1.6	0.004	0.02	0.5
12-28-92	Conventional		13.3	9.7	1.7	79.8	0.092	0.43	12.1
	Alternative		13.5	10.1	1.8	83.5	0.091	0.38	11.5
	SE		0.3	0.2	0.1	1.5	0.005	0.05	0.6

† Years differ at initiation of grazing ($P<0.05$).
‡ Years differ at end of grazing period ($P<0.05$).
§ Averaged over year, systems differ at end of grazing period ($P<0.05$).
¶ Averaged over year, systems tend to differ at end of grazing period ($P<0.07$).
# Year-by-system interaction ($P<0.05$).

reduced root growth (Tisdale, 1985); Ca was lower in forages in yr 1 than in yr 2. Serum Ca rose ($P<0.05$) for cattle in both systems in yr 2. In both years, fescue-alfalfa cattle ended with higher ($P<0.05$) serum Ca levels than N-fertilized fescue cattle.

Sulfur did not differ between years at the end of the grazing period, but declined ($P<0.05$) for cattle of both systems between initiation of grazing and end of grazing, perhaps because S tends to decline in plants as they age (Fleming, 1963). Cattle grazing fescue-alfalfa ended with higher ($P<0.05$) serum S levels than cattle grazing N-fertilized fescue, not because alfalfa had higher levels of S than fescue, but possibly because S was more available from alfalfa and younger fescue than from N-fertilized fescue (Chapter 5).

Blood urea nitrogen levels differed ($P<0.05$) between years at initiation of grazing. Averaged over both years, fescue-alfalfa cattle tended ($P<0.07$) to have higher BUN levels than N-fertilized fescue cattle at the end of the grazing period. In yr 1, fescue-alfalfa cattle had much higher BUN levels than the others. Nitrogen accumulates in plants which are not actively growing but have a supply of N, which was the case for fescue-alfalfa in yr 1. Crude protein was higher in fescue grown with alfalfa than N-fertilized fescue in yr 1. Steers grazing this forage had access to elevated forage N, which may have accounted for higher BUN levels.

In yr 2, fescue-alfalfa cattle had slightly lower BUN values at the end of the grazing period, possibly reflecting greater utilization of N by either forages or animals. A year-by-system interaction occurred, since in yr 1, BUN rose for cattle grazing fescue-alfalfa, but in yr 2, BUN fell for both groups of cattle.

Experiment 2.

Forage quality. Initial values for fiber, crude protein, and mineral concentrations for both years 1 and 2 are presented in Table 3. The drought of summer 1991 had a large effect upon fiber concentrations of the forages. Lignin is expected to be higher in legumes than in grasses, but the other fiber components should be lower in legumes, while CP should be higher (Van Soest, 1985). In yr 1, alfalfa was lower in CP than the mean of the fescues ($P<0.05$), higher in ADF, cellulose, and lignin ($P<0.05$), and tended to be higher ($P<0.20$) in NDF than the fescues. This contrary result could be explained by considering that alfalfa was very stemmy at sampling, with few leaves, most of which were entirely desiccated and brown.

In yr 1, N-fertilized fescue tended to be lower ($P<0.15$) in NDF, lignin and CP than fescue grown with alfalfa. Fescue grown with alfalfa was possibly more drought-stressed than fescue grown alone, since the former had to compete with alfalfa for the little available water; fiber components may have been higher in fescue grown with alfalfa for this reason. More N may have been available to fescue grown with alfalfa; also, N does accumulate in stressed plants because they are not able to grow and to dilute N. This factor may account for higher CP in fescue grown with alfalfa.

In yr 2, alfalfa was of higher quality than the fescues. Alfalfa was higher ($P<0.05$) in CP, as expected (Van Soest, 1985); lower ($P<0.05$) in NDF, ADF, and lignin. Alfalfa is expected to be higher in lignin than fescue. The reason that it appears to be lower is because N-fertilized fescue was high in lignin, which increased the mean of lignin of the fescues.

In yr 2, fescue grown with alfalfa was lower ($P<0.05$) in NDF, ADF and lignin, and

Table 3. Crude protein and fiber concentrations of stockpiled N-fertilized tall fescue, tall fescue grown with alfalfa, and alfalfa at the beginning of grazing stockpiled forages in 2 years.

Forage	Date sampled	Crude protein	Fiber component			
			NDF	ADF	Cellulose	Lignin
		g 100g^{-1}				
Conventional	11-25-91					
N-fertilized fescue		14.71	61.70	30.65	24.63	4.68
Alternative						
Fescue		16.73	62.19	33.66	26.24	6.29
Alfalfa		13.20†	68.48	46.48†	32.48†	14.10†
SE		0.77	5.56	2.25	1.21	0.69
Conventional	11-1-92					
N-fertilized fescue		13.02	55.34	32.84‡	26.00	5.69‡
Alternative						
Fescue		14.50	50.33	27.77	22.86	3.79
Alfalfa		21.66†	29.20	19.68†	15.57	5.13†
SE		1.03	0.74	2.27	1.22	0.69

† Alfalfa differs from the mean of tall fescue ($P<0.05$).
‡ N-fertilized fescue differs from fescue-alfalfa ($P<0.05$).

tended to be lower (P<0.15) in cellulose than N-fertilized fescue. These effects are probably due to age of forage at sampling time, since N-fertilized fescue was stockpiled beginning in August and fescue-alfalfa stockpiled in September.

Time of initiation of stockpiling affected quality (Table 4) of stockpiled forages. When fescue-alfalfa was stockpiled beginning 1 Aug., very little alfalfa was available to sample from small plots on 1 Nov. Alfalfa had become old, deteriorated, and was stemmy, with little leaf. Insects had damaged leaves. Stockpiling fescue-alfalfa in August greatly reduces the value of having alfalfa in the mix because of this aging effect. Alfalfa present in samples was used for mineral analysis, NDF, and CP analysis. Crude protein was higher (P<0.05) in alfalfa stockpiled beginning in September, and NDF was lower than in alfalfa stockpiled in August, but was too variable to be statistically different (34.2 vs 58.8; SE 18.2). Alfalfa stockpiled in September was lower (P<0.05) in NDF, ADF, and cellulose; higher (P<0.05) in CP; and tended to be higher (P<0.20) in lignin than fescue stockpiled in September.

Nitrogen-fertilized fescue was lower (P<0.05) in all fiber components when stockpiling was initiated on 1 Sept. compared to 1 Aug.; the result is probably due to age of forage, since fiber concentrations increase with physiological maturity (Van Soest, 1985). Nitrogen-fertilized fescue stockpiled in August tended to be lower (P<0.15) in fiber components than fescue grown with alfalfa stockpiled in August. Nitrogen-fertilized fescue stockpiled in September tended to be lower in (P<0.10) in cellulose and higher (P<0.30) in CP than fescue grown with alfalfa stockpiled in September.

Fescue grown with alfalfa tended to be lower (P<0.30) in NDF and lignin when stockpiling began in September rather than August, but stockpiling date did not affect ADF,

Table 4. Influence of stockpiling date on crude protein and fiber content of stockpiled N-fertilized fescue, tall fescue grown with alfalfa, and alfalfa sampled at initiation of grazing of stockpiled forages on 1 Nov. 1992.

			Fiber component			
Forage	Date	Crude protein	NDF	ADF	Cellulose	Lignin
		g 100 g^{-1}				
Conventional	Aug. 1					
N-fertilized fescue		13.02	60.3‡	34.3‡	28.1‡	4.9‡
Alternative						
Fescue		15.07	58.5	32.1	26.1	4.0
Alfalfa		14.20	58.8	-§	-	-
SE		0.86	4.5	2.5	1.8	0.6
Conventional	Sept. 1					
N-fertilized fescue		17.17	50.3	27.0	22.1	3.7
Alternative						
Fescue		14.50	58.4	26.0	24.0	3.5
Alfalfa		21.66†	34.2†	20.6†	16.0†	5.0
SE		1.59	5.5	1.7	0.6	0.7

† Alfalfa differs from the mean of fescue ($P<0.05$).
‡ Means differ between stockpiling dates ($P<0.05$).
§ No sample available for analysis from this treatment.

cellulose, or CP concentrations in fescue grown with alfalfa. Van Soest (1985) suggests that age does not necessarily affect fiber concentrations, especially when temperatures are cooling in autumn. The reason that forage quality of N-fertilized fescue was affected by date of stockpiling while forage quality of fescue grown with alfalfa was not is unclear and should be further examined.

Minerals. Values for mineral concentrations in forages at initiation of grazing of stockpiled forages are presented in Table 5. Mineral content differed numerically between years for all forages. Generally, minerals were lower for yr 1 for all forages, except Cu, which was similar for the fescues; and Fe, which was higher for all forages in yr 1 than in yr 2. Drought conditions were probably responsible for these differences, since most minerals move primarily in soil solution and are taken up by actively growing roots, although root interception and diffusion does occur (Tisdale, 1985). Younger tissue is often higher in minerals than older tissue. Sampling later in yr 1 than in yr 2 may have been another reason that minerals were generally higher in yr 2 forages.

Grasses are tolerant to low soil Cu levels because of more efficient uptake mechanisms or other reasons, while alfalfa often responds to Cu fertilization, especially in high pH soils (Lanyon and Griffith, 1988). The fescues in this study may have been able to scavenge Cu from dry soil better than alfalfa, which was higher in Cu when adequate water was present. Iron is not a very soluble mineral, and at normal pH, may not be available to supply plant needs, even when soil contains adequate amounts of Fe. Dry soil tends to favor uptake of Fe over soils which are wet, especially when weather is cool and rainy (Tisdale, 1985). Since yr 1 was dry and yr 2 wet, plants in yr 1 had more Fe available to them.

Stockpiled tall fescue grown with alfalfa was higher ($P<0.05$) in P than N-fertilized

Table 5. Mineral concentrations of stockpiled N-fertilized tall fescue, tall fescue grown with alfalfa, and alfalfa sampled at the beginning of grazing stockpiled forages for 2 years.

		Mineral					
Forage	Date	P	Ca	Mg	S	Cu	Fe
		$g\ 100g^{-1}$				ppm	
Conventional	11-25-91						
N-fescue		0.15†	0.32	0.22	0.19	3.8	112
Alternative							
Fescue		0.19	0.41	0.23	0.20	4.1	143
Alfalfa		0.12‡	0.99‡	0.19‡	0.17‡	4.4	140
SE		0.01	0.05	0.01	0.01	0.2	18
Conventional	11-1-92						
N-fescue		0.24	0.42	0.35	0.26	3.8	65†
Alternative							
Fescue		0.24	0.67	0.36	0.29	4.1	77
Alfalfa		0.21‡	1.84‡	0.39‡	0.30	5.4‡	79
SE		0.01	0.30	0.01	0.01	0.4	4

† N-fertilized fescue differs from fescue grown with alfalfa ($P<0.05$).
‡ Alfalfa differs from the mean of fescue ($P<0.05$).

tall fescue in yr 1. Fescue grown with alfalfa tended to be higher ($P<0.30$) in Ca, Mg, S, Cu, and Fe. In yr 2, P, Ca, Mg, and Cu did not differ between fescues. Copper tended to be higher ($P<0.15$) in fescue grown with alfalfa than in N-fertilized fescue in yr 2. Iron was higher ($P<0.05$) for fescue grown with alfalfa than in N-fertilized fescue in yr 2.

In yr 1, alfalfa was lower ($P<0.05$) in P, Mg, and S than the mean of the fescues. This result may be explained since water was limited for mineral uptake and most leaf tissue was gone from alfalfa at sampling in yr 1. Alfalfa was higher ($P<0.05$) than grasses in Ca even in yr 1, as expected. In yr 2, alfalfa was lower ($P<0.05$) than the fescues only in P. In Ca, Mg, and Cu, alfalfa was higher ($P<0.05$) than the fescues and tended to be higher ($P<0.20$) in S and Fe. In yr 2, water was not limiting and leaf area was present for sampling. Also, when conditions are favorable, alfalfa can reach deeper into soil than grasses, thus reaching minerals located where grass cannot reach (Griffith, 1974).

Some minerals in stockpiled forages were inadequate for growing steers, according to NRC (1984). Copper levels in all forages were lower than required in yr 1 and very marginal in yr 2, since 4 to 6 ppm in the diet is needed, and forages supplied less than 5 ppm, except for alfalfa in yr 2. Iron requirements for beef cattle are not well documented, but 100 ppm is usually recommended for calves (NRC, 1984). Iron in all forages in yr 1 was adequate but may not have been adequate in yr 2, since N-fertilized fescue had only 65 ppm; fescue grown with alfalfa had 77 ppm, and alfalfa had 79 ppm Fe.

Normal plasma levels of Mg are 1.8 to 2.0 mg dl^{-1} (NRC, 1984). Table 2 indicates that serum Mg values were lower than usual in yr 1, but on the low end of normal for yr 2. Forages may have been slightly deficient in Mg, but in yr 2, forages did supply enough Mg. To prevent grass tetany in lactating beef cows, diets need at least .2% Mg; all forages did supply adequate Mg for this purpose in yr 2. Beef cows should be able to graze either stockpiled N-fertilized fescue or fescue-alfalfa with minimum risk of tetany if fall calving occurs, according to values for forage Mg content, assuming high biological availability of Mg to cows. Normal plasma levels of P are 4 to 8 mg dl^{-1}. Phosphorus is often deficient in forages for cattle. Cattle grazing either forage in both yrs had serum P levels of 9 to 13 mg dl^{-1}, measured by ICP. Serum P values are within the range reported by Cochran (1988), who also measured minerals in steer serum by ICP.

Normal Ca serum concentrations in beef cattle are about 10 mg dl^{-1} (NRC, 1984). Steers grazing both N-fertilized fescue and fescue-alfalfa in yr 1 ended the grazing period with serum Ca levels which might have been slightly lower than desirable (less than 9 mg dl^{-1}). In yr 2, serum Ca levels at the end of the grazing period were 9.7 mg dl^{-1} for steers which grazed N-fertilized fescue and were 10.1 mg dl^{-1} for steers which grazed fescue-alfalfa. Since Ca is the most abundant mineral in the body, an adequate supply of Ca is essential for optimum growth and development, especially of young animals which are actively growing bone tissue.

Sulfur requirements for finishing cattle are not well-known, since research on S-requirements has been done mostly on dairy cattle and sheep; these animals require .2% and .18% to .26%, respectively (NRC, 1985; NRC, 1986). Based on these data, S in all forages except alfalfa was adequate in yr 1; in yr 2, all forages had more than adequate S for sheep and dairy cattle, and therefore for beef steers, which do not produce high-S products.

Stockpiling date affected mineral content of forages very little (Table 6). This was not expected considering Griffith's (1974) statement that younger plant parts usually have higher mineral content than older ones. Only Cu for N-fertilized fescue was higher ($P<0.05$),

Table 6. Influence of stockpiling date on mineral concentrations in stockpiled N-fertilized tall fescue, tall fescue grown with alfalfa, and alfalfa sampled at initiation of grazing of stockpiled forages on 1 Nov. 1992.

Forage	Date	Mineral					
		P	Ca	Mg	S	Cu	Fe
		g 100g^{-1}				ppm	
Conventional	Aug. 1						
N-fertilized fescue		0.20	0.30‡	0.28	0.20§	4‡	65
Alternative							
Fescue		0.22	0.29	0.26	0.23	3§	71§
Alfalfa		0.16†§	0.98†	0.21†	0.20	5†§	303
SE		0.01	0.01	0.02	0.01	0.3	119
Conventional	Sept. 1						
N-fertilized fescue		0.24	0.37	0.36	0.25	5	62‡
Alternative							
Fescue		0.25	0.31	0.27	0.22	4	93
Alfalfa		0.21	1.40†	0.30	0.25	6†	79
SE		0.01	0.09	0.05	0.01	0.4	7

† Alfalfa differs from the mean of fescue ($P<0.05$).
‡ N-fertilized fescue differs from fescue-alfalfa ($P<0.05$).
§ Means differ between stockpiling dates ($P<0.05$).

although P and Mg tended to be higher ($P<0.10$) for September-stockpiling as opposed to August-stockpiling. Copper was higher ($P<0.05$) and Ca tended to be higher ($P<0.15$) in fescue grown with alfalfa stockpiled in September rather than August. Phosphorus was higher ($P<0.05$) and Ca, S, and Cu tended to be higher ($P<0.25$) in alfalfa stockpiled in September than alfalfa stockpiled in August.

Possibly under good growing conditions, such as characterized the stockpiling period of yr 2, plants did not deteriorate with age and retained minerals. Plants may also have continued to grow actively throughout the entire stockpiling period; thus young parts, high in minerals, were sampled in yr 2.

Yield. Forage mass of N-fertilized fescue and fescue-alfalfa at initiation of grazing of stockpiled forages is presented in Table 7. Estimated forage mass of forages stockpiled at different times is presented in Table 8. Fescue-alfalfa stockpiled in August had less ($P<0.05$) forage mass than fescue-alfalfa stockpiled in September, possibly due to decomposition due to maturity of alfalfa in the mix. Fescue-alfalfa stockpiled in September had more ($P<0.05$) forage mass than N-fertilized fescue stockpiled in September, possibly due to the influence of alfalfa. Nitrogen-fertilized fescue stockpiled in September had less ($P<0.05$) forage mass than N-fertilized fescue stockpiled in August, and also less than fescue-alfalfa stockpiled at either date. Nitrogen-fertilized fescue stockpiled in September did not have time to accumulate as much yield as August stockpiled fescue and lacked a legume to compensate for loss in yield. In conclusion, N-fertilized fescue should be stockpiled in August and fescue-alfalfa stockpiled in September for best yield and quality.

Table 7. Forage mass at initiation of grazing of stockpiled N-fertilized tall fescue and mixed tall fescue-alfalfa for 2 years.

Forage	Date	Forage mass[§]
		kg ha^{-1}
N-fertilized fescue	11-25-91[†]	1400
Fescue-alfalfa		1100
N-fertilized fescue	11-1-92[‡]	4500
Fescue-alfalfa		4700

[†] Forage mass sampled by Gravely yield strips.
[‡] Forage mass sampled by quadrats.
[§] Forage mass does not differ between systems at either date.

Table 8. Forage mass of N-fertilized tall fescue and mixed tall fescue-alfalfa stockpiled beginning 1 Aug. or 1 Sept. and sampled at initiation of grazing of stockpiled forages, 1 Nov. 1992.

Forage	Stockpiling date	Forage mass†‡
		kg ha^{-1}
N-fertilized fescue	Aug. 1	4500
Fescue-alfalfa		3700
N-fertilized fescue	Sept. 1	3000
Fescue-alfalfa		4700

† N-fertilized fescue differs from fescue-alfalfa at both stockpiling dates ($P<0.05$).
‡ Forages differ between stockpiling dates ($P<0.05$).

Summary

August-stockpiled N-fertilized fescue and September-stockpiled fescue-alfalfa produced acceptable animal performance both years. Fescue-alfalfa produced superior animal performance when adequate water was available for forage growth. Phosphorus, Cu, and Ca may have been low for animal requirements in yr 1 for both types of forage, but in yr 2, mineral content of N-fertilized fescue and fescue-alfalfa was adequate for animal requirements in yr 2, except that Cu was marginal for animal production. Iron was higher in yr 1 forages because of the dry season. September-stockpiled N-fertilized fescue was lower-yielding than August-stockpiled N-fertilized fescue; September-stockpiled fescue-alfalfa was higher yielding than August-stockpiled fescue-alfalfa, possibly due to influence of alfalfa, which disappeared from August-stockpiled fescue-alfalfa. Forage quality of N-fertilized fescue was higher, as measured by CP and fiber analysis when it was stockpiled in September, but fescue grown with alfalfa did not change in quality between stockpiling dates, except for a trend towards higher quality from the September stockpiling date. Stockpiling N-fertilized fescue in August and fescue-alfalfa in September appears to be of most benefit to each forage and to animals.

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Chapter 4

Seasonal Management of N-Fertilized Tall Fescue and and Tall Fescue and Alfalfa Grown in Combination: Grazing vs Mechanical Harvest

Abstract

Tall fescue and alfalfa are two important forages in the southeastern United States, but they are not often grown in combination; little is known about the most effective management of this forage mix. 'Kentucky 31' endophyte-free tall fescue fertilized with 160 kg ha^{-1} N and similar fescue grown with 'Cimarron' alfalfa were grown in a complete randomized block design with four field replications. This study investigated effects of mechanical harvest vs intermittent grazing plus mechanical harvest on yield, stand persistence, and forage quality of mixed tall fescue-alfalfa and N-fertilized tall fescue during the summer of 1992. Both forage types were stockpiled in autumn 1991. Grazing was initiated in both forage types on 25 Nov. 1991. Nitrogen-fertilized fescue was grazed continuously until 4 Aug. 1992, when stockpiling was initiated. Steers grazing stockpiled fescue-alfalfa left pastures in Feb. 1992. Hay harvests were taken three times during summer

1992, and steers grazed part of fescue-alfalfa pastures in July. Stockpiling was initiated in Sept. 1992. Grazing of stockpiled forages for yr 2 began 1 Nov. 1992. Steers again remained on N-fescue pastures until stockpiling was initiated in August 1993. Steers left fescue-alfalfa pastures on 17 Feb. 1993. One hay harvest was taken from fescue-alfalfa pastures on 17 May 1993. Steers returned to fescue-alfalfa pastures and were rotationally stocked beginning 20 June 1993, and continued until stockpiling was initiated in September 1993. Small exclosures were placed in each pasture to investigate effects of mechanical harvest. Steers were not allowed access to forage in these plots. Forage was harvested with a Gravely when fescue-alfalfa reached hay-cut stage. Samples were obtained when exclosures were harvested.

Nitrogen-fertilized fescue had higher ($P<0.05$) total forage mass than fescue-alfalfa when harvest method was grazing. Fescue-alfalfa had higher ($P<0.05$) total forage mass than N-fertilized fescue when harvest method was total mechanical harvest. Nitrogen-fertilized fescue yielded more ($P<0.05$) under total mechanical harvest than under continuous grazing; fescue-alfalfa did not differ between harvest treatments. Nitrogen-fertilized fescue was taller ($P<0.05$) under total mechanical harvest than grazing. Fescue grown with alfalfa was taller ($P<0.05$) at some dates under total mechanical harvest than when harvest included intermittent grazing. Grazing treatment did not affect fiber composition of forages, but generally mineral content was slightly higher in ungrazed forages than in grazed forages. Soil fertility, averaged over forage type, was not affected by harvest treatment except that P and K were higher ($P<0.05$) in ungrazed treatments. Soil bulk density was higher ($P<0.05$) in grazed areas than in ungrazed areas. Botanical composition of N-fescue did not differ between grazing treatments or change over time; pastures and small plots remained virtually 100% grass. Composition of fescue-alfalfa pastures was affected by grazing treatment, but results were not consistent over replications. Fescue tended to disappear from ungrazed plots, especially when water was limiting. Harvesting at least partially by grazing seemed to be beneficial to yield and botanical composition of fescue-alfalfa pastures.

Introduction

Tall fescue (*Festuca arundinacea* Schreb.) and alfalfa (*Medicago sativa* L.) are two important forages in the southeastern United States, although tall fescue ranges north into Canada and west into the Great Plains (Buckner, 1985), while alfalfa is grown in every state of the contiguous United States (Barnes and Sheaffer, 1985). Mixing tall fescue with legumes is a common practice, with many benefits, including reduced need for N-fertilization (Allen et al., 1992), which is of concern in the movement toward more sustainable agricultural systems, higher-quality forage (Hamilton et al., 1969; Matches, 1979; Allen et al., 1992), and extension of the grazing season (Johnson and Nichols, 1979). Using alfalfa as the legume is not common; often red clover (*Trifolium pratense* L.) or white clover (*Trifolium repens* L.) is used (Matches, 1979). The management of tall fescue grown in combination with a legume is usually more complicated than the management of tall fescue alone.

Tall fescue, when grown alone, may be either continuously or rotationally grazed (Buckner, 1985). Very close defoliation should be infrequent, but is tolerable, and results in high yields (Matches, 1979). Buckner (1985) recommended a management system which uses fescue for hay or for pasture in spring and early summer, with stockpiling initiated in midsummer. Management in Virginia follows this pattern except that stockpiling is generally begun in August (Brown et al., 1963; White, 1977; Bagley et al., 1983). The choice to graze fescue or to make hay must be made on an individual basis, since fescue will tolerate either management practice as long as timing of hay cuts and stocking rates are correct.

Mixing fescue with alfalfa can complicate management. Alfalfa will tolerate continuous grazing in early spring, when it is growing quickly (Allen et al., 1986); but in summer, alfalfa must be grazed rotationally and have adequate recovery time (Allen et al., 1986; Van Keuren and Matches, 1988). Timing of hay cuts in mixed fescue-alfalfa stands is important. Alfalfa survives best and produces highest yield when hay cuts are taken near to full bloom (Smith, 1986; Latheef et al., 1988). Usually hay cuts are taken at 0.10 bloom in Virginia, in order to obtain hay of acceptable quality as well as acceptable yield (Sheaffer et al., 1988). Best yields are obtained by leaving 7-cm to 10-cm stubble height, which is as close as most machines will cut (Barnes and Sheaffer, 1985).

If spring hay cutting is delayed until alfalfa nears full bloom, fescue will have already seeded. Cutting fescue at this stage will weaken the grass significantly and allow alfalfa to out-compete fescue (Matches, 1979). Burger et al. (1958) found that yields were highest and survivability of fescue acceptable when forage was cut three times per season. Grazing of fescue-alfalfa has not been well-investigated. Allen et al. (1992) grew fescue-alfalfa but did not graze this forage except as stockpiled winter forage. Absher (1989) found that fescue-alfalfa pastures were higher in percent legume than fescue-red clover pastures.

The objectives of this study were to compare yield, survivability, and quality of tall fescue-alfalfa and N-fertilized tall fescue under management systems of either complete mechanical harvest or under mechanical harvest with intermittent grazing. Grazing and mechanical harvest can have very different effects upon soil fertility and bulk density. A further objective of this study was to compare soil fertility and bulk density under these two management alternatives.

Materials and methods

'Kentucky 31' endophyte-free tall fescue and tall fescue grown in mixture with 'Cimmarron' alfalfa were established in 1988 for use in a long-term grazing and farm systems research study at the Whitethorne-Kentland Virginia Agricultural Research Station in Montgomery County, Virginia, as described in Chapter 3. A complete randomized block design with four field replications was used. The present study took place from November 1991 to Sept. 1993. Fescue grown alone was fertilized in split application with 160 kg N ha^{-1} yr^{-1} and received P according to soil test recommendations. Fescue-alfalfa received no N-fertilization, but did receive 65 kg P ha^{-1} yr^{-1} and 140 kg K ha^{-1} yr^{-1}, according to soil test recommendations.

In each pasture, a small permanent exclosure, 2.5 m by 2.5 m, was built, using fence posts and regular non-electric fence (Fig. 1, Chapter 3). These plots were designed to exclude cattle entirely. Forage was harvested with a Gravely mower to a height of approximately 5 cm whenever the fescue-alfalfa reached hay cut stage, which was considered late bud for the first hay cut of spring, and thereafter, 0.10 bloom. Small plots were harvested in both treatments 23 Jan. 1992, 22 May 1992 and 14 July 1992. Additionally, to initiate stockpiling, N-fertilized fescue was harvested 4 Aug. 1992, and fescue-alfalfa on 29 Aug. 1992.

Grazing of stockpiled forages began on 25 Nov. 1991. Initiation of grazing was delayed due to a severe drought the preceding summer and autumn. Six Angus steers grazed each pasture replicate until 23 Dec. 1991, when hay-feeding began for fescue-alfalfa steers. Steers were removed from the fescue-alfalfa pastures 21 Feb. 1992, but remained on the N-fertilized fescue pastures through spring and summer, until 4 Aug., when stockpiling was initiated for the following year. Steers which had grazed fescue-alfalfa pastures grazed crop fields on another part of the project area. First hay harvest was taken from fescue-alfalfa pastures on 1 June 1992. Hay harvest was delayed from 22 May due to rain. On 8 July 1992, part of each fescue-alfalfa pasture was blocked off and steers were allowed to graze approximately .35 ha until 4 Aug. 1992. A second hay harvest was taken from the rest of these pastures on 20 July 1992. A third hay harvest occurred on the entire fescue-alfalfa pastures 29 Aug. 1992, in preparation for stockpiling.

Stockpiling continued for both types of pasture until 1 Nov. 1992, when a new group of steers began to graze. Hay-feeding began on fescue-alfalfa pastures on December 29, 1992. Steers were removed from fescue-alfalfa pastures on 17 Feb. 1993, while steers on N-fescue continued to graze through spring and summer, as in yr 1. First hay harvest was taken from fescue-alfalfa pastures on 17 May 1993. Steers returned to fescue-alfalfa pastures on 3 June 1993. They were rotationally stocked until 10 June, were removed until 14 June, and returned in a rotational stocking pattern until 1 Sept. Stockpiling began for fescue-alfalfa pastures on 1 Sept. 1993 (see Table 9).

At each sampling of small plots, five extended plant height measurements were taken from each small plot. Additionally, 10 measurements were taken randomly across each pasture. One .25 m^2 quadrat was clipped from within each small plot for yield and quality analysis. Three quadrats were taken randomly approximately 6 m away from each small plot. Samples were taken at a small distance from the exclosures in order to evaluate forage grown

Table 9. Calendar of events.

Date	Event
25 Nov. 1991	Grazing of stockpiled forages initiated
23 Dec. 1991	Hay feeding began for fescue-alfalfa cattle Small plots clipped
21 Feb. 1992	Fescue-alfalfa cattle moved out of pastures
22 May 1992	Forage samples taken from pastures
1 June 1992	First hay cut from fescue-alfalfa
6 July 1992	Forage samples taken from pastures
8 July 1992	Cattle grazed part of fescue-alfalfa pastures
20 July 1992	Hay cut from remainder of fescue-alfalfa pastures
4 Aug. 1992	Stockpiling initiated on N-fescue pastures Cattle removed from fescue-alfalfa pastures
29 Aug. 1992	Third hay cut from fescue-alfalfa pastures Stockpiling initiated on fescue-alfalfa pastures
1 Nov. 1992	Grazing of stockpiled forages initiated
29 Dec. 1992	Hay feeding began for fescue-alfalfa cattle Small plots clipped
17 Feb. 1993	Fescue-alfalfa cattle moved out of pastures
17 May 1993	Forage samples taken from pastures First hay cut from fescue-alfalfa
10 June 1993	Cattle grazed fescue-alfalfa pastures rotationally
11 Aug. 1993	Stockpiling initiated for N-fescue pastures
5 Sept. 1993	Stockpiling initiated for fescue-alfalfa pastures

on similar soil types and landscape position similar to that within the exclosures, but to ameliorate effects caused by cattle investigating the fence. Fescue and alfalfa were evaluated separately for yield and quality by hand-separating samples in the field. Visual evaluations across entire pastures and from each small plot were performed by three people, using the Double DAFOR technique (Abaye, 1991).

Sampling of small plots and pastures began 22 May 1992, when hay should have been harvested from fescue-alfalfa pastures. Sampling of both N-fescue and fescue-alfalfa occurred 6 July 1992. Sampling also occurred when grazing of stockpiled forages began, 1 Nov. 1992. In 1993, sampling and harvest occurred on 17 May, when the first hay harvest was taken from fescue-alfalfa pastures, and on 6 July. In preparation for stockpiling, N-fertilized fescue small plots were sampled on 4 Aug. 1993 and fescue-alfalfa small plots were sampled 8 Sept. 1993.

All forage samples were dried at 55°C, weighed to estimate yield, and ground in a stainless steel Wiley mill through a 1-mm mesh screen. Dry matter was determined by drying subsamples at 110°C. Yield was calculated on a DM basis. Samples from areas around exclosures were composited proportionately. Analysis of fiber concentrations (Goering and Van Soest, 1970) was performed on botanically separated samples taken from both inside and outside exclosures for 22 May 1992 and 1 Nov. 1992. These dates were chosen for analysis because they represent the two most critical operations of the season and would be expected to reflect effects of other operations over the season. Samples from inside exclosures for 17 May 1993 were lost in an oven fire.

Mineral analysis was performed on samples from 22 May 1992, 6 July 1992, and 1 Nov. 1992. Analysis was performed by wet-ashing forages with nitric and perchloric acids and analyzing the residue by inductively coupled plasma spectrophotometry (Muchovej, 1986).

Soil was sampled on 10 Feb. 1992 and 8 Mar. 1993, by taking three fertility cores inside exclosures and six cores outside exclosures (six m away from exclosures), to a depth of 10 cm. Bulk density was determined by the core method (Blake and Hartge, 1986) on March 8, 1993. Three bulk density samples were taken inside exclosures and five were taken outside, six m away from exclosures.

Data were analyzed as a complete randomized block (SAS, 1990) using a model that tested effects of forage, block, grazing, and all two- and three-way interactions. Forage and block were tested using their interaction as the error term. Since treatment effects at specific dates, rather than effects of date, were of interest, data were analyzed separately for each date. Differences among forage of chemical composition were further tested by orthogonal contrasts (SAS, 1990) to compare 1) alfalfa vs fescue and 2) N-fertilized fescue vs fescue grown with alfalfa.

Results and Discussion

Yield. Estimated forage mass of grazed and ungrazed portions of both N-fertilized fescue and fescue-alfalfa is presented in Fig. 2. Total seasonal forage yield of these forages under total mechanical harvest was: 12,913 kg ha^{-1} and 9,599 kg ha^{-1}, respectively. Total seasonal forage yield for the 1992 season of grazed plus mechanically harvested N-fertilized fescue and fescue-alfalfa was 8,829 kg ha^{-1} and 7,926 kg ha^{-1}, respectively.

On 22 May 1992, there was more ($P<0.05$) forage mass for mechanically-harvested N-fertilized fescue than for grazed N-fertilized fescue. Also, grazed fescue-alfalfa had more

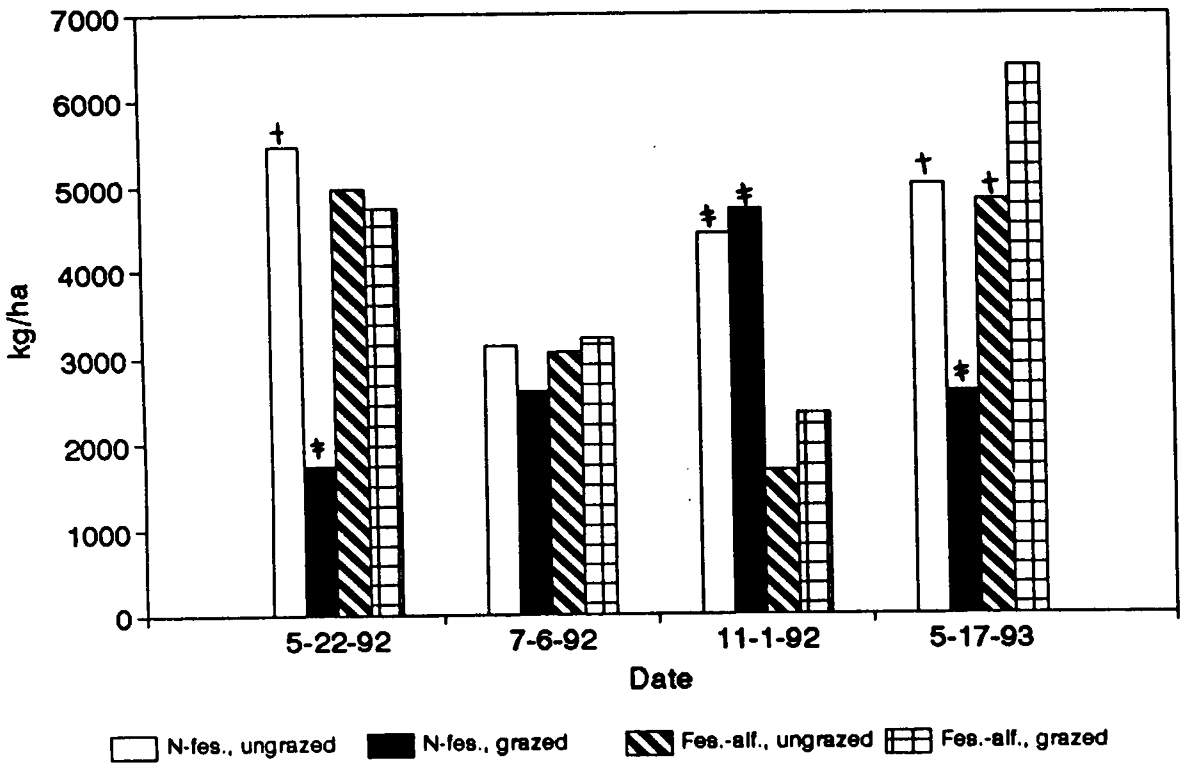

Figure 2. Forage yield of N-fertilized tall fescue and tall fescue-alfalfa, grazed or mechanically harvested.

† Yield differs between harvest methods for same forage.
‡ Yield differs between forages with same harvest method.

($P<0.05$) forage mass than grazed N-fertilized fescue. These results are expected because N-fertilized fescue was grazed continuously prior to sampling, while cattle had not grazed fescue-alfalfa since February. Mechanically harvested N-fertilized fescue had slightly more ($P<0.30$) forage mass than mechanically harvested fescue-alfalfa.

On 6 July 1992, forage mass was similar for both forage types and harvest treatments. Grazed N-fertilized fescue had slightly less ($P<0.15$) forage mass than grazed fescue-alfalfa, but continuous grazing of N-fertilized fescue prior to the sampling date was responsible for this effect. Fescue-alfalfa had not been grazed, but a hay cut had been taken on 20 June. By 1 Nov. 1992, N-fertilized fescue had more ($P<0.05$) forage mass than fescue-alfalfa for both harvest treatments because N-fertilized fescue had been accumulating since August, while fescue-alfalfa was accumulated beginning in September. Forage mass of N-fertilized fescue did not differ between prior harvest treatment, while fescue-alfalfa tended to have higher ($P<0.30$) forage mass under grazing compared to mechanical harvest.

On 17 May 1993, there was more ($P<0.05$) forage mass when N-fertilized fescue had not been previously grazed than when grazing had occurred. For fescue-alfalfa, there was more ($P<0.05$) forage mass when grazing did occur over winter, prior to sampling, than when no previous grazing occurred. Under grazing, N-fertilized fescue had less ($P<0.05$) forage mass than fescue-alfalfa, because N-fertilized fescue had been continuously grazed prior to the sampling date, as in May 1992. Forage mass was similar for ungrazed treatments of N-fertilized fescue and fescue-alfalfa.

Chamblee and Collins' (1988) review of literature reported that alfalfa-grass mixtures may or may not have higher yields than pure grass stands, and over several years, any increase in yield will be only 10 to 15%. They also report that alfalfa-grass mixtures will often have higher yields than pure alfalfa stands. Fescue-alfalfa stands take a year or two to become established, yielding very low in the first year (Templeton et al., 1965); the stands in this study were well established and should have been yielding to their fullest extent under good growing conditions.

Little research has been done on harvest techniques for fescue-alfalfa, especially comparing yields under different harvest regimes. In this study, samples were clipped at 5-cm heights, in grazed and mechanically harvested treatments, so differences in forage mass truly reflect previous effects of harvest method. Under mechanical harvest with intermittent grazing, fescue-alfalfa yielded more over 12 mo than N-fertilized fescue; but N-fertilized fescue yielded more over the same 12 mo than fescue-alfalfa when harvest was totally mechanical. This result was due to the continuous removal of forage by grazing of N-fertilized fescue, compared to only short periods of grazing for fescue-alfalfa

Differences in yields due to harvest regime were not great in fescue-alfalfa pastures, but in N-fertilized fescue pastures, differences were large because of continuous grazing. Harvest treatment for fescue-alfalfa seemed to have little effect upon yield at first, but grazed fescue-alfalfa yielded progressively more than ungrazed fescue-alfalfa as time passed. Effects of grazing fescue-alfalfa may not show in the first year; more years of research on these effects should clarify results.

Plant height. Plant heights of grazed and ungrazed forages are presented in Figures 3, 4, and 5. Grazed N-fertilized fescue was consistently shorter ($P<0.05$) than ungrazed N-fertilized fescue, except on 1 Nov. 1992, when no difference was measured (Fig. 3). Since N-fertilized fescue was continuously grazed from November to August, this result was expected. In August, both treatments were clipped. From August to November, fescue was

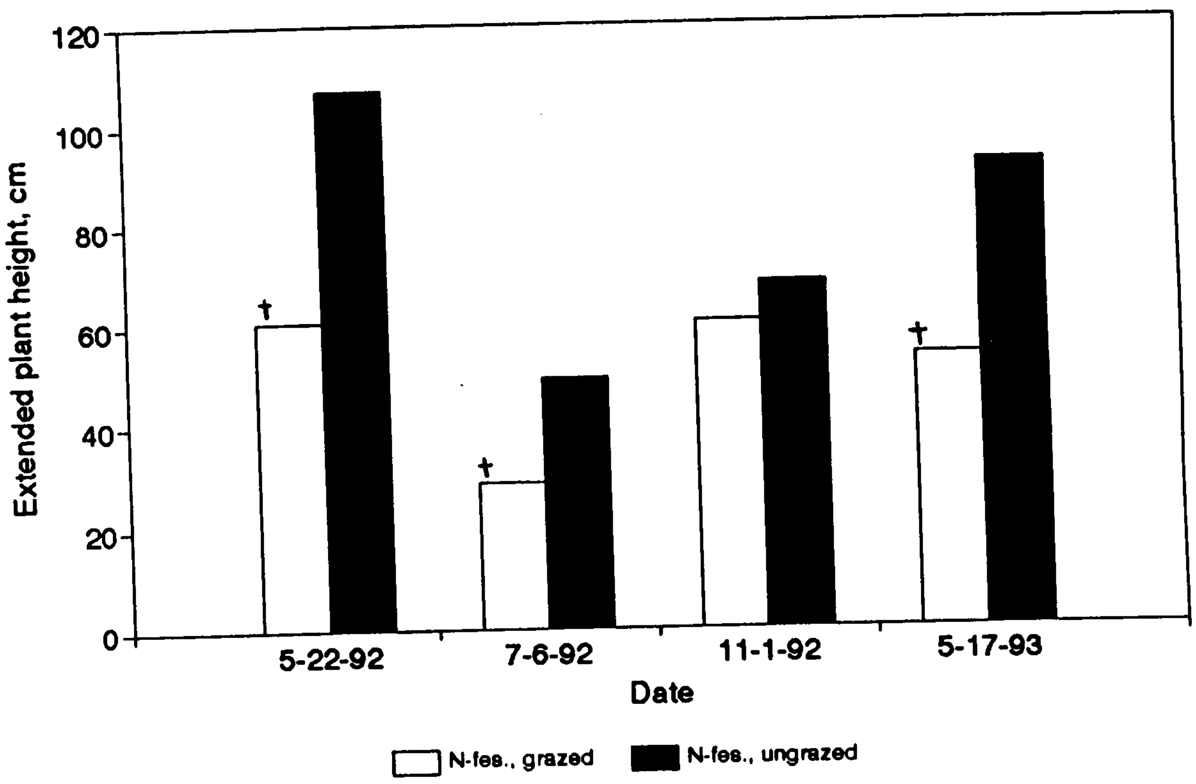

Figure 3. Extended plant height of N-fertilized tall fescue, grazed or mechanically harvested.

† Height of grazed forage differs from height of mechanically harvested forage ($P<0.05$).

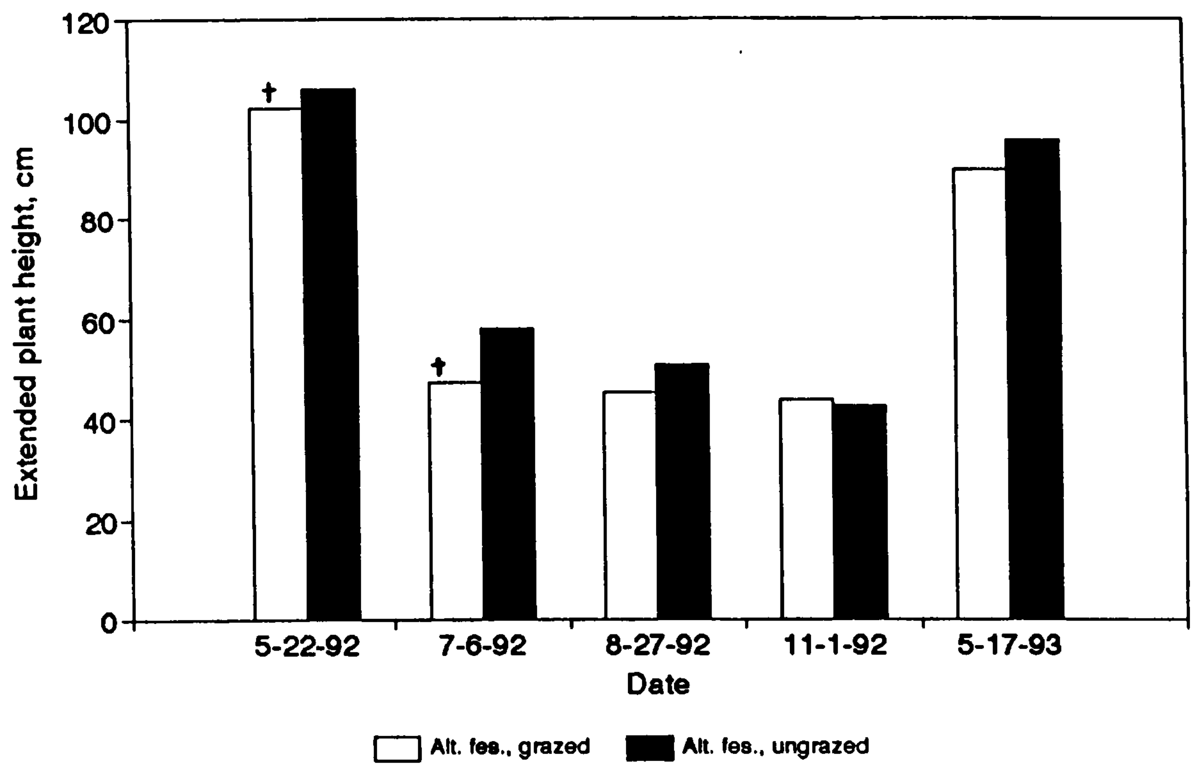

Figure 4. Extended plant height of tall fescue grown with alfalfa, grazed plus mechanically harvested or mechanically harvested.

† Height of grazed plus mechanically harvested forage differs from height of mechanically harvested forage (P<0.07).

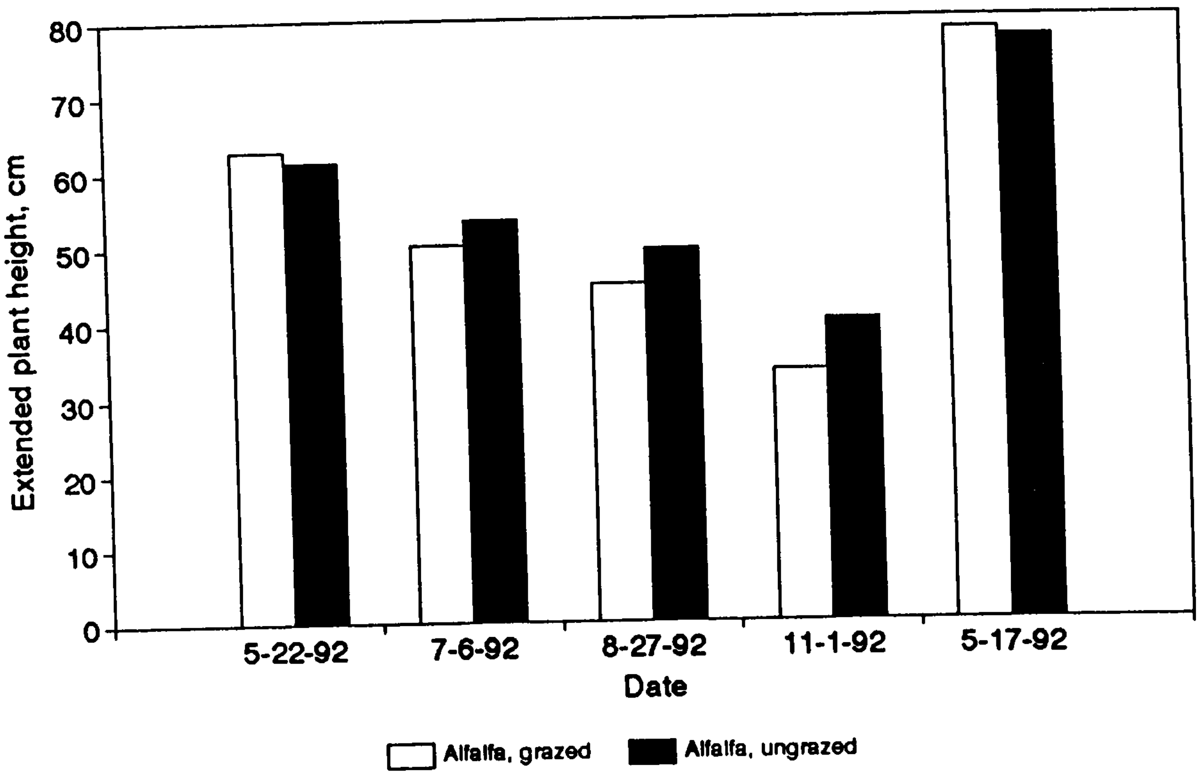

Figure 5. Extended plant height of alfalfa, grazed plus mechanically harvested or mechanically harvested.

allowed to grow undisturbed.

Ungrazed fescue grown with alfalfa was taller ($P<0.05$) than grazed fescue grown with alfalfa on 22 May 1992, and 6 July 1992 (Fig. 4). Winter grazing apparently reduced height of fescue grown with alfalfa even over the rest of the year, until stockpiling was complete for the next winter's grazing. Harvest treatment did not significantly affect height of alfalfa at any date (Fig. 5). All samplings were performed at hay harvest dates, except 1 Nov. 1992.

Botanical composition. Effects on botanical composition of pastures of grazing plus mechanical harvest vs total mechanical harvest, as observed by visual evaluation of forages on 22 May 1992 and 1 Nov. 1992, were more consistent over replications of N-fertilized fescue than fescue-alfalfa. Botanical composition of ungrazed plots was not different from grazed parts of N-fertilized fescue pastures. Pastures and small plots ranged from 90% to 100% fescue, with 0% to 10% weed or 0% to 10% legume. Replication 4 did change from May to November: in May, the small plot had 90% fescue and 5% weed, while the grazed pasture had 85% fescue and 15% weed. Major weeds in N-fertilized fescue pastures were Canada thistle (*Cirsium arvense*) and wild geranium (*Geranium maculatum*). In November, both treatments had virtually 100% grass. When pastures were originally seeded, replication 4 was not as weed-free as the other replications. Also, pastures nearby are heavily populated with thistle. During autumn, fescue was able to crowd out weeds because it grew quickly as summer weeds declined.

In fescue-alfalfa pastures, the effect of grazing on botanical composition was more pronounced, but not consistent over replication. From May to November in replication 2 small plot, fescue almost entirely disappeared in favor of alfalfa and chickweed (*Stellaria* *media*). In replication 3 small plot, orchardgrass invaded and alfalfa rose from 35% to 50%. Replications 1 and 4 remained constantly 45% to 50% grass and 45% to 50% alfalfa, in both grazed and ungrazed treatments, until September 1993, when fescue was only 30% to 40% of the forage, probably due to dry conditions during summer.

Burger et al. (1958) in Illinois found that legume percentage remained adequate in fescue-alfalfa pastures when pastures were harvested 3 times for hay. The shift of fescue-alfalfa plots to alfalfa under total mechanical harvest may have had an effect upon yield of small plots. Mechanically harvested fescue-alfalfa had lower yield than grazed fescue-alfalfa, and grazed areas maintained a more acceptable botanical composition of the pasture than total mechanical harvest did.

Very little weed was observed in fescue-alfalfa pastures, but of weeds present, horse nettle (*Solanum carolinense*) and wild mustard (*Brassica caber*) were dominant. Leach (1978) reports that botanical composition of alfalfa-grass mixtures often depends upon moisture: if moisture is limiting, alfalfa will have an advantage over grasses, particularly annuals. Perennial temperate grasses may compete better with alfalfa for moisture.

Selective grazing is a factor in the response of botanical composition to harvest. Steers were more likely to select fescue rather than alfalfa, especially in autumn, based on Forwood's (1989) observations on orchardgrass-alfalfa pastures. However, cattle do not shear forages as mechanical blades do, so they will leave leaf area behind, especially when forage is abundant and tall. Fescue regrows well from leaf area (Booysen and Nelson, 1975; Smith et al., 1986). Leach (1978) suggests that grazing pressure for mixed grass-alfalfa stands should be heavy enough that the grass and the alfalfa are both grazed, so that selective grazing does not remove one species.

In small plots, where fescue and alfalfa were mechanically harvested, alfalfa may have had an advantage, since alfalfa regrows primarily from stored TNC. The Gravely harvested forage at approximately 5 cm, which is shorter than most mowing machines will cut; this removes even more leaf area from fescue and gives the advantage to alfalfa in Gravely-harvested plots. Possibly in areas always harvested with hay-mowing machines, fescue would stay in the mix. Wolf et al. (1962) found that percentage grass rose in alfalfa-orchardgrass, alfalfa-timothy, and alfalfa-brome mixes as stubble height rose from 2.5 cm to 12.7 cm. Increasing stubble height in hay cuts does lower harvest yield.

Fiber concentration. Forage quality as influenced by grazing and mechanical harvest is presented in Tables 10 and11. On 22 May 1992 (Table 10), harvest method did not affect NDF or lignin. Cellulose and ADF tended to be higher ($P<0.20$) in mechanically harvested forages than in grazed forages. Averaged over harvest method, means of the forages differed. Alfalfa was lower ($P<0.05$) than the mean of the fescues in NDF and tended to be higher ($P<0.20$) in lignin, as expected (Van Soest, 1985). Fescue grown with alfalfa was higher ($P<0.05$) in ADF and cellulose than N-fertilized fescue. This effect may have occurred because, under continuous grazing, N-fertilized fescue was able to renew itself and maintain a physiologically less mature state than fescue grown with alfalfa, which was not continuously grazed.

On 1 Nov. 1992 (Table 11) previous harvest method also had little effect upon fiber concentrations. Cellulose and ADF tended to be higher ($P<0.10$) in ungrazed forages than in grazed forages. Averaged over harvest method, alfalfa was lower ($P<0.05$) in NDF, ADF, and cellulose than fescue, as expected. Alfalfa did not differ in lignin because N-fertilized fescue was high in lignin, being older than fescue-alfalfa. Fescue grown with alfalfa was

Table 10. Fiber concentrations of N-fertilized tall fescue and mixed tall fescue-alfalfa, mechanically harvested or grazed and mechanically harvested, sampled at first hay harvest.

Forage		Date	Fiber component			
			NDF†	ADF‡	Cellulose‡	Lignin
			g $100g^{-1}$			
Conventional		5-22-92				
N-fertilized fescue	Grazed		62.7	31.7	24.5	6.0
	Ungrazed		67.0	34.8	29.2	6.1
Alternative						
Fescue	Grazed		62.0	37.5	30.6	5.8
	Ungrazed		61.5	39.7	29.4	6.9
Alfalfa	Grazed		42.0	31.5	22.4	8.5
	Ungrazed		41.0	32.7	24.3	8.0
SE			2.1	2.2	0.9	0.8

† Averaged over harvest method, alfalfa differs from the mean of fescue ($P<0.05$).
‡ Averaged over harvest method, N-fertilized fescue differs from fescue grown with alfalfa ($P<0.05$).

Table 11. Fiber concentrations of N-fertilized tall fescue and mixed tall fescue-alfalfa, mechanically harvested or grazed and mechanically harvested, sampled at initiation of grazing of stockpiled forages.

Forage		Date	Fiber component			
			NDF†	ADF†‡	Cellulose†‡	Lignin
			g $100g^{-1}$			
Conventional		11-1-92				
N-fertilized fescue	Grazed		60.3	33.0	27.2	4.6
	Ungrazed		58.6	31.6	25.6	5.0
Alternative						
Fescue	Grazed		55.6	25.8	23.8	3.4
	Ungrazed		55.2	30.6	24.9	5.0
Alfalfa	Grazed		35.5	21.3	16.0	5.1
	Ungrazed		33.4	24.5	17.5	5.7
SE			3.1	1.5	0.9	0.5

† Averaged over harvest method, alfalfa differs from the mean of fescue ($P<0.05$).
‡ Averaged over harvest method, N-fertilized fescue differs from fescue grown with alfalfa ($P<0.05$).

lower in ADF and cellulose, and tended to be lower ($P<.20$) in lignin than N-fertilized fescue, due to difference in physiological maturity at sampling.

Mineral concentration. Harvest treatment seemed to affect mineral contents of the forages more than it affected fiber concentration. On 22 May 1992 (Table 12), P was higher ($P<0.05$) in ungrazed plots than in grazed pastures, averaged over forage. Other minerals did not differ between harvest method, averaged over forage. Sulfur and Fe had forage x grazing interactions ($P<0.05$). Sulfur concentration in N-fertilized fescue was higher in grazed treatments, but was not influenced by grazing in fescue grown with alfalfa or alfalfa. Iron concentration in N-fertilized fescue was numerically higher in grazed vs ungrazed treatments, but did not differ in fescue-alfalfa (forage x grazing interaction, $P<0.05$).

Averaged over grazing effect, alfalfa was higher ($P<0.05$) in Ca, Mg, and S than the mean of the fescues, an expected result since alfalfa is often higher in these minerals than grasses are (NRC, 1984). Averaged over grazing effect, N-fertilized fescue was lower ($P<0.05$) in P and higher ($P<0.05$) in S than fescue grown with alfalfa.

On 6 July 1992 (Table 13), only P and Ca differed ($P<0.05$) between harvest treatments: P was higher in grazed forages and Ca was higher in ungrazed forages. Iron strongly tended to be higher ($P<0.10$) in grazed forages and Mg tended to be higher ($P<0.20$) in ungrazed forages. Averaged over harvest treatment, alfalfa was higher ($P<0.05$) in Ca and lower ($P<0.05$) in S than the mean of the fescues. Averaged over harvest treatment, N-fertilized fescue was lower in P ($P<0.05$) than was fescue grown with alfalfa.

On 1 Nov. 1992 (Table 14), harvest treatment had the most effect upon mineral concentration. Averaged over forage, Ca, Mg, S, and Fe were higher ($P<0.05$) in ungrazed forages. Sulfur and Fe had forage x grazing interactions ($P<0.05$), since the magnitude in

Table 12. Mineral concentrations of N-fertilized tall fescue, tall fescue grown with alfalfa, and alfalfa, grazed and mechanically harvested or completely mechanically harvested, sampled at first hay harvest.

Forage		Date	Mineral					
			P†‡	Ca§	Mg§	S†¶	Cu§	Fe†¶
			g $100g^{-1}$				ppm	
Conventional		5-22-92						
N-fescue	Grazed		0.26	0.21	0.19	0.21	4.0	62
	Ungrazed		0.21	0.39	0.22	0.19	3.7	45
Alternative								
Fescue	Grazed		0.28	0.41	0.24	0.19	2.3	47
	Ungrazed		0.26	0.40	0.23	0.19	3.6	50
Alfalfa	Grazed		0.24	0.96	0.27	0.21	3.2	47
	Ungrazed		0.23	0.96	0.28	0.21	14.8	55
SE			0.01	0.08	0.02	0.01	4.6	4

† Averaged over grazing effect, N-fertilized fescue differs from fescue grown with alfalfa ($P<0.05$).
‡ Averaged over forage, grazed forages differ from ungrazed forages ($P<0.05$).
§ Averaged over grazing effect, alfalfa differs from the mean of fescue ($P<0.05$).
¶ Forage-by-grazing interaction ($P<0.05$).

Table 13. Mineral concentrations of N-fertilized tall fescue, tall fescue grown with alfalfa, and alfalfa, grazed and mechanically harvested or completely mechanically harvested, sampled at second hay harvest.

Forage		Date	Mineral					
			P†‡	Ca‡	Mg	S§	Cu	Fe
			g 100g^{-1}				ppm	
Conventional N-fescue	Grazed	7-6-92	0.26	0.25	0.22	0.22	5.0	246
	Ungrazed		0.22	0.38	0.28	0.27	5.3	65
Alternative Fescue	Grazed		0.32	0.33	0.30	0.26	5.0	98
	Ungrazed		0.28	0.34	0.32	0.27	5.3	47
Alfalfa	Grazed		0.30	0.65	0.29	0.24	4.9	76
	Ungrazed		0.20	0.91	0.28	0.20	4.6	47
SE			0.02	0.08	0.03	0.01	0.4	60

† Averaged over harvest method, N-fertilized fescue differs from fescue grown with alfalfa ($P<0.05$).
‡ Averaged over forage, grazed forages differ from ungrazed forages ($P<0.05$).
§ Averaged over harvest method, alfalfa differs from the mean of fescue ($P<0.05$).

Table 14. Mineral concentrations of N-fertilized tall fescue, tall fescue grown with alfalfa, and alfalfa, grazed and mechanically harvested or completely mechanically harvested, sampled at initiation of grazing of stockpiled forages.

Forage		Date	Mineral					
			P[†]	Ca[‡§]	Mg[‡§]	S[†§¶]	Cu[‡]	Fe[†§¶]
			g 100g^{-1}				ppm	
Conventional		11-1-92						
N-fescue	Grazed		0.20	0.30	0.28	0.20	4.3	65
	Ungrazed		0.20	0.35	0.32	0.33	5.5	76
Alternative								
Fescue	Grazed		0.25	0.31	0.27	0.22	3.9	92
	Ungrazed		0.26	0.45	0.39	0.30	4.7	194
Alfalfa	Grazed		0.21	1.43	0.32	0.25	5.5	72
	Ungrazed		0.21	1.80	0.49	0.26	5.5	101
SE			0.01	0.10	0.04	0.01	0.3	18

† Averaged over grazing effect, N-fertilized fescue differs from fescue grown with alfalfa ($P<0.05$).
‡ Averaged over grazing effect, alfalfa differs from the mean of fescue ($P<0.05$).
§ Averaged over forage, grazed forages differ from ungrazed forages ($P<0.05$).
¶ Forage-by-grazing interaction ($P<0.05$).

S concentration varied to grazing among forages. Alfalfa changed less between harvest methods than the fescues in S concentration. Nitrogen-fertilized fescue changed less between harvest methods than either alfalfa or fescue grown with alfalfa in Fe concentration. Unlike the previous harvest dates, P concentration was not influenced by the harvest method. Averaged over harvest treatment, alfalfa was higher in Ca, Mg, and Cu than the mean of the fescues ($P<0.05$); while fescue grown with alfalfa was higher in P than N-fertilized fescue ($P<0.05$) and lower in S ($P<0.05$). In general, ungrazed forages were higher in mineral concentration than forages where grazing had previously occurred.

Soil parameters. Differences in yield and mineral concentrations of forages between harvest treatments cannot be explained on the basis of soil fertility or bulk density. Soil bulk density and soil fertility results are presented in Tables 15 and 16. All pastures received fertilizer based on soil test recommendations, according to the needs of specific forages. Phosphorus was higher ($P<0.05$) in fescue-alfalfa pastures, because fescue-alfalfa pastures received more P-fertilizer than N-fertilized fescue pastures, although both were fertilized according to soil test recommendations; but P did not differ between harvest treatments. Potassium was not different between pastures, but was higher ($P<0.05$) in ungrazed plots. Fescue-alfalfa pastures received K-fertilizer while N-fertilized fescue pastures did not require K, based on soil tests. Possibly there was no difference in soil K between the pastures because plants will consume K readily, thus removing fertilizer K from the soil.

Potassium may have been different between grazed and ungrazed treatments because, when animals grazed, they removed potassium from the entire pasture and concentrated it in a smaller area. Scott (1973) estimated that, under grazing, K can be concentrated on no more than 17% of the pasture area. Soil samples were not taken close to manure, so

Table 15. Soil bulk density, soil organic matter, and plant macronutrients in N-fertilized tall fescue (conventional) pastures and in mixed tall fescue-alfalfa (alternative) pastures.

System	Bulk[‡§] density	Organic[†] matter	pH[†]	Mineral[†] P[¶]	K[§]	Ca	Mg
	$g\ cm^{-3}$	$g\ 100g^{-1}$		$kg\ ha^{-1}$			
Conventional							
Grazed	1.51	3.14	6.48	26.8	243.2	1434.1	392.0
Ungrazed	1.34	3.31	6.40	30.2	344.1	1684.2	470.4
Alternative							
Grazed	1.50	3.35	6.45	54.0	236.7	1767.7	445.3
Ungrazed	1.35	3.39	6.40	51.6	318.8	1670.2	413.8
SE	0.05	0.11	0.10	5.4	34.6	138.8	40.4

† Data averaged over 2 years.
‡ Data for 1 year only.
§ Averaged over system, grazed positions differ from ungrazed ($P<0.05$).
¶ Averaged over grazed and ungrazed positions, systems differ ($P<0.05$).

Table 16. Plant micronutrients in N-fertilized tall fescue (conventional) pastures and in mixed tall fescue-alfalfa (alternative) pastures.

	Mineral†					
System	Mn	Zn	Fe	Cu	B	Al
	kg ha^{-1}					
Conventional						
Grazed	76.0	3.4	17.0	0.3	0.9	404.3
Ungrazed	78.7	3.4	16.4	0.3	0.9	370.5
Alternative						
Grazed	73.0	3.7	15.4	0.3	0.9	447.7
Ungrazed	75.6	3.5	20.8	0.7	0.8	379.3
SE	4.2	0.2	2.1	0.3	0.1	25.0

† Data averaged over 2 years.

recycling of nutrients may not have been evident in sampling. Other minerals, organic matter, and pH did not differ between forage or grazing treatment.

Bulk density did not differ between N-fertilized fescue and fescue-alfalfa pastures, but was higher ($P<0.05$) in grazed areas than in ungrazed plots. Sods tend to be lower in bulk density than cultivated land (Brady, 1990), but grazing animals do compact soil as they walk, especially in wet weather (Watkin and Clements, 1978). Bulk density was not excessively high in grazed areas: normal bulk density for mineral soils ranges from 1.0 to 1.6 g cm^{-3}.

Cattle did tend to gather about the permanent plots, in some places completely stamping out grass from rings around plots, so samples needed to be taken far enough away that the effect of this gathering would not confound results. It is possible that a truer measure of bulk density in grazed pastures could have been obtained if sampling was farther away from permanent exclosures so that cattle would be less likely to cross the sampling range, but samples were taken at 6 m away from permanent exclosures in an attempt to remain on like soil types and like landscape positions for grazed and ungrazed treatments. Visual observations, though, did not indicate that sample areas did not represent the entire pastures.

Summary

Harvest by mechanical means, as opposed to grazing, appears to be of benefit to yield of N-fertilized fescue, but this effect was due to continuous grazing of N-fertilized fescue during the sampling period. Grazing vs mechanical harvest did not cause yield losses in fescue-alfalfa; fescue-alfalfa yielded only slightly less under mechanical harvest with intermittent grazing than under total mechanical harvest. Botanical composition of N-fertilized fescue stands was not affected by harvest method; stands remained virtually 100% fescue. Fescue-alfalfa plots under total mechanical harvest tended to lose fescue, shifting to alfalfa, and in one replication, alfalfa and chickweed. Grazing had little effect upon forage quality and mineral composition, compared to total mechanical harvest, for either forage type. Grazing did not affect percentage alfalfa in fescue-alfalfa stands detrimentally. Grazing had no effect upon soil fertility, but bulk density was higher in grazed areas than in mechanically harvested areas of both N-fertilized fescue and fescue-alfalfa. Bulk density in grazed areas was not excessively high, but was higher in grazed areas than ungrazed areas for both forages. Growers of fescue-alfalfa may choose whether to graze or to harvest hay, depending upon the needs of their systems and other factors, such as weather and expense of mechanical harvest.

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Chapter 5

Rate and Extent of Mineral and Dry Matter Disappearance of N-Fertilized Tall Fescue, Tall Fescue Grown in Combination with Alfalfa, and Alfalfa, by the Dacron Bag Method.

Abstract

Rate and extent of mineral release in the rumen of P, Ca, Mg, S, Cu, and Fe from stockpiled N-fertilized tall fescue (*Festuca arundinacea* Scheb.), fescue grown with alfalfa (*Medicago sativa* L.), and alfalfa was determined by the dacron bag technique. Bags containing 2.1 g of sample were placed in the rumen of a 5-yr old Angus steer for 0 h, 24 h, and 72 h. Samples were dried and weighed to determine DM digestibility. Remaining forage was wet-ashed with nitric and perchloric acid for mineral analysis by inductively-coupled plasma spectrophotometry. Alfalfa was highest ($P<0.05$) in DM digestibility of the forages, at all time increments, followed by fescue grown with alfalfa. At time 0, all minerals except Ca were released from all forages to at least 75%. Alfalfa released less minerals than the fescues at time 0, but at time 24 and 72, alfalfa released all minerals except Cu to a greater extent than fescues. At all times, fescue grown with alfalfa and alfalfa released S to a greater extent than N-fertilized fescue, especially at 24 h. This occurrence has importance for

producers in areas where S may be limiting for optimum animal performance.

Introduction

Sulfur is an essential nutrient for both plants and animals; it is a component of proteins of all types, cofactors, and vitamins. Sulfur is necessary for N-utilization and can have a beneficial effect upon intake and digestibility of feed (Rendig, 1986; Momont et al., 1993) and N-utilization (Starks et al., 1954; Bull and Vandersall, 1973; Kahlon et al., 1975; Buttrey et al., 1985; Qi et al., 1992; Momont et al., 1993). The recommended amount of S for animal diets is an N:S ratio of 10:1 (NRC, 1980; NRC, 1984; NRC, 1985). Ruminants are often supplemented with inexpensive inorganic forms of S, since rumen microbes have the ability to synthesize organic compounds from inorganic S, but non-ruminants require organic forms of S (NRC, 1980). Researchers have found that organic forms of S, such as those found in plants, are more biologically available even to ruminants, and that using plants with adequate S concentrations for animal needs improves productivity over animals which were fed inorganic supplements (Starks et al., 1954; Kahlon et al., 1975; Buttrey et al., 1987).

Sulfur is often limiting for optimum plant production, and therefore optimum animal production in Virginia (Reneau, 1982). Maximum utilization of S which is present is important. Tall fescue is an important forage in Virginia, but its S content, while high compared to other Virginia forages such as orchardgrass (Barney et al., 1984), may be less biologically available than desirable (Glenn et al., 1981). Alfalfa is another important forage, whose S content is even higher than that of tall fescue (Barney et al., 1984).

Alfalfa and tall fescue are not commonly grown together in Virginia, but recent evidence suggests that animals grazing stockpiled mixed tall fescue and alfalfa perform better than animals grazing stockpiled tall fescue fertilized with N and grown alone (Allen et al., 1992), possibly because S in alfalfa is more available than in tall fescue. Also, the possibility exists that fescue grown with alfalfa has more available S than fescue fertilized with N, since current management practices include stockpiling fescue-alfalfa beginning in September, rather than in August, which is the case for N-fertilized fescue. Sulfur tends to decrease in concentration in forage as they age, so younger fescue may have a higher concentration of S than older fescue (Fleming, 1963). The objective of the present study was to determine ruminal availability of S and other minerals from tall fescue fertilized with N, tall fescue grown with alfalfa, and the alfalfa alone.

Materials and Methods

'Kentucky 31' endophyte-free tall fescue, and similar fescue grown in mixture with 'Cimmaron' alfalfa, established in 1989 for use in a long-term farm systems research study as described in Chapter 3, were used in the present study. The study was a complete randomized block design with four field replications. The studies in Chapter 3 were over the 1991-1992 and 1992-1993 stockpiling seasons; the present study deals only with samples collected from pastures at initiation of grazing of stockpiled forages in the 1992-1993 season, when rainfall was adequate for plant growth. Forages were stockpiled as described in Chapter 3. Forage samples were taken on 1 Nov. 1992. Samples were collected by criss-crossing pastures and clipping forage every 20 paces. Tall fescue and alfalfa were collected separately from mixed pastures. Samples were dried at 55°C, then ground in a stainless steel

Wiley mill to pass though a 1-mm sieve. Samples were previously analyzed (Chapter 3) for fiber concentration (Goering and Van Soest, 1970), crude protein (CP) concentration, and mineral concentrations (Muchovej, 1986).

Dacron bags (5 cm by 10 cm, 53 um pore size, pre-sealed on 3 sides, Ankom Company, Fairport, NY) were used for the study. Following the procedure of Emanuele and Staples (1990, 1991), 2.1 g of forage sample were placed into the bags, so that the ratio of forage mass to bag surface area was 21 g 100 cm^{2-1}. Bags were marked with a blue Sharpie marker. The open end of each bag was folded down twice, sewed shut with 2.7-kg test nylon fishing line on a sewing machine, and sealed with rubber cement. Bags were weighed after the cement had dried for at least 24 h, to obtain a tare weight. Bags were attached to doubled lines of 13.6-kg test nylon fishing line by placing knots at intervals in the lines, then tying bags by their sewed ends to knots with 11.4-kg fishing line. At the end of each line, a dacron bag full of clear glass marbles was attached as weight. Six sample bags were randomly placed on each line, with a sample of alfalfa standard always attached closest to the weight.

A 5-yr old, 570-kg Angus steer, ruminally fistulated, was used for the study. The steer was fed 11.4 kg alfalfa hay daily, at 2000 h, and had ad lib access to water at all times. Samples of N-fertilized fescue, fescue grown with alfalfa, and alfalfa were placed into dacron bags. Samples were placed in the rumen at 0800 h. Approximately 30 cm of line was left free of samples. Ten cm of free line was drawn though a small hole in the cannula top. The line was tied to a washer which remained outside the cannula at all times. Bags were placed in the rumen for 72, 24, or 0 h, with 72 h treatments placed in the rumen first. Twenty-four h bags were placed in the rumen 48 h later. Zero-h bags were not placed in the rumen.

There were four field replications of each forage for each incubation time. A maximum of 32 bags, including four field replications of each of the three forages for each time increment, two alfalfa standards for each time increment, and four weight bags were present in the rumen at once.

All bags were removed at 0800 h when 72 h had elapsed from the time the first bags were placed in the rumen. Bags were immediately placed into deionized ice water for 15 min. Zero-hour bags never entered the rumen and were placed into a separate ice-bath. Bags were rinsed with deionized water until rinse water ran nearly clear, or for at least 25 min. Bags were clipped from their lines, dried at 55°C and weighed after cooling in a dessicator to determine dry matter disappearance (Monson et al., 1969).

After weighing, bags were clipped open to access forage. For mineral analysis, 0.2 g of forage were used from each bag. Some bags did not contain 0.2 g forage; all material left in these bags was used. Forage samples were wet-ashed with 2 ml nitric and 1 ml perchloric acid (Muchovej, 1986). Residue was diluted to 25 ml with deionized water, then analyzed for mineral concentration by inductively coupled plasma spectrophotometry. Samples less than .2 g were diluted to 25 ml as well, but calculations took sample weight into account. Mineral release from forages was calculated as a percentage of the initial mineral concentration in the forages.

Two trials were conducted. Each trial included samples of each forage from each field replication for all digestion times. If more than 5% variability in digestibility among field replicate samples occurred, these samples were re-run in a third trial. Data were analyzed as a randomized complete block design (SAS, 1990) using a model that tested effects of forage, trial, field block, and their interactions. Since no interaction was present between trial and forage, trial was dropped from the model. Forage and block were tested using the residual error term. Differences among forages were further tested by orthogonal contrasts (SAS, 1990) to compare 1) alfalfa vs fescue, and 2) N-fertilized fescue vs fescue grown with alfalfa.

Results and discussion

Initial forage quality as measured by fiber and CP concentrations of all thee forages - N-fertilized fescue, fescue grown with alfalfa, and alfalfa - was high (Table 3, Chapter 3), as expected from stockpiled fescue and alfalfa (Bagley et al., 1983; Sheehan et al., 1985). Fescue grown with alfalfa was of higher quality than N-fertilized fescue, and alfalfa had highest quality of all. Initiation of stockpiling of fescue-alfalfa did not occur until the beginning of September, while N-fertilized fescue was stockpiled at the beginning of August. Tall fescue stockpiled later in the season is expected to be of higher forage quality than fescue stockpiled earlier, all else being equal (Rayburn et al., 1980). Alfalfa is expected to be of higher forage quality than tall fescue of similar age (Van Soest, 1985).

Based on initial analysis after digestion with nitric and perchloric acids, all forages appeared adequate in Ca, Mg, and S to meet requirements of growing steers (NRC, 1984). See Table 6, Chapter 3, for date 11-1-92. Copper was lower than desirable. National Research Council (1984) recommends that dietary Cu be 4 to 6 ppm for beef steers; in the forages in this study, Cu was only 3 to 5 ppm. Iron may have been lower than desirable, since NRC (1984) recommends 100 ppm Fe for growing steers and the forage in this study were lower than that. Plants do not take up Fe well in cool, wet weather (Tisdale, 1985), which characterized the 1992 stockpiling season. Alfalfa was lower ($P<0.05$) than the fescues in P, higher ($P<0.05$) in Ca, Mg, and Cu, but did not differ significantly in S or Fe, though it tended to be higher ($P<0.10$) than the fescues in these minerals. Fescue grown with alfalfa tended to be higher ($P<0.20$) in S and Fe than N-fertilized fescue but did not differ in other minerals.

Table 17 presents digestibility and release of minerals from forages over the thee incubation periods. During incubation in the rumen, alfalfa was more ($P<0.05$) digestible than either grass, at all times. At 0 h, fescue grown with alfalfa was significantly higher ($P<0.05$) in digestibility than N-fertilized fescue. By 24 h, this difference had disappeared. At 72 h, however, N-fertilized fescue was slightly more ($P<0.10$) digestible than fescue grown with alfalfa. Brown et al. (1963) found that age at time of harvest did not necessarily decrease total digestibility of stockpiled tall fescue. However, in this study, initial rate of digestion was faster for fescue grown with alfalfa, indicating that nutrients were more readily available from the less-mature fescue. Absher (1989) found that fescue-alfalfa stockpiled in September was higher in dry matter digestibility than fescue grown with red clover or fertilized with N, stockpiled in mid-August.

At 0 h, alfalfa released only Ca to a greater ($P<0.05$) extent than the fescues. Alfalfa released P, S, Cu, and Fe to a lesser ($P<0.05$) extent than the fescues, while the release of Mg did not differ from the fescues. Fescue grown with alfalfa released Ca, Mg, S, and Fe to a greater ($P<0.05$) extent than did N-fertilized fescue. Release of Cu did not differ at all between the fescues at 0 h. Release of Cu was virtually 100% for all thee forages.

The extent of mineral release at 0 h seems very high, considering water was the only

Table 17. Mineral release in the rumen as % initial mineral concentration in N-fertilized tall fescue, tall fescue grown with alfalfa, and alfalfa, for 3 time increments in the rumen.

			Mineral					
Forage	Time	DMD[†‡]	P[†‡]	Ca[†‡]	Mg[†‡]	S[†‡]	Cu[†‡]	Fe[†‡]
	h	g $100g^{-1}$						
Conventional N-fescue	0	41.0[§]	85.5	56.4[¶]	83.3[§]	77.2[§]	99.8	99.7[§]
Alternative Fescue		48.2	86.9	67.2	87.1	81.2	99.8	99.8
Alfalfa		54.3[¶]	82.3[¶]	71.0[¶]	85.0	73.5[¶]	99.6[¶]	99.6[¶]
SE		1.4	1.0	1.4	0.6	0.8	0.01	0.01
Conventional N-fescue	24	64.2	95.0	81.8[#]	95.2[#]	85.1[#]	100	99.8[#]
Alternative Fescue		67.3	96.5	85.3	96.2	88.3	100	99.9
Alfalfa		87.9[¶]	98.6[¶]	92.0[¶]	98.4[¶]	94.0[¶]	100	100[¶]
SE		2.1	0.9	1.2	0.4	1.1	0.01	0.1
Conventional N-fescue	72	83.5	96.3	90.4	97.6	90.7	100	83.5[§]
Alternative Fescue		83.3	97.2	92.8	98.4	93.1	100	83.3
Alfalfa		91.3[¶]	99.0[¶]	93.9	99.0[¶]	95.7[¶]	100	91.3[¶]
SE		1.4	0.6	1.3	0.3	0.9	0.01	0.03

† Means differ due to length of time in rumen ($P<0.05$).
‡ Forage-by-time interaction ($P<0.05$).
§ N-fertilized fescue differs from fescue grown with alfalfa ($P<0.05$).
¶ Alfalfa differs from the mean of fescue ($P<0.05$).
# N-fertilized fescue tends to differ from fescue grown with alfalfa ($P<0.07$).

solute was used. Emanuele and Staples (1990) found that 46.7% Ca, 75.9% P, 71.8% Mg, and 88.9% Cu were released from alfalfa at 0 h; the difference between the value reported in this study and in theirs could be due to the differences in maturity, cultivar, season of harvest, or other factors, of the alfalfa used. Another possible source of discrepancy between the studies is the technique used for mineral analysis, since Emanuele and Staples digested forage in HCl and used atomic absorption spectrophotometry and this study used nitric-perchloric acid digestion and inductively coupled plasma spectrophotometry.

At 24 h, alfalfa released all minerals except Cu to a greater ($P<0.05$) extent than the fescues. Copper was 100% released from all forages at 24 h, but since Cu was not high enough to meet animal requirements in the initial sample, the fact that it is readily available does not mean that animals will receive enough Cu from any of these forages. Fescue grown with alfalfa released Ca, Mg, S, and Fe to a greater ($P<0.07$) extent than did N-fertilized fescue. Fescue grown with alfalfa tended to release slightly more ($P<0.25$) P than N-fertilized fescue. All minerals were released from all forages to a greater extent than they had been at 0 h.

At 72 h, all minerals except Fe were released from all forages to a greater extent than at 24 h. Iron was released less than 85% from the two fescues, and 91.3% from alfalfa, but all other minerals were released to at least 90% from all forages. Alfalfa released P, Mg, S, and Fe to a greater ($P<0.05$) extent than the fescues. Calcium tended to be released to a slightly greater ($P<.20$) extent. Fescue grown with alfalfa tended to release Ca Mg, and S to a greater ($P<0.25$) extent than did N-fertilized fescue. Iron was released to a greater ($P<0.05$) extent from N-fertilized fescue than from fescue grown with alfalfa. Phosphorus and Cu release did not differ between the fescues.

Compared to values obtained by Emanuele and Staples for alfalfa, alfalfa in this study released minerals more completely, but some of the difference could be due to particle size and analysis technique, as well as to differences in alfalfa digestibility and quality. Emanuele and Staples' (1990) worked with flowering alfalfa, which was higher in NDF, and lower in CP and digestibility than the vegetative alfalfa used in this study. They also ground alfalfa to pass though a 2-mm screen, while the alfalfa in this study was ground for a 1-mm screen. They suggest that more digestible, higher quality forages will release minerals to a greater extent and rate than less digestible ones; the alfalfa used in this study did release minerals more quickly and completely than the alfalfa in their study.

At 72 h, Emanuele and Staples found that release of minerals was as follows: Ca, 59.3%; P, 85.1%; Mg, 95.2%; and Cu, 92.9%. In the present study, Ca and P were more completely released than observed by Emanuele and Staples. Calcium is associated with cell wall; in older alfalfa, when more cell wall is present, Ca may not be released as completely as in younger alfalfa, if the Ca concentration in the alfalfa is the same.

Except at 0 h, alfalfa in this study released minerals at a faster rate, and to a greater extent, than either type of fescue. Alfalfa was more digestible than the fescues. Fescue grown with alfalfa was more digestible than N-fertilized fescue, and it released minerals to a greater rate and extent than N-fertilized fescue. These results concur with Emanuele and Staples' suggestion that more digestible forage can release minerals better than less digestible ones.

Legumes, specifically alfalfa, and legume-grass mixtures can improve animal performance over grass alone. Animals may use metabolizable energy in some legumes more efficiently than they use the energy in grasses for fattening due to higher crude protein in legumes and higher proportions of propionic acid in the rumen when legumes are consumed (Joyce and Newth, 1987; Rattray and Joyce, 1969; Thomson, 1978; Minson, 1990). Intake is higher for alfalfa than for grass of comparable maturity, since alfalfa has less NDF than grasses (Ulyatt, 1981; Van Soest, 1985). Alfalfa is often more digestible than grasses (Thomson, 1978), as is shown in this study and in Emanuele and Staples (1990), which means that alfalfa will proceed more quickly though the rumen and release its nutrient to the animal quickly. Furthermore, alfalfa has higher mineral content than fescue, especially in Ca and Mg (Barnes and Sheaffer, 1985). Alfalfa was superior to the fescues in providing minerals to animals for these reasons. Less mature fescue may also provide more minerals to animals than older fescue, for the same reasons.

The performance of cattle which grazed stockpiled fescue-alfalfa from 1 Nov. 1992 to 29 Dec. 1992 was better ($P<0.05$) than that of cattle which grazed N-fertilized fescue during this time (Table 1, Chapter 3), a result which agrees with Allen et al. (1990) and with the literature reviewed by Thomson (1978). This improved performance is probably related to the presence of alfalfa in the mix, for reasons discussed previously, and to the higher quality of fescue grown with alfalfa, stockpiled in September rather than August.

Sulfur nutrition is another possible factor in the performance of cattle grazing fescue-alfalfa. Sulfur was higher in alfalfa than in fescue, and was slightly higher ($P<0.20$) in fescue grown with alfalfa, stockpiled in September, than in N-fertilized fescue stockpiled in August. Since S was at least slightly higher in fescue-alfalfa and released to a greater extent and faster in the rumen for fescue-alfalfa than for N-fertilized fescue, steers grazing this forage had more S available to them for synthesizing proteins and for other functions requiring S. Further evidence of the improved availability of S was the increase in serum S in steers grazing fescue-alfalfa compared to steers grazing N-fertilized fescue (Table 2). These steers may have been able to use and retain N more efficiently because S was available in the diet (Starks et al., 1954; Bull and Vandersall, 1973; Kahlon et al., 1985; Buttrey et al., 1987).

The results in this study pertain to one sampling date only: the initiation of grazing of stockpiled forages, 1 Nov. 1992. The stockpiling season of 1992 had good rainfall and ideal temperatures for the production of alfalfa, so alfalfa in this study was high-quality. Stockpiled fescue is a forage high in TNC and of high digestibility, so mineral were very available from the fescues. It is entirely possible that, should this study be repeated on these forages from different sampling dates, results would be different simply because of seasonal variation in the quality of the forages.

Summary

September-stockpiled alfalfa was more digestible and released minerals to a greater extent and more quickly than fescue stockpiled beginning in August or September. September-stockpiled fescue grown with alfalfa released minerals to a greater extent and more quickly than August-stockpiled N-fertilized fescue. This effect is probably related to greater digestibility in the less-mature forages as well as inherent differences in grasses and legumes. Digestible forages which move rapidly though the rumen provide more nutrients than feeds which move slowly, so fescue-alfalfa probably provided cattle with better nutrition than did N-fertilized fescue. Specifically, S was more available from alfalfa and fescue grown with alfalfa than from N-fertilized fescue. The higher availability of S from mixed fescue-alfalfa could be beneficial to livestock performance, since available S in the diet can improve

N-utilization, feed consumption, protein utilization, and digestibility of feeds.

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General Summary

Forage-livestock systems can form integral parts of alternative agricultural systems which seek to minimize inputs while maintaining output and reducing environmental damage. Growing grass-legume mixtures can be a helpful tool in reducing fertilizer requirements, raising forage quality, and improving animal performance.

Fescue-alfalfa is a forage mix about which little is known, particularly when managed as stockpiled forage for autumn and winter grazing. During a stockpiling season when conditions were optimal for forage production, animal performance was improved when steers grazed stockpiled fescue-alfalfa as opposed to stockpiled N-fertilized fescue. When drought occurred in summer previous to stockpiling, there was no difference in animal performance between the forages, due primarily to lack of forage availability. Legume-grass mixtures are known to be of higher quality than grass alone, so the fact that animals grazing fescue-alfalfa performed better than those grazing fescue alone while animals grazed stockpiled forages is not unexpected.

Other studies with fescue-alfalfa have shown that improved animal performance may continue beyond the grazing period. Possibly, sulfur and nitrogen nutrition in fescue-alfalfa may be responsible for this effect. Sulfur is involved with many functions in the body, including protein synthesis. If animals have optimal S status, then N may be better retained and utilized more efficiently for protein synthesis; development and weight gain may be improved. Alfalfa sometimes contains more S than fescue. Even if S levels are comparable in fescue and alfalfa, other research has shown that S in fescue may not be as biologically available as that in orchardgrass, another cool season forage. The studies in this report demonstrate that S was more quickly and completely released from alfalfa than from fescue in the rumen. Animals grazing alfalfa may have an advantage in S nutrition over animals grazing fescue alone.

Steers grazing stockpiled fescue-alfalfa had higher levels of serum Ca, S, and BUN at the end of the grazing period than those which grazed stockpiled N-fertilized fescue, indicating that minerals may have been more available to animals from fescue-alfalfa. The dacron bag study, in conjunction with the results of the serum mineral investigation, showed that S and other minerals are more fully and rapidly released in the rumen from stockpiled alfalfa and fescue grown with alfalfa than from stockpiled N-fertilized fescue, so that more of these nutrients may be available to an animal grazing stockpiled fescue-alfalfa.

Alfalfa was more digestible than fescue, and so was able to release more minerals. Fescue grown with alfalfa was not appreciably more digestible than N-fertilized fescue, and so the reason for its more complete release of minerals is unknown. Further research may include metabolism trials to determine utilization of S and N from these two forages, since unavailability of nutrients in the rumen does not preclude availability in some other part of the digestive system. Based on the results of the experiments discussed, animals grazing stockpiled fescue-alfalfa have a definite advantage in S and N nutrition over those grazing stockpiled N-fertilized fescue.

Stockpiled forages can be of high nutritional quality if management is correct. Fescue fertilized with N is usually stockpiled in August. Stockpiling fescue-alfalfa in August caused alfalfa to become too mature for benefit by the time grazing begins. This study showed that stockpiling fescue-alfalfa in September improved yield over August stockpiling of fescue-alfalfa, probably due to the fact that alfalfa deteriorated and disappeared from August-stockpiled fescue-alfalfa. September stockpiling had little effect upon quality of the fescue in fescue-alfalfa, but since alfalfa was present, forage quality overall was higher in September-stockpiled fescue-alfalfa. Both N-fertilized fescue stockpiled in August and fescue-alfalfa stockpiled in September produced acceptable animal performance.

Grazing of fescue-alfalfa seems to be a management alternative as desirable as mechanical harvest, since mechanical harvest is expensive. Intermittent grazing of fescue-alfalfa did not lower seasonal yield compared to total mechanical harvest during the first summer of the grazing study, but botanical composition of mechanically harvested fescue-alfalfa changed. Fescue began to disappear from the mix, to be replaced by alfalfa and weeds. Grazing by appropriate management may help to maintain desirable botanical composition of fescue-alfalfa stands.

By the first hay cut of the second year, however, some effect of total mechanical harvest on yield of fescue-alfalfa was seen, in that fescue-alfalfa which had been grazed during the winter had less forage mass than fescue-alfalfa which had not been grazed over winter. More seasons of research on this issue may clarify effects of grazing vs mechanical harvest. Nitrogen-fertilized fescue produced more total seasonal yield than fescue-alfalfa in this study, even when water was not limiting for growth. Reduction of N-fertilization and improved animal performance by animals grazing fescue-alfalfa may offset reduced yields of fescue-alfalfa compared to N-fertilized fescue.

Fescue-alfalfa has the potential to become a major part of alternative livestock production systems in Virginia. Management of this forage mix is more complicated than that of fescue grown alone and fertilized with N, but can include either hay harvest or grazing. Improved animal performance and reduced N-fertilization requirements compared to N-fertilized fescue may help to make fescue-alfalfa a more commonly-used forage mix.

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