COMPATIBILITY, YIELD, AND QUALITY OF MATUA PRAIRIE GRASS, *Bromus willdenowii* (Kunth), WITH LEGUMES.

by

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ABSTRACT

Matua prairie grass has a potential to extend the grazing season in Virginia due to its higher early spring and fall production. However, little is known about the compatibility of Matua prairie grass with legumes or the effects of legumes on the yield and quality of Matua prairie grass/legume mixtures. An experiment was conducted in 1998 and 1999 to investigate the botanical composition, yield, and chemical composition of Matua prairie grass grown with legumes. Legume treatments consisting of ladino clover (*Trifolium repens*), red clover (*Trifolium pratense)*, alfalfa (*Medicago sativa*), and annual lespedeza (*Lespedeza stipulacea*) were drilled into a Matua prairie grass stand. Nitrogen was applied once each fall at two treatment levels of 0 or 84 kg/ha. The experiment was arranged in a randomized split block design with four replications. Legume treatments had no effect on percentage Matua prairie grass or total dry matter yield in 1998. However, in 1999 the ladino clover and red clover treatments increased ($P<0.05$) total dry matter yield, but also resulted in a substantial decrease ($P<0.05$) in percentage Matua prairie grass. Nitrogen application in the fall of 1998 had a residual effect ($P<0.05$) on the percentage Matua prairie grass and yield in 1999. The highest response to nitrogen fertilization occurred in the harvest immediately after fertilization, in October of 1999, which resulted in the largest increase ($P<0.05$) in percentage Matua prairie grass and yield, and the greatest decrease ($P<0.05$) in percentage legumes. The legume and nitrogen treatments similarly influenced the chemical composition of the Matua prairie grass/legume mixed forage. Ladino clover, red clover, and alfalfa treatments generally improved forage quality as indicated by a decrease ($P<0.05$) in NDF, ADF, hemicellulose, and cellulose, and an increase ($P<0.05$) in CP and IVDMD. Nitrogen fertilization did not influence the chemical composition of the forages to the same extent as the legume treatments, as a decrease in fiber components and an increase in CP and IVDMD were observed due to nitrogen. Overall, alfalfa appeared to be most compatible with Matua prairie grass, and the incorporation of alfalfa into a Matua prairie grass stand

resulted in some improvements in total dry matter yield and nutritive value of the forage, without the detrimental suppression of Matua prairie grass.

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Chapter I

Introduction

In terms of area, forage is the number one crop in Virginia. Although there are several well-adapted forages for Virginia climate, early spring, midsummer and late fall are periods that are often low in forage productivity. Any forage crop that extends the grazing season by providing additional feed in early spring, midsummer, and late fall when the productivity of the typical cool season forages is low could provide many livestock producers with lower feed costs and boost animal performance.

Matua prairie grass (Matua), *Bromus willdenowii* (Kunth), is a short-lived perennial plant capable of high forage production. Matua has the potential to extend the grazing season, since this grass grows earlier in the spring and later in the fall than most other cool season grass species (LaCasha et al., 1999). Research conducted evaluating the yield potential of Matua has found it to be highly productive during fall months (Jung et al., 1994).

Matua has a bunch-type growth, and is a very palatable forage, including the seed heads. Unlike most cool season grasses, seed heads are produced after every harvest. Matua is known to have persistence problems. The mechanism by which Matua persists is not well known. However, natural re-seeding and increased tiller weights and numbers are known to contribute to its persistence.

Defoliation management is also critical to stand longevity. Matua is very sensitive to intensive grazing management that utilizes frequent or continuous defoliation. Matua stands are weakened if defoliation intervals are too frequent, leading to a decline in the stand because of insufficient energy reserves for regrowth (Bell and Ritchie, 1989; Jung et al., 1994). Infrequent defoliation can also weaken the stand through reduced seedling and tiller survival, due to excessive shading from the forage canopy (Jung et al., 1994). Carefully managed livestock grazing rotations or hay harvesting is necessary to maintain adequate Matua stands. Matua is less sensitive to defoliation height than to frequency of cutting (Bell and Ritchie, 1989). Little is known about management of grown in combination with legumes.

The value of the addition of legumes to a stand of grass is well known. Legumes generally increase the protein content and digestibility of the grass/legume mixed forage and may also increase the crude protein content of the nonlegume components of the mixture (Schultz and Stubbendieck, 1983). Improvements in livestock production have been realized when the legume component in grass/legume stands was increased (Fairey and Lefkovitch, 1990). Maintenance of legume in pastures is imperative in terms of optimizing nutritive value and sustainability of mixed species swards (Turner et al., 1998).

Additionally, the incorporation of legumes into a grass sward can benefit producers by improving soil and water conservation and weed control, through more efficient ground coverage, as compared to monoculture conditions (Casler and Walgenbach, 1990). Also grass/legume mixtures have the potential to out yield monocultures (Casler and Walgenbach, 1990; Haynes, 1980).

Unfortunately, many cultivar recommendations for grass/legume mixtures are based on cultivars that perform favorably under monoculture conditions, which can lead to errors in the development of optimal mixtures (Casler and Walgenbach, 1990). High production in pure stands is often associated with poor competitive ability in mixed stands (Casler and Drolsom, 1984). Other challenges with grass/legume mixtures include differences in growth habit, regrowth potential, and physiological growth requirements, which make it difficult to manage and maintain components in the mixture (Casler, 1988). Therefore, the compatibility of Matua with legumes is of interest due to the potential of legumes to benefit Matua prairie grass stands, but this has not been documented.

The overall objective of this research was to investigate the agronomic adaptability, yield and quality of Matua. Specific objectives include:

1) To evaluate the morphological compatibility of Matua with various legumes.
2) To compare the yield and quality of Matua in pure stands versus mixed with legumes.
3) To investigate the influence of a single fall nitrogen application on the botanical composition, yield, and quality of the Matua and legume mixtures.

Chapter II

Literature Review

Plant origin and agronomic characteristics

Some of the most recent and extensive breeding research on Matua prairie grass (Matua) (*Bromus willdenowii*) has been conducted in New Zealand. Other breeding work has been conducted on Matua in Australia and the United States. It is believed that Matua originated in South America and was introduced to the Southern U.S. prior to the Civil War (Rumball, 1974; Newell, 1973; Hoover et al., 1948).

Matua belongs to the genus *Bromus*. Several grass species, including *B. catharticus, B. unioloides,* and *B. willdenowii*, have all been called Matua. These three species of grasses are very similar and are often misidentified (Rumball, 1974). Due to close similarities between species, taxonomic uncertainty exists in this group (Table 1).

Matua is a cool season short-lived perennial grass that has a bunch-type growth habit. Unlike most cool season grasses, it produces seed heads with every harvest (Jung et al., 1994). The seed heads are self-fertilizing, promoting variety uniformity in stand (Rumball, 1974; Rumball et al., 1972). Seed head production is important in stand persistence. Stand density can be improved by allowing natural reseeding during the summer months (Jung et al., 1994).

Another important survival mechanism for Matua is tillering. Rumball (1974) concluded that Matua has the potential to be a true perennial, if properly managed. However, under certain conditions, such as overgrazing on dry or infertile soils, or selective grazing by livestock in mixed pastures, individual plants may die out (Rumball, 1974). Individual plants may have fewer than 10 tillers at any one time, but some of these tillers can be over one centimeter in diameter (Rumball, 1974). The importance of tillers in Matua persistence has been documented by several researchers (Bell and Ritchie, 1989; Jung et al., 1994).

Table 1. Various prairie grass species with in the *Bromus* genus, used in previous research.

Source	Scientific Name	Common Name/Cultivar
Bell and Ritchie (1989)	*B. willdenowii*	prairie grass cv. Grasslands Matua
Cameron et al. (1969)	*B. unioloides*	prairie grass cv. Priebe
Fulkerson et al (2000)	*B. willdenowii*	prairie grass cv. Matua
Grof et al. (1969)	*B. unioloides*	prairie grass cv. Priebe
Jung et al. (1994)	*B. unioloides*/ *B. willdenowii*	prairie grass cv. Grasslands Matua
LaCasha et al. (1999)	*B. willdenowii*	prairie grass cv. Grasslands Matua
Pineiro and Harris (1978a & b)	*B. cartharticus*	prairie grass cv. Grasslands Matua
Rumball (1974)	*B. cartharticus*	prairie grass cv. Grasslands Matua
Rumball (1972)	*B. carinatus*	California/Mountain bromegrass
	B. erectus	Upright bromegrass
	B. firmior	
	B. inermis	Smooth bromegrass
	B. marginatus	Mountain bromegrass cv. Ness
	B. popovii	
	B. riparius	Meadow bromegrass
	B. sitchenis	Blizzard or Bosir bromegrass
	B. stamineus	Grazing bromegrass
	B. uruguayensis	
	B. unioloides x B. haenkeanus	prairie grass
	B. unioloides	prairie grass/rescuegrass
Vartha (1977)	*B. cartharticus*	prairie grass cv. Grasslands Matua

Matua is a short-lived perennial grass; however, with proper management, its persistence can be increased (Rumball, 1974). Management practices that promote natural reseeding and tillering are beneficial to its persistence (Jung et al., 1994; Bell and Ritchie, 1989). The origin of Matua is unclear; however, it may have originated in Argentina (Newell, 1973; Hoover et al., 1948). Also, unclear is the taxonomic classification of several closely related species of *Bromus*, which are often misidentified as Matua (Rumball, 1974).

Defoliation management

Careful management of either grazing of Matua by livestock or mowing for hay is critical for long term stand yield and persistence. Matua was intended for use on high-fertility dairy farms (in New Zealand) under a rotational grazing system and lax defoliation (Rumball, 1974). Either too frequent or infrequent cutting can lead to reduced stand persistence (Bell and Ritchie, 1989; Jung et al., 1994). Cutting height also influences Matua yields and persistence, although, to a lesser extent than cutting frequency (Bell and Ritchie, 1989). Promoting tiller survival and regrowth through a cutting height that will leave residual stubble after harvesting can increase the persistence of Matua.

An experiment conducted by Bell and Ritchie (1989) in New Zealand investigated the effects of five defoliation intervals (10, 20, 30, 40, and 50 days) and two defoliation heights (3 cm and 8 cm) on the production and persistence of a three year old stand of Matua. They found that Matua dry matter yields and tiller numbers increased with a decrease in defoliation frequency. The 8-cm defoliation height tended to have a 10-15 percent increase in total dry matter and increased tiller numbers. They concluded that defoliation frequency was more important than defoliation height in increasing Matua production. A 40 to 50 day rest period was recommended by the authors to increase the persistence of Matua stands.

Similar results were obtained in two separate experiments with Matua conducted by Jung et al. (1994) in Pennsylvania. Approximately 95 percent of the potential fall dry matter yield was obtained in the last week of October through the first week of November (Jung et al., 1994). The highest dry matter yields obtained for fall harvests were 4.0 Mg/ha, 4.3 Mg/ha, and 3.0 Mg/ha for 1987, 1988, and 1989, respectively. They found that the higher residue stubble heights left in the fall reduced that fall's yields by approximately 20 to 60 percent, but increased the subsequent spring yields. Subsequent spring yields were significantly decreased as the previous fall's harvest was delayed. Average spring yields from the early September cutting treatments were 4.5 Mg/ha, but decreased as the fall harvests were delayed. The authors concluded that harvesting in late fall is deleterious, but can be compensated for by using a higher cutting height and leaving more stubble. Tiller densities were also reduced in plots harvested late in the fall, again reinforcing the benefit of harvesting earlier in the fall.

The second study, conducted from September 1990 to June 1993, evaluated the influence of the frequency of fall harvest and residual stubble height on fall and spring yields and tiller densities of Matua. Fall harvest frequencies of 20, 30, 40, and 80 days were used. Also, residue stubble height treatments of 7.5 and 12.5 cm were imposed. Jung et al. (1994) found that optimal fall yields were obtained in the 40 day cutting frequency at the 7.5-cm cutting height, and that yields were most reduced, by 40 percent, in the 20 and 80 day cutting frequencies at the 12.5-cm cutting height. The authors concluded that bunch-type grasses, such as Matua, would have reduced energy reserves for regrowth when clipped short and frequently. However, lengthening the rest period too much can lead to yield reductions due to leaf senescence and lodging. The authors found that plots harvested only once in the fall, in the 80 day cutting frequency treatment, recovered slower and had a lower spring yield potential than plots in the more frequent cutting treatments. At early seed stage, total yield for the 80 day fall cutting frequency treatment averaged approximately 5.0 Mg/ha, as compared to 7 to 8 Mg/ha for the 20 to 40 day treatments.

Jung et al. (1994) concluded that Matua was a highly productive forage crop for the fall months. They found that DM yields of over 4.0 Mg/ha were obtained in mature stands of Matua. In order to improve winter survival of Matua, they recommended harvesting in early fall rather than late fall, leaving a higher stubble height, and taking multiple harvests. These fall management practices would also improve spring yield and vigor. This experiment found that Matua also had an acceptable potential spring yield of approximately 4.0 Mg/ha at 50 percent seed head emergence, which is the growth stage recommended for hay or silage.

Earlier work conducted in Australia and New Zealand on Matua reinforces the importance of proper defoliation management. Several experiments were conducted in the 1960's and 1970's, examining Matua's persistence under different grazing and mechanical harvesting management. In addition, some early work was conducted to examine Matua's persistence in a stand that also contained a legume. Although, strict compatibility studies were not carried out, the results of these studies are of interest.

An experiment conducted by Vartha (1977) in New Zealand compared the growth of Matua

(*Bromus cartharticus*), ryegrass (*Lolium perenne*), timothy (*Phleum pratense*), and orchardgrass (*Dactylis glomerata*) harvested monthly cut at either 2.5 or 5.0 cm. The author found that annual Matua yields were significantly higher than the other grass species. Total yield of Matua averaged 10,000 kg/ha/yr over three years. Matua yields were significantly higher in summer months, presumably due to seed head contribution. During the winter, Matua also performed better than the other grasses. This indicates Matua grows more actively in cold, wet weather than the other cool season grass species used in this experiment. During other times of the year, Matua yields were not significantly higher.

Grof et al. (1969) conducted an experiment evaluating the effect of grazing management on persistence of Priebe prairie grass (*Bromus unioloides*)/legume mixture in an irrigated pasture (See Table 1). The grass was seeded at a rate of 6.72 kg/ha in combination with 2.24 kg/ha of ladino clover (*Trifolium repens*). Treatments consisted of either four- or six-week rotational grazing intervals. Grazing deferment treatments, of either no deferment or deferment in spring and fall to allow for natural seeding, were also imposed. The plots were heavily and quickly grazed by dairy cattle, and then mowed to remove all residues and weeds left behind by the cattle. They found that none of the treatments adequately maintained prairie grass in the plots by the end of the experiment. At the initiation of the experiment, prairie grass comprised 65 to 70 percent of the stand; by end of the third year of the experiment, it comprised only 20 percent or less of the stand. In the third year of the experiment, prairie grass yielded only 175 kg/ha (five percent of total yield in the four-week grazing interval without spring and fall grazing deferment), while ladino clover yielded 7,133 kg/ha. The four-week grazing interval without grazing deferments had the lowest prairie grass yields. Both lengthening the time between grazings and utilizing grazing deferments in the spring and fall improved prairie grass persistence. The treatment with the highest prairie grass yield was the six-week grazing interval with spring and fall grazing deferments. This treatment yielded 1,342 kg/ha prairie grass, 20 percent of total yield, and 4,304 kg/ha ladino clover. Although significantly higher prairie grass yield was obtained under the least aggressive treatment, the level maintained was inadequate. In order to prevent health problems (specifically bloat) in ruminants, a grass/legume mixture should contain no more than 50 percent clover (Ball et al., 1996). Grof et al. (1969) concluded that some factor other than grazing deferment and recover period between grazing influenced the persistence of prairie grass in this experiment; however, the authors did not speculate what the other factor(s) could be. The results may have been influenced by the seeding rate of prairie grass used in this experiment. Perhaps the amount of prairie grass was inadequate to compete with the clover as they established.

In an experiment conducted by Cameron et al. (1969), Priebe prairie grass persistence was evaluated under nitrogen fertilization and mowing treatments. They suggested that prairie grass should not be grazed any lower than 7.62 to 10.16 cm; however, the authors observed that pastures are normally mowed to 5.08 to 7.62 cm in Australia, immediately after grazing in a rotation system, to remove residue. This experiment was designed to evaluate the influence of this mowing management practice on prairie grass yields along with nitrogen treatments. The experiment was conducted using prairie grass/ladino clover mixed plots established in 1960. The fertilization treatments consisted of no nitrogen or 56 kg/ha applied each September, starting in 1963. In the remainder of the study, the nitrogen fertilization rate was increased to 112 kg/ha. Mowing treatments were imposed; plots were either mowed or not mowed after each grazing. The plots were grazed approximately every four to six weeks by dairy cattle. Cameron et al. (1969) found that at the beginning of the study, the pastures contained 20 percent prairie grass and 75 percent clover. After a reduction in clover levels, due to lack of moisture, prairie grass responded to the nitrogen treatments. By the October 1966 harvest, prairie grass yield in the nitrogen treated plots increased to 4,094 kg/ha, as compared to 853 kg/ha yield from the plots that received no nitrogen. The October 1966 harvest demonstrated the highest increase in prairie grass yield due to mowing treatments. The plots that were not mowed yielded 3,147 kg/ha, while the plots that were mowed after each grazing yielded 1,810 kg/ha. This experiment showed that pastures which initially contained minimal amounts of prairie grass in the mixture were improved with proper management. Minimal mowing, after grazing, also allowed the prairie grass yields to increase.

In an extensive examination of Matua, Pineiro and Harris (1978a,b) conducted two studies to evaluate the performance of Matua mixed with three varieties of red clover (*Trifolium pratense*). The Matua mixtures were also compared to ryegrass/red clover mixtures. Pineiro and Harris (1978a) initiated the first experiment to evaluate forage production in the establishment year, in New Zealand in April of 1975. Matua was seeded at a rate of 60 kg/ha with Grasslands Hamua, Grasslands Turoa, or Grasslands Pawera red clover varieties seeded at a rate of 10 kg/ha, 9.68 kg/ha, and 16.5 kg/ha, respectively. Plots were grazed either frequently (at two to four week intervals) or infrequently (at four to six week intervals) by mature sheep. Rate of forage regrowth regulated the variation in each grazing interval. Averaged over mixture, plots that were grazed infrequently were higher yielding than the frequently grazed plots, by approximately 35 percent. Matua mixed with Pawera yielded more than the other two Matua/red clover mixtures. The highest yielding mixture was Nui ryegrass/Pawera red clover. The lowest yielding mixture was Matua/Hamua red clover with 11,908 kg/ha and 17,910 kg/ha, total annual forage production in the frequent and infrequent grazing treatments, respectively. Grazing frequency did not have an effect on the amount of legume present in the stands (approximately 20 to 30 percent), but it did have an effect on the amount of grass in the stands. Pineiro and Harris (1978a) concluded that Matua performed poorly under frequent grazings. They also suggested that the wider use of Matua would depend on farmers' willingness to apply specific grazing management.

In the second study, Pineiro and Harris (1978b) evaluated shoot populations and natural reseeding of Matua using the same plots and during the same time frame as the experiment earlier described (Pineiro and Harris, 1978a). They found that Matua tiller densities were not affected by the associated red clover variety. However, that experiment did not have a control plot (Matua sown alone) with which to compare results. The authors also found that Matua had higher tiller numbers in the infrequent grazing treatments. Red clover variety had no effect on the amount of Matua seed heads (255 kg DM/ha average) or the amount of seeds on the soil surface (168-seeds/m^2 average). The authors concluded that tillering is usually reduced by frequent defoliation, which can be attributed to reduced carbon assimilation by removal of photosynthetic tissue. However, they also stated that tillering could be decreased in infrequent defoliation treatments, which can be attributed to shading. The authors also suggest Matua has potential for being cultivated in combination with legumes. In that experiment, erect arrangement of tillers and slower establishment growth rate provided ample space between grass plants for red clover establishment. Pineiro and Harris (1978b) also concluded that natural reseeding, to aid persistence of Matua stands, is practical. They observed that stands are characteristically open after grazing, allowing space for seedling establishment. Also, they observed that the sheep were reluctant to consume seed heads.

Fulkerson et al. (2000) compared the production of Matua to perennial ryegrass and tall fescue (*Festuca arundinacea*), in Australia from 1997 to 1999. The authors stated that previous work, conducted by Lowe et al. (1999) in the same environment, found Matua to be most productive, but tall fescue was the most persistent. The stands were grazed by dairy cattle, with the frequency based on the time taken to reach 1.5, 2.5, or 4.0 leaves/tiller of regrowth. Matua pastures yielded more than perennial ryegrass or tall fescue. Matua annual yields ranged from 7,784 kg/ha to 13,277 kg/ha.

The highest yields were obtained from the 4.0 leaves/tiller grazing interval treatment. In each type of grass, white clover, on average, comprised less than 20 percent of the stands in all three years. Matua tiller densities in late spring of the establishment year were 298, 352, and 315 tillers/m^2 for the 1.5, 2.5, and 4.0 leaves/tiller grazing treatments, respectively. Tiller densities also increased over time. Matua root distribution was most concentrated in soil depth 0 to 50 mm at an amount of 0.72 g/plant, which was less than the other two grass species. Fulkerson et al. (2000) concluded that grazing intervals should be based on morphological growth of Matua, since the number of leaves determines the level of replenishment of carbohydrate reserves and leaf senescence. The authors stated that these physiological factors should be used to determine minimum and maximum defoliation interval. They recommended a 3.5 to 4.0 leaves/tiller grazing interval, which could range from 20 days in the spring to 45 days in winter. The authors observed that the shortest grazing interval had a negative effect on yield, reduced plant survival, and reduced seed set in Matua.

Proper defoliation management is important in maintaining the persistence of Matua. A 40 day cutting interval for Matua results in optimal yields and persistence (Bell and Ritchie, 1989; Jung et al., 1994). However, stockpiling of Matua in the fall is detrimental to its persistence. Harvesting very late in the fall or utilizing too long of a defoliation interval reduces its persistence (Jung et al., 1994). Cutting height is also important in maintaining the persistence of Matua, however, to a lesser extent than cutting frequency. An approximate cutting height of 7.5 or 8 cm may also optimize yields and persistence (Bell and Ritchie, 1989; Jung et al., 1994). Grazing management is similarly important in maintaining Matua. If grazed too frequently, its persistence is reduced. Four to six week grazing intervals are necessary to maintain its persistence (Cameron et al., 1969; Pineiro and Harris, 1978a,b; Fulkerson et al., 2000). In addition, mowing pastures after each livestock rotation is detrimental to Matua, resulting in reduced persistence (Grof et al., 1969; Cameron et al., 1969). With proper management and the right growing conditions, Matua has the potential to out yield other cool season grass species, including ryegrass, timothy, orchardgrass, and tall fescue (Vartha, 1977; Fulkerson et al., 2000).

Chemical composition

In general, few experiments have been conducted evaluating the potential nutritive value of Matua as a forage source for livestock. Subsequently, little data is available on the chemical composition of Matua.

Fulkerson et al. (2000) evaluated the quality of Matua mixed with white clover as a potential forage for dairy cattle. In the vegetative state, Fulkerson et al. (2000) found that Ca concentration in the forage tended to increase over time while P concentration decreased. The authors stated that the Ca to P ratio gradually improved toward the recommended level of 1.6:1 recommended by the NRC (1989) for dairy cattle. The authors found that the Mg content is lower (less than 0.2% DM) than the requirement for lactating dairy cows, which could pose a problem. In the reproductive state, Fulkerson et al. (2000) found that Ca to P ratios continued to rise and exceeded the minimum requirements for dairy cattle. Potassium levels over time eventually fell from 0.35 percent DM to of 0.20 percent DM. Metabolizable energy declined from 10.7 MJ/kg DM at 15 days of regrowth to 9.2 MJ/kg DM at 42 days of regrowth. Water-soluble carbohydrates rose rapidly up to approximately 12 percent DM and then declined. The authors presumed that this was due to an onset of senescence. They concluded that the rate of water-soluble carbohydrate accumulation in tiller bases was nine times greater in the reproductive growth stage than in vegetative growth stage. This finding would support the recommendations of previous studies to allow for infrequent defoliation management and natural reseeding. Fulkerson et al. (2000) recommended an infrequent grazing interval to allow for adequate replenishment of water-soluble carbohydrate reserves and to subsequently maximize root regrowth and plant persistence.

Rumball et al. (1972) evaluated variation in chemical composition in populations of prairie grass. Rumball utilized numerous species in the *Bromus* genus (Table 1). The first part of the experiment evaluated 12 breeding lines of prairie grass of *B. unioloides*, established in swards in May 1967 in New Zealand, for K, Na, Ca, Mg, Cl, P, S, total N, nitrate N, Fe, Mn, Zn, Cu, Si, Se, and I. The second part of the experiment evaluated Mg content of 106 breeding lines of prairie grass, including lines from species other than *B. unioloides*. Spring and summer concentrations of Mg were 0.170 and 0.125 percent DM, respectively. Differences were detected between *Bromus* species used in that experiment, with *B. unioloides* having the lowest levels of Mg. Rumball et al. (1972) concluded that the prairie grass lines evaluated appeared to contain sufficient K, Na, Cl, Fe, Mn, Cu, and Zn to meet ruminant requirements, based on Agriculture Research Council (1966) recommendations. However, the authors stated that Ca, P, Mg, and I appeared to be deficient, if utilized in a ruminant diet. Rumball et al. (1972) concluded there is potential for breeding for higher Mg content in prairie grass lines, but might be at the expense of yield.

In another study conducted by LaCasha et al. (1999) at Texas Tech University, Matua hay was evaluated as a potential feed source for horses. Matua, alfalfa, and bermudagrass (*Cynodon dactylon*) hays were compared in a horse digestion and palatability study. Matua was intermediate in quality. Generally, alfalfa was the best quality, while bermudagrass was the poorest in quality. Matua had 13.5, 62.4, 36.1, and 12 percent crude protein, neutral detergent fiber, acid detergent fiber, and total nonstructural carbohydrates, respectively. Also, Matua had Ca, Mg, and P levels of 0.49, 0.27, and 0.18 percent, respectively. Apparent digestibility of dry matter, crude protein, neutral detergent fiber, acid detergent fiber, and in vitro dry matter digestibility were 51, 74, 47, 20, and 58 percent, respectively. During the digestion trial, voluntary intake of Matua was intermediate between alfalfa and bermudagrass. Voluntary dry matter intake was 10.9, 10.0, and 7.4 kg DM/d for alfalfa, Matua, and bermudagrass, respectively.

However, during the palatability study voluntary dry matter of the three hays was influenced greatly by the type of hay the horses had been fed in the prior digestion trial. Horses fed alfalfa tended to continue consuming alfalfa, but added more grass hays to their diet, preferring Matua over bermudagrass. Horses fed Matua tended to consume more alfalfa. Horses fed bermudagrass tended to consume more alfalfa; however, Matua was also consumed at a higher rate than bermudagrass. LaCasha et al. (1999) suggested a longer trial would be needed to determine the long-term influence of the consumption of a previous type of forage on subsequent hay selection. Also, the authors note that horses with no prior experience with any of the three forages could more accurately indicate preference. LaCasha et al. (1999) concluded that Matua is an acceptable forage for horses and should meet nutritional requirements of yearling horses in terms of protein and most minerals.

Overall, Matua appears to be an acceptable forage source for livestock in terms of palatability and nutritive value. The fiber components of neutral detergent fiber and acid detergent fiber are 62 and 36 percent, respectively, while the crude protein is 13 percent (LaCasha et al., 1999). However, Matua may be deficient in Mg, because its Mg content is generally 0.2 percent DM or less (Fulkerson et al., 2000; Rumball et al., 1972; LaCasha et al., 1999). Calcium and P may also be potentially inadequate in Matua, depending on its stage of maturity (Fulkerson et al., 2000).

Physiological and morphological mechanisms of grass/legume compatibility

In order to evaluate Matua's potential compatibility with legumes, the mechanisms behind general grass/legume compatibility and competition must first be examined. These physiological and morphological mechanisms include microorganism symbiosis, period and rate of growth, light requirements, water use efficiency, exchange capacity, foliage architecture, growth habit in relation to defoliation, and root morphology. All of these factors influence how grasses and legumes are able to compete in a pasture setting. The three main environmental factors for which grasses and legumes compete are light, nutrients, and water (Haynes, 1980). More than one of these morphological and physiological factors can be present at one time influencing plant competition in pastures, and can be interrelated (Haynes, 1980). To further complicate the subject, legume populations can fluctuate widely over a long period of time and are often patchily distributed within the sward (Schwinning and Parsons, 1996a). Field scale stability may depend on the establishment of a patchy pasture (Schwinning and Parsons, 1996b). It is generally accepted that grasses normally have a competitive advantage over legumes; however, pasture management techniques (such as fertilization and defoliation management) are utilized in order to secure a desirable balance (Rhodes and Stern, 1978).

Microorganism symbiosis. Legumes are able to obtain nitrogen from the atmosphere through the symbiosis with rhizobia bacteria. Most perennial legumes have the potential to fix 112 to 224 kg of nitrogen/ha/year (Tisdale et al., 1993). Legumes are able to transfer some of this fixed nitrogen to nonlegume components of the pasture; however, this can vary from 0 to 75 percent, depending on species of legume and grass, percentage of legume in the sward, age of the sward, and type of management (Haynes, 1980). The nitrogen transfer occurs through nutrient cycling by grazing animals and legume decay. However, the transfer rate can vary (Vallis, 1978). Alfalfa can take over a year to gradually release fixed nitrogen (Simpson, 1965), while white clover and annual legumes appear to transfer nitrogen faster and more efficiently (Vallis, 1978). Generally, legumes have an advantage over grasses when grown in a nitrogen deficient soil environment (Camlin, 1981). Turkington et al. (1988) stated that inoculation of red clover with rhizobium reduced the competitive ability of associated grasses. However, nitrogen fertilizer application will reduce the amount of rhizobium nodules on legume roots, thus reducing legume’s ability to fix atmospheric nitrogen (McAuliffe et al., 1958).

Period and rate of growth. Seasonal growth rates will influence the stability of grass/legume mixed pastures (Haynes, 1980). Different species of grass and legumes have different optimal day length and temperature requirements. For example, white clover has an optimal temperature for growth of 24^{o} C, while ryegrass has an optimal temperature of 18 to 21^{o} C (Harris and Thomas, 1973). Having maximum yield contributions of grass and legume components occurring at different times of the year distributes total dry matter production throughout the year, resulting in continuously high dry matter production throughout the growing season (Brougham, 1959). Overall growth and yield are also factors that influence compatibility. Grasses that are high yielding in pure stands are also often high yielding when grown with legumes and are, therefore, less compatible with the legumes (Cowling and Lockyer, 1967; Donald, 1978).

Light requirements. Grasses and legumes, in general, have different light requirements. Legumes tend to be less tolerant of shade than grasses. Clover growth can be greatly depressed when grown with grasses at reduced light levels (Blackman and Templeman, 1938), and grasses appear to be more readily adaptable to reduced light conditions than clovers (Haynes, 1980). Therefore, shading in a pasture setting, either by the taller species of forage in the grass/legume mixture or by other plants, such as trees, can alter the balance in the grass/legume mixture. Generally, shading would shift the balance in favor of the grass species.

Water use efficiency. Grasses and legumes differ in their water use efficiency. Legumes are the least efficient in their water use, as compared to a variety of other plants (Leach, 1978), and when compared to grasses, legumes have poorer stomatal control, resulting in poor control of transpiration (Burch and Johns, 1978). Also, leaf senescence was the main mechanism for balancing transpiration with water uptake, as the soil dried out (Burch and Johns, 1978). This information gives an indication as to why legumes often experience a reduction in growth and a general decline in pastures in hot and dry summer conditions. Haynes (1980) suggested that grasses generally make more efficient use of soil water than legumes.

Foliage architecture. Leaves absorb most of the solar radiation in a field, and plant height is of great significance in competition for light (Rhodes and Stern, 1978). Generally, grasses are taller than legumes; a taller height gives grass an advantage and leads to shading of the legume (Haynes, 1980). However, the height relationship between grasses and legumes is altered due to defoliation. Also, leaf shape and structure is an important aspect. Broad horizontal leaves of legumes are more efficient at absorbing and reflecting light than are grasses which have a vertical leaf structure. Legumes generally absorb most of the light they intercept within a few layers of leaves, while grasses are able to distribute and absorb light more evenly throughout the canopy. Therefore, legumes are more susceptible to being shaded by other plants and are poor competitors for light (Rhodes and Stern, 1978).

Growth habit in relation to defoliation. Any plant which will successfully adapt to defoliation in a pasture setting needs to have meristematic tissue close to the ground, out of danger of being removed (Harris, 1978). Regrowth of leaves after defoliation are from meristematic tissue at the base of each leaf and formation of new leaves arise from axillary buds also located near the base of leaves (Smith, 1973). It is critical that these tissues be close to the soil surface to escape damage during defoliation to permit regrowth. Plants with an upright growth habit are more sensitive to defoliation, and are slower to recover than plants with a prostrate growth habit (Butler et al., 1959). In a comparison of red clover (upright) and white clover (prostrate), Butler et al. (1959) concluded that red clover is more competitive for light than white clover and better adapts to shading in pastures, but white clover recovers more rapidly from defoliation. Plants are also able to adapt their morphology to suit their environment. White clover is able to produce a mat of stolons close to the ground, with small leaves, in response to overgrazing (Sucking, 1975). Another aspect of the effect of defoliation on plants is the type of defoliation. Grazing by livestock can have a different effect on plants than mechanical defoliation. Livestock grazing can influence grass/legume composition of a pasture (Schwinning and Parsons, 1996a). Livestock generally will selectively graze more palatable legumes, in preference to less palatable grasses, which can lead to grass domination in pastures, especially in continuously grazed systems (Watkin and Clements, 1974). Thornley et al. (1995) stated that stable persistence of unfertilized mixtures of ryegrass and white clover are not achievable, except when grazing eliminated the dominance of white clover. If a legume is highly competitive with grasses, the grass can often only be maintained in the mixture by the presence of grazing animals (Schwinning and Parsons, 1996a).

Root morphology. Root morphology is a very important factor in competition for water and nutrients in a pasture (Evans, 1977). A more developed and deeper root system generally gives one component of a pasture an advantage over another (Davidson, 1978). In general, grasses have longer, thinner, more finely branched roots, and more root hairs, than legumes (Evans, 1977). The differences in root structure could give grasses a competitive advantage over legumes in respect to nutrient and water uptake (Haynes, 1980), and may partially explain why grasses are able to better absorb limiting nutrients. Root depth is another aspect to consider. In general, most of the roots of several species of pasture plants were found in the top 20 cm of soil (Evans, 1978). A deep root system could be advantageous in water or nutrient limited situations.

Competition. In general, the three main environmental factors that plants compete to obtain are light, nutrients, and water (Haynes, 1980). Management of pastures plays an important role in altering the competition for light. Nutrient availability and defoliation management can influence the competition for light (Rhodes and Stern, 1978). Nitrogen fertilization of pastures influences competition for light between grasses and legumes. Nitrogen fixation by legumes is depressed by nitrogen fertilization (McAuliffe et al., 1958). Legumes generally absorb only a small portion of the applied nitrogen, as compared to grasses, and the subsequent growth of grasses is stimulated to a greater extent than legumes (Vallis, 1978). However, frequent defoliation can alleviate the shading of legumes by preventing long term shading (Rhodes and Stern, 1978). Harris (1978) stated that dominance or suppression could be explained by defoliation. Defoliation can allow light to penetrate a canopy and reach prostrate or low growing species and restrict the height of taller growing species (Harris, 1978). For example, white clover is suppressed by infrequent defoliation and is stimulated by frequent defoliation (Brougham, 1959). In general, taller grass species tend to dominate grass/legume mixtures by shading shorter legume species.

Competition for nutrients can interact with the competition for light. The ability of one species to more efficiently absorb a limiting nutrient can cause an increase in growth and subsequently shade other species (Haynes, 1980). Legumes tend to be poor competitors for nitrogen (Vallis, 1978), P (Jackman and Mouat, 1972a,b), K (McNaught, 1958), and S (Haynes, 1980). This poor competition for nutrients by legumes is possibly due to root morphology (Evans, 1977). Fertilization of pastures with P, K, and S can increase total dry matter production and percent legume in the sward (Haynes, 1980). Inputs of mineral nitrogen disadvantages clover relative to grasses (Nuttall et al., 1980; Thornley et al., 1995). Another important source of nutrients in pastures is nutrient recycling by livestock through wastes (Wolton, 1963). Livestock urine contains nitrogen and K, while livestock feces contain K, Ca, Mg, and some nitrogen (Watkin and Clements, 1974). Feces tend to stimulate legume growth by providing P when P is limiting, while urine tends to stimulate grass growth by providing nitrogen (Brougham, 1959).

Competition for water also affects the yield and composition of grass/legume mixtures. Important factors influencing competition for water are the rate and extent of soil exploitation by roots and a plant's ability to regulate water loss (Turner and Begg, 1973). Fertilization can increase water use efficiency of pastures, based on the theory that an increase in vegetation will help retain moisture in the soil (Browning, 1973). In general, grasses tend to be less affected by drought than legumes. Possible explanations as to why grasses are generally less affected by limits in water, as compared to legumes, include a greater extent of soil exploration by a more extensive root system

(Evans, 1977 and 1978) and depth of rooting (Burch and Johns, 1978). Also suggested, is the ability of grasses to remain dormant during long periods of water stress, during which legumes may die (Haynes, 1980).

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Chapter III

Yield and Botanical Composition of Matua Prairie Grass-Legume Mixtures with and without Nitrogen Fertilization

ABSTRACT

Matua prairie grass is a short-lived perennial grass with high fall yield potential. Matua prairie grass also has the potential to extend the grazing season, as it grows in cool weather during early spring and late fall. An experiment was conducted at Whitethorne, VA to investigate the yield and morphological compatibility of Matua prairie grass with various legumes. In 1998, four legumes, ladino clover (*Trifolium repens*), red clover (*Trifolium pratense)*, alfalfa (*Medicago sativa*), and annual lespedeza (*Lespedeza stipulacea*), were drilled into an existing stand of Matua prairie grass sod (established in 1994) at the rate of 2.5, 5.6, 11.2, and 19.0 kg/ha, respectively. Nitrogen treatments were also imposed at a rate of 0 or 84 kg/ha applied each September. In 1998, the legume establishment year, legume treatments had no effect on percent Matua prairie grass. By 1999, the percent Matua prairie grass was reduced by as much as 48 and 51 percent, where grown with ladino clover and red clover, respectively, when compared to the annual lespedeza treatment or Matua prairie grass grown alone. The ladino clover and red clover exceeded 50 percent of the forage components during the spring and early summer months. Alfalfa and annual lespedeza appeared to be compatible with Matua prairie grass, since minimal reduction in percent Matua prairie grass was observed in these treatments, as compared to the reduction observed with the ladino clover and red clover. Nitrogen fertilization increased percent Matua prairie grass by over 30 percent and total dry matter yield by 639 kg/ha, and decreased percent treatment legumes by 9 percent, during October of 1999. The ladino and clover treatments increased total dry matter yield only in the spring of 1999. Legume treatment had no effect on annual total dry matter yields, which averaged 1,363.9 and 984.4 in 1998 and 1999, respectively. Matua prairie grass in combination with alfalfa or annual lespedeza has the potential to be a good forage source for early spring or late fall grazing.

INTRODUCTION

Matua prairie grass (Matua), *Bromus willdenowii* (Kunth) is a short-lived perennial grass capable of high forage production, has the ability to grow at cool temperatures, and is suited for early spring and late fall grazing. Matua has the potential to extend the grazing season, since it grows earlier in the spring and later in the fall than most other cool season grass species (LaCasha et al., 1999). Jung et al. (1994) found Matua was highly productive in the fall, with fall dry matter yield exceeding 7 Mg/ha. Any forage crop that extends the grazing season could decrease feed costs and increase animal performance.

Matua has a bunch-type growth and is very palatable, including the seed heads, which are produced with every harvest. Matua has been found to have persistence problems. However, natural reseeding and tillering are known to increase its persistence. Defoliation management is also critical in maintaining Matua stands. Matua stands are weakened if defoliation occurs too frequently, due to insufficient energy reserves for regrowth (Bell and Ritchie, 1989; Jung et al., 1994). Too infrequent defoliation is also detrimental to Matua, due to reduced seedling and tiller survival, because of excessive shading from the forage canopy (Jung et al., 1994). Proper management of defoliation frequencies, either by livestock grazing rotations or hay harvests, is critical in terms of long-term stand survival. Matua was originally intended for use in a rotational grazing system with lax defoliation Rumball (1974). A 40 to 50 day rest period between defoliations is recommended (Bell and Ritchie, 1989). However, Matua is less sensitive to cutting height than frequency (Bell and Ritchie, 1989). Also, Jung et al. (1994) found that a 40 day cutting frequency at a 7.5 cm cutting height was necessary to obtain optimal fall yields, but advised against stockpiling. However, little is known about the compatibility of Matua grown in combination with legumes.

The value of the addition of legumes to a stand of grass is well known. Legumes increase the protein content and digestibility of mixed forage (Schultz and Stubbendieck, 1983). Livestock performance can be improved when legume components in pastures are increased (Fairey and Lefkovitch, 1990). Maintaining legumes in grass/legume mixed pastures is important, since legumes increase the nutritional quality and long term sustainability of mixed species swards (Turner et al., 1998). The incorporation of legumes into a grass sward can benefit producers by increasing soil and water conservation and reducing weeds, because of increased ground coverage (Casler and Walgenbach, 1990). Also, grass/legume mixtures have the potential to have higher yields than monocultures of either component (Casler and Walgenbach, 1990; Haynes, 1980).

Differences in habit, regrowth, and physiological growth requirements make management of grass/legume mixtures difficult (Casler, 1988). These differences make it difficult to maintain the proper proportions of each component in the grass/legume mixture (Casler, 1988). Also, many recommendations for grass/legume mixtures are based on monocultures, which leads to errors in developing suitable mixtures (Casler and Walgenbach, 1990). Species that are highly productive in monocultures are often incompatible in mixtures (Casler and Drolsom, 1984). Therefore, the compatibility of Matua with legumes is of interest, due to the potential of legumes to benefit Matua stands, but is not well documented. Additionally, the influence of nitrogen fertilization is of interest, since Matua has high fall yield potential (Jung et al., 1994) and is responsive to nitrogen fertilization (Cameron et al., 1969). However, nitrogen fertilization has been found to be detrimental to legumes (McAuliffe et al., 1958). The potential growth of cool season legumes is highest in the spring; therefore, the influence of a fall nitrogen application on the legume components is of interest.

The overall objective of this research was to investigate the agronomic adaptability and yield of Matua. Specific objectives include:

1) To evaluate the morphological compatibility of Matua with various legumes.
2) To compare the yield performance of Matua in pure stands versus mixed with legumes.
3) To investigate the influence of a single fall nitrogen application on the botanical composition, yield, and quality of the Matua and legume mixtures.

METHODS AND MATERIALS

In 1994, Matua was established at the seeding rate of 39.2 kg/ha, at the Kentland Research Farm near Blacksburg, Virginia. One year after establishment, the stand was used for a cutting frequency experiment. From 1995 through 1997, Matua was allowed to reseed itself once each growing season to adequately maintain the stand. The site was at an elevation of 550 m and the soil type was Shottower cobbly loam (two to seven percent slope). In May of 1998, treatments consisting of two levels of nitrogen (0 and 84 kg/ha applied each September, immediately following harvest) in combination with four different legumes were imposed.

The treatment legumes consisted of ladino clover (*Trifolium repens*), red clover (*Trifolium pratense)*, alfalfa (*Medicago sativa*) (hay type), and annual lespedeza (*Lespedeza stipulacea*). In May of 1998, legumes were drilled into the existing stand of Matua sod at the rate of 2.5, 5.6, 11.2, and 19.0 kg/ha, for ladino clover, red clover, alfalfa, and annual lespedeza, respectively. Also, control plots containing no legume treatments were included in the experimental design. All treatment plots were 1.83 m by 7.62 m. Treatments were arranged in a randomized split block design, and replicated four times. After seeding, plots were mowed frequently to ensure successful legume establishment. After legumes were established (approximately June 1998), a sampling interval of approximately 28 days was used. The stands were harvested in June, July, August, September, and November of 1998. In 1999, samples were obtained in May, June, July, September, October, and December. The stands were not harvested in October of 1998, because of low forage production, and in August of 1999 to allow for natural reseeding.

Botanical composition and yield were determined by clipping two 0.25-m^2 quadrats per treatment within each replication, prior to each harvest, to a residual stubble height of 7.6 cm. After obtaining samples for the determination of botanical composition, the entire stand was mowed to a residual stubble height of 7.6 cm, and all clippings were removed from the plots to allow for even regrowth and prevent thatch build up. Samples were hand separated into grass species (Matua versus other grasses), legume species (treatment legume versus other legumes), broadleaf weed species, and dead material components. These components were dried in a forced air oven at 65°C and weighed. Percentage of each component and total yield were calculated on a dry matter basis. All dried samples were saved for subsequent quality determination.

Data analysis

Statistical analysis was performed using the JMP software (a product of SAS Institute) (JMP, 1996). Data for November 1998 were analyzed separately from the rest of the 1998 harvests, since it was the only harvest in 1998 to receive a nitrogen treatment. For June through September 1998 data, analysis of variance was calculated, testing the effects of block, legume treatment, harvest month, and all interactions. For November 1998 data, analysis of variance was calculated, testing the effects of block, legume treatment, nitrogen treatment, and all interactions. For 1999 data, analysis of variance was calculated, testing the effects of block, legume treatment, nitrogen treatment, harvest month, and all interactions. Means were then compared to find significant differences. The Student's t test was performed if comparing only two means, and the Tukey-Kramer Honestly Significant Difference (HSD) test was performed if comparing multiple means. Significance was declared at the $P < 0.05$ level.

RESULTS AND DISCUSSION

Weather

Total rainfall was higher for the 1998 growing season (934 mm) compared with 1999 (890 mm), but lower than the 30 year average (938 mm) (Fig. 1). During the months of January through June, and again in August, monthly precipitation was greater in 1998 than 1999, and was also greater than the 30 year average (Fig. 1). However, in the months of July and September, precipitation in 1998 was lower than in 1999, as well as the 30 year average. During the months of October through December in both 1998 and 1999, precipitation was lower than the 30 year average. Precipitation in November of 1998 was the lowest recorded that year, while the precipitation for 1999 was lowest in June.

Legume effect on Matua prairie grass percentage

From June through September 1998, which was the establishment year, the percentage Matua in the stands was not affected by legume treatments (Fig. 2). However, percent Matua was higher in spring and fall months, as compared to midsummer (harvest date effect). During November 1998, which was after the September nitrogen application, no effect due to legume treatment was observed. Average percentage Matua during November 1998 was 6 percent.

However, by 1999, the legume treatments had an effect on the percentage Matua (Fig. 3). In May, the percentage Matua was reduced ($P<0.05$) from 81 percent where it was grown alone and 75 percent where it was grown with annual lespedeza to 33, 30, and 48 percent where it was grown with ladino clover, red clover, and alfalfa, respectively. During the month of June, ladino clover reduced ($P<0.05$) the percentage Matua to 13 percent compared to 38 percent, where Matua was grown with annual lespedeza. There were no differences among the other legume treatments. For the remainder of the growing season in 1999, legume treatments had no effect on the percentage Matua in the stands. Percentage Matua from July to December ranged from 20 to 52 percent (harvest date effect).

A legume treatment x harvest date interaction was observed for 1999 data. During May, the legume treatments of ladino clover, red clover, and alfalfa reduced ($P<0.05$) percentage Matua as compared to annual lespedeza and Matua grown alone. In June, only the ladino clover treatment resulted in a reduction ($P<0.05$) in percentage Matua.

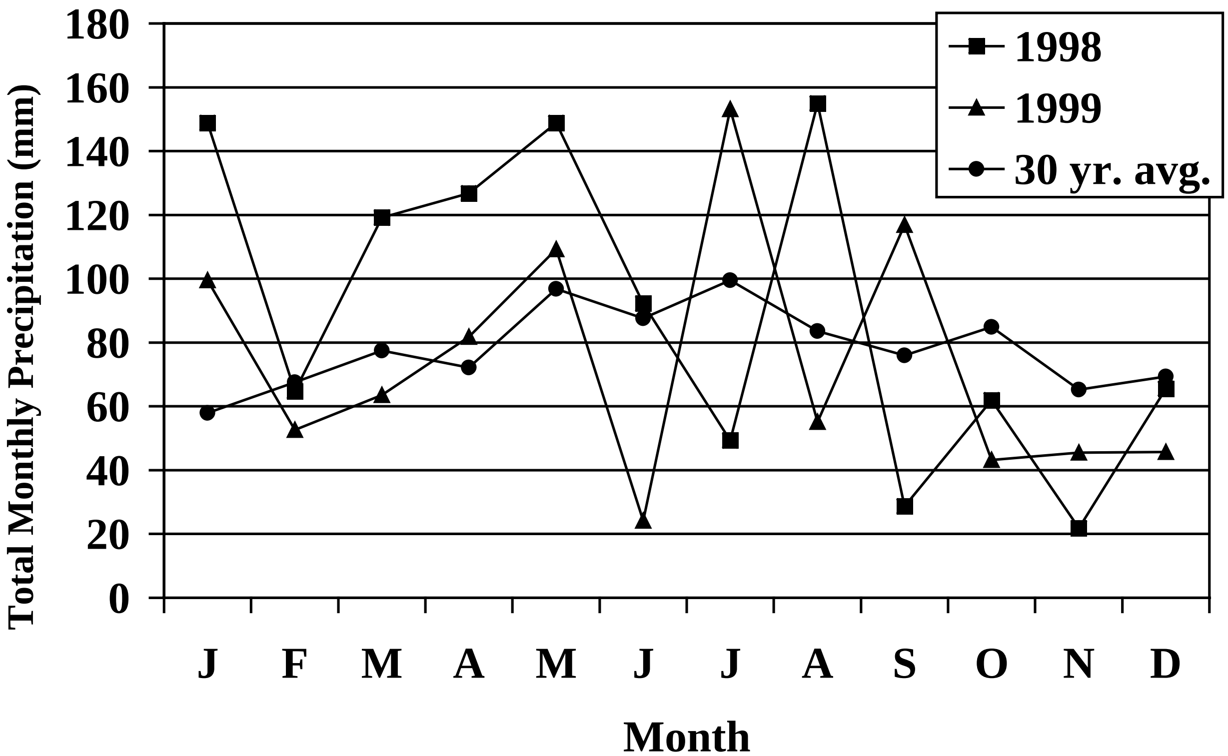

Fig. 1. Monthly precipitation (mm) for the 1998 and 1999 growing seasons and the long term average precipitation at the Kentland Research Farm, Whitethorne, Virginia.

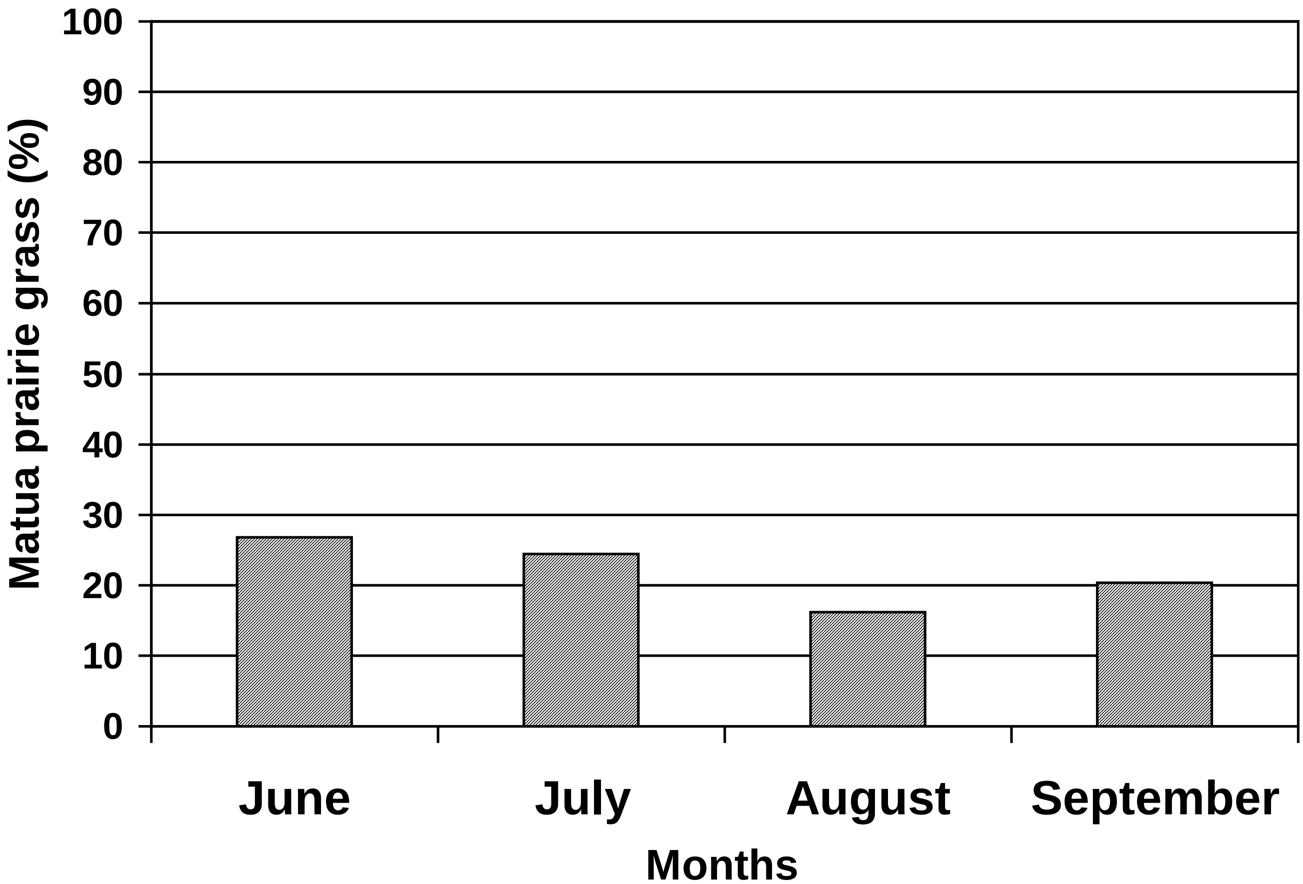

Fig. 2. Mean percentage Matua prairie grass by months: 1998.

Legume treatment effect not significant.
Harvest date effect (P < 0.01).

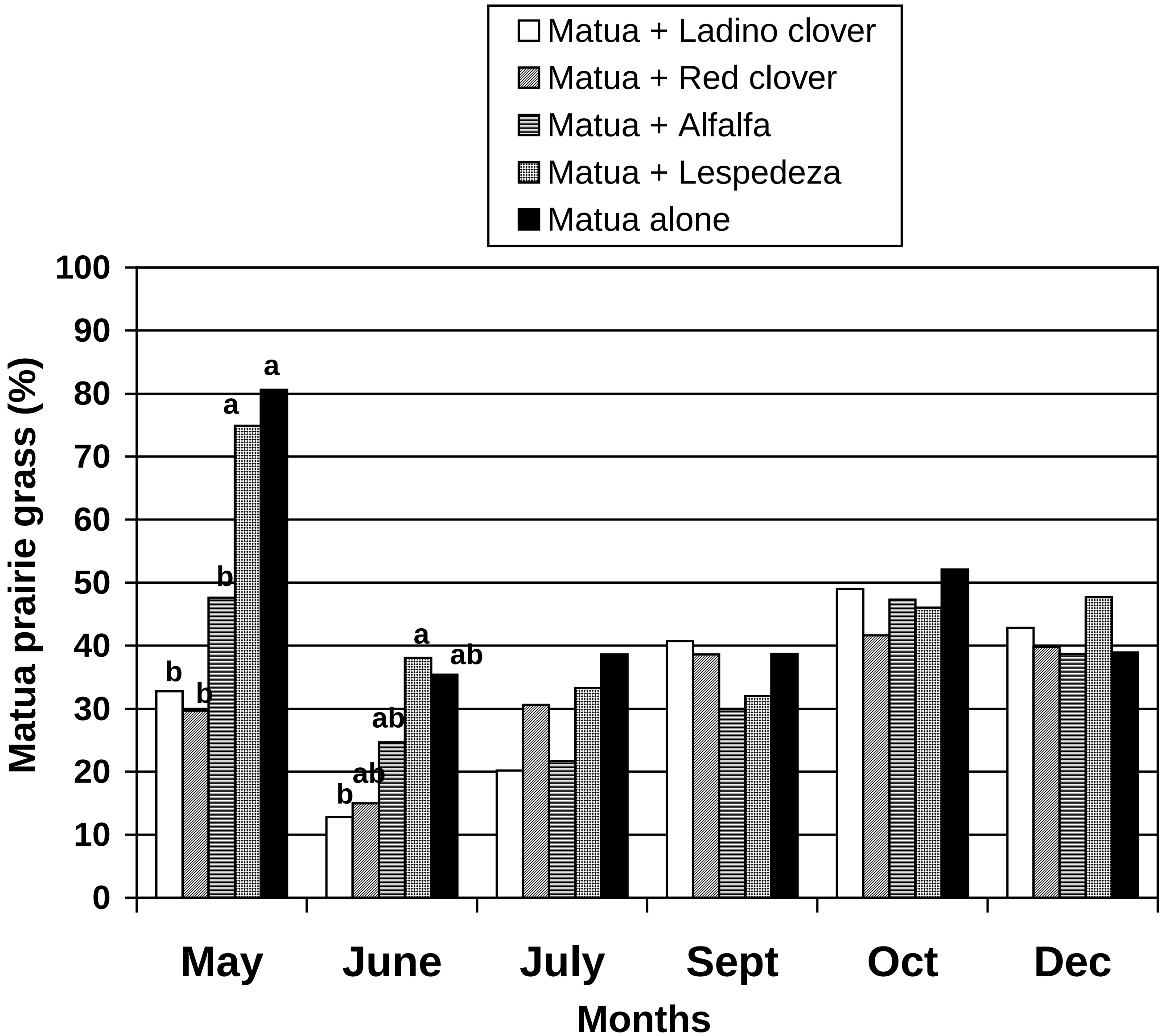

Fig. 3. The effect of legume treatments on percentage Matua prairie grass by months: 1999. Means for bars within months followed by the same letters are not significantly different ($P < 0.05$) (Tukey-Kramer HSD).

Harvest date effect ($P < 0.0001$)
Legume treatment * harvest date interaction ($P < 0.0001$).

During the remainder of 1999, no differences in percentage Matua due to legume treatments were observed.

Legume percentage in mixtures

In 1998, the establishment year, as the growing season progressed, the newly seeded legumes increased in their respective treatment plots (Fig. 4). In June, the percentage legume in the red clover treatment was higher ($P<0.05$) than the rest of the legume treatments. However, in July, the percentage red clover was only higher ($P<0.05$) than the percentage alfalfa. In June and July, the amounts of treatment legumes present were less than 12 percent in all instances. Toward the end of the summer, annual lespedeza, being a warm season legume, was found in a higher percentage than the other legumes. The highest amount of annual lespedeza (33 percent) was observed in September and was higher ($P<0.05$) than all other legume treatments. The gradual increase in the cool season legume components throughout the growing season and the appearance of annual lespedeza during the summer months, with the highest amount observed in September, resulted in a legume treatment x harvest date interaction.

In November of 1998, after the September nitrogen application, averaged over nitrogen treatments, percentage legume in the ladino clover treatment was higher (14 percent) than the alfalfa treatment (4 percent) or the annual lespedeza treatment (Fig. 5). The red clover treatment contained 13 percent and only differed ($P<0.05$) from the annual lespedeza treatment. No measurable amount of annual lespedeza was found during this sampling period. In November, a legume treatment x nitrogen treatment interaction was present (Fig 6). Nitrogen treatment resulted in an overall reduction in percentage legumes, with the exception of annual lespedeza, as no annual lespedeza was observed in either nitrogen treatment. Also nitrogen fertilization impacted the ladino clover and alfalfa to a greater extent than the red clover.

By 1999, the legumes were well established, and in some months, exceeded 60 percent of the forage components (Fig. 7). In May and June, ladino and red clover were higher ($P<0.05$) than the alfalfa and lespedeza treatments (ladino clover and red clover ranged from 49 to 65 percent). In July, ladino clover was higher ($P<0.05$) than alfalfa and annual lespedeza, but not the red clover treatment. Annual lespedeza, a warm season forage, was first observed in July. In September, annual lespedeza treatment contained higher ($P<0.05$) percentage legume than all other legume treatments. Also during 1999, a harvest date effect and a legume treatment x harvest date interaction occurred. Generally, the treatment legume components were higher in the spring as compared to the

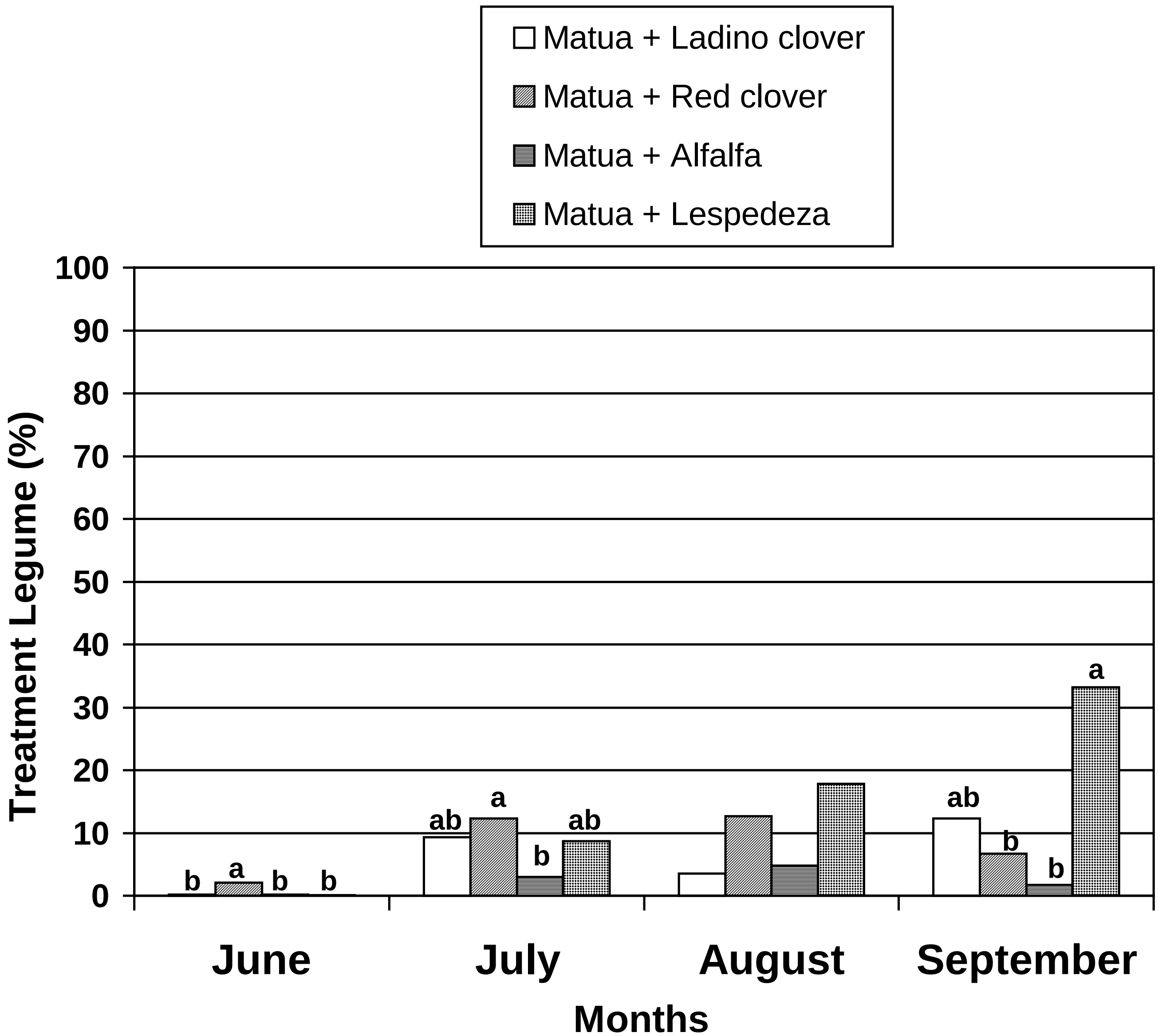

Fig. 4. The effect of legume treatments on percentage treatment legume by months: 1998. Means for bars within months followed by the same letters are not significantly different ($P < 0.05$) (Tukey-Kramer HSD).

Harvest date effect ($P < 0.0001$).
Legume treatment * harvest date interaction ($P < 0.0001$).

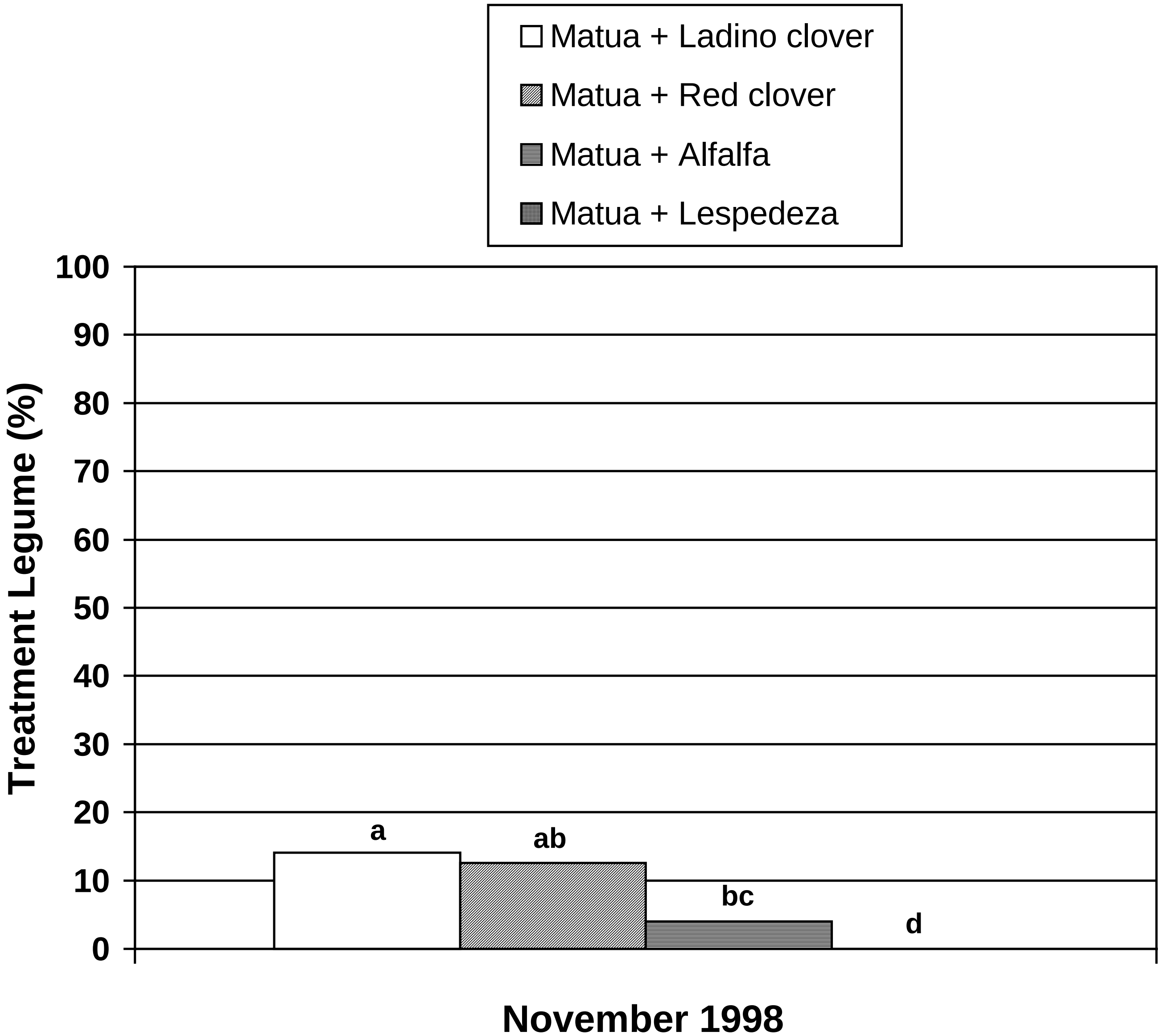

Fig. 5. The effect of legume treatments on percentage treatment legume: November 1998. Means for bars followed by the same letters are not significantly different (P<0.05) (Tukey-Kramer HSD).

Nitrogen treatment * legume treatment interaction (P < 0.001).

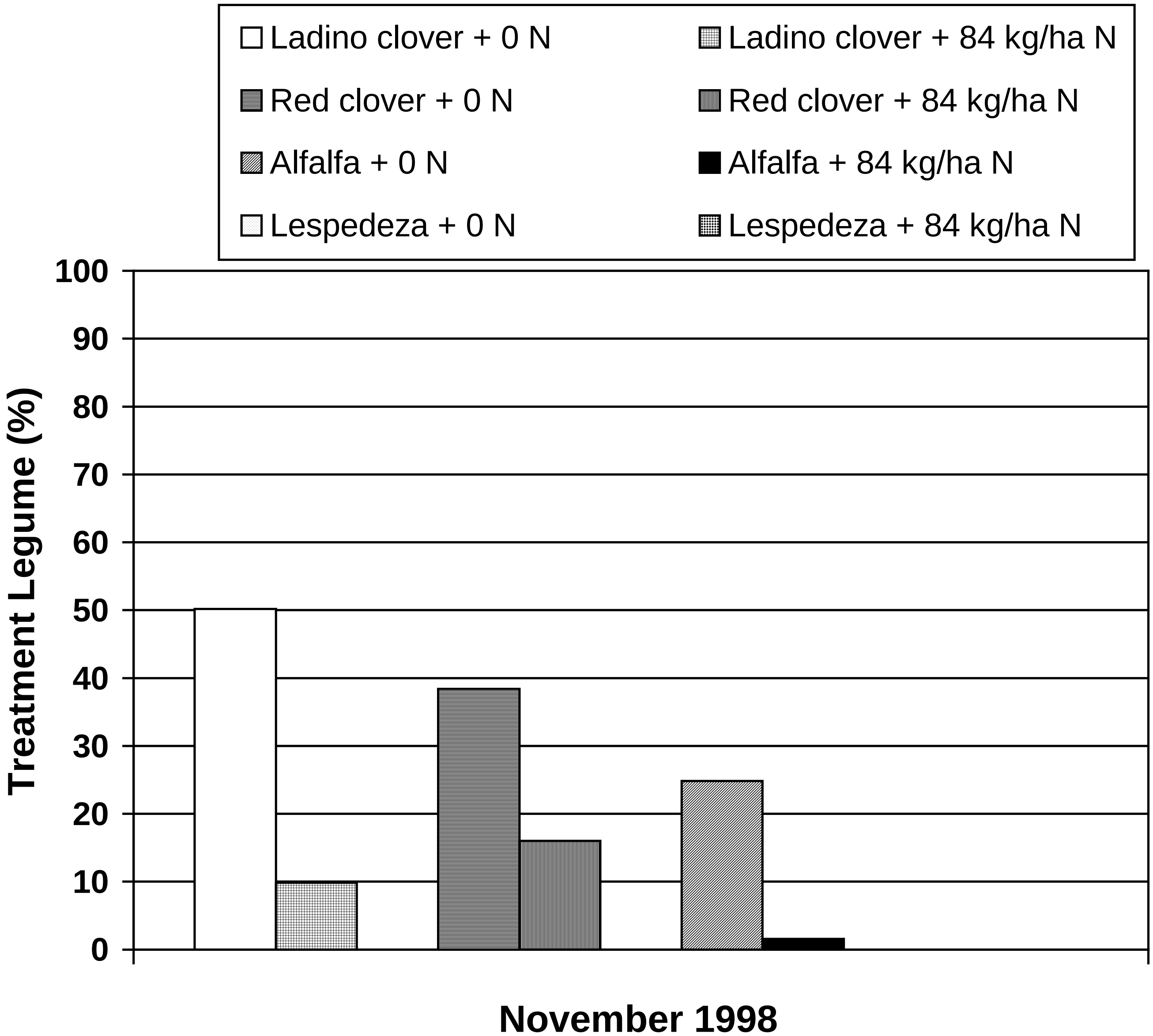

Fig. 6. The effect of legume and nitrogen treatment interactions on percentage treatment legume: November 1998.

Nitrogen treatment * legume treatment interaction ($P < 0.001$).

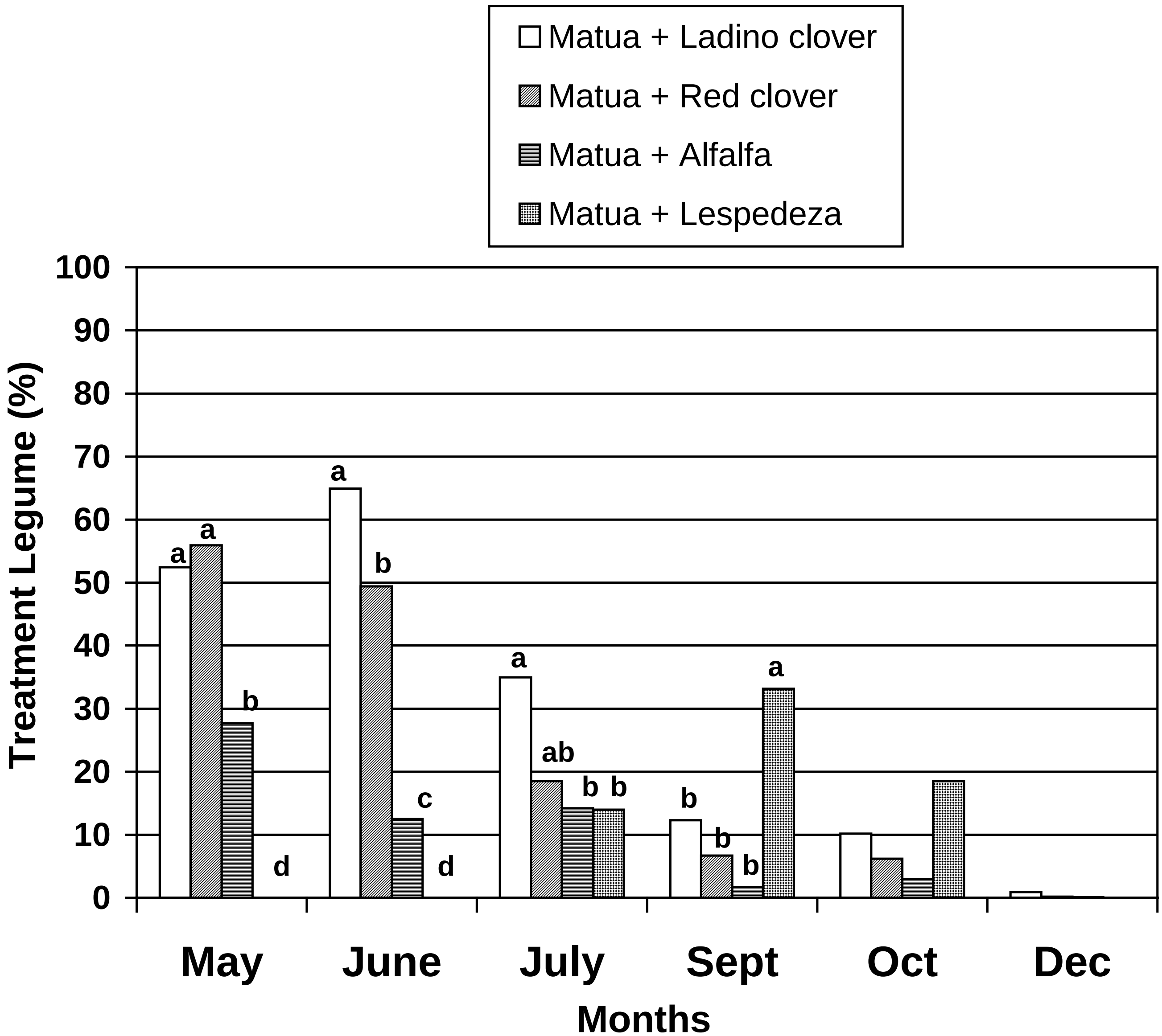

Fig. 7. The effect of legume treatments on percentage treatment legume by months: 1999. Means for bars within months followed by the same letters are not significantly different (P < 0.05) (Tukey-Kramer HSD).

Harvest date effect (P < 0.0001)
Legume treatment * harvest date interaction (P < 0.0001).

remainder of the growing season (harvest date effect). The ladino clover and red clover treatments were present at a higher amount in spring and summer as compared to the other legume treatments, while the annual lespedeza was present at a higher amount than the other legume treatments in September (legume treatment x harvest date interaction).

In general, the percentage treatment legume had an inverse relationship with percentage Matua. The legume treatments that resulted in a higher level of percentage legume also resulted in a lower percentage Matua. Overall, the greatest responses to legume treatments occurred in 1999, where more legumes were present. This was especially true for ladino and red clover treatments, which appear to be the least compatible with Matua. Alfalfa also caused a reduction in the Matua component of the stands, but not to the extent that ladino and red clover did. During some months in 1999, the percentage ladino and red clover exceeded 50 percent. This excessive amount of clover is both incompatible with Matua and could pose a bloat problem with grazing livestock (Ball et al., 1996). However, annual lespedeza component appeared in the plots only during the latter part of the summer, was not present in an excessive amount, and did not cause a reduction in the Matua component. Alfalfa and annual lespedeza appeared to be most compatible with Matua.

Results of other research has had mixed success of maintaining Matua when grown in combination with legumes. In an experiment conducted by Grof et al. (1969), prairie grass (*B. unioloides*) was not able to survive in a stand that also contained ladino clover. However, in several experiments conducted by Cameron et al. (1969) using *B. unioloides* and ladino clover, Pineiro and Harris (1978) using Matua and red clover, and Fulkerson et al. (2000) using Matua and ladino clover, found prairie grass to be compatible with the legumes used in their experiments. The difference in the amounts of prairie grass maintained in the stands in these experiments may be due to management factors employed in those experiments rather than the legume component. The experiments that successfully maintained prairie grass when grown in combination with legumes tended to use livestock to graze the stands instead of mechanical harvesting and tended to have less intensive defoliation intervals (Cameron et al., 1969; Pineiro and Harris, 1978; Fulkerson et al., 2000).

The defoliation method we used (mechanical defoliation) may have actually caused an increase in the legume component. Close and frequent defoliation can give legumes a competitive advantage (Butler et al., 1959; Brougham, 1959; Sucking, 1975). If defoliation height was higher, or if the interval between defoliations was increased, the competitive advantage may be shifted in favor of

Matua. A more infrequent defoliation frequency would allow Matua to recover better from defoliation and allow for quicker regrowth (Bell and Ritchie, 1989; Jung et al., 1994), due to leaving more carbohydrate reserves (Fulkerson et al., 2000). A higher defoliation height would also give Matua an advantage (Jung et al., 1994). A higher cutting height and less frequent defoliation would permit the grasses to more efficiently shade the legume component (Haynes, 1980). Perhaps the excessive level of legumes could also be controlled through the use of grazing livestock. Livestock tend to selectively graze legumes, which can cause a reduction in the legume component and favor grasses (Thornley et al., 1995; Watkin and Clements, 1974). Prior research with prairie grass and legumes has generally found that grazing by livestock does permit prairie grass to be maintained in the stands (Cameron et al., 1969; Pineiro and Harris, 1978; Fulkerson et al., 2000). Potential future work involving a grazing study evaluating the compatibility and grazing selection of Matua and various legumes by livestock would be of interest.

The overall productivity of both cool season grasses and legumes is relatively lower during the summer months compared with spring and fall. However, research had shown that yield potential of cool season legumes during midsummer is much lower than that of cool season grasses during the same time period. Burch and Johns (1978) conducted an experiment evaluating the water uptake, physiological responses to water deficit, and root absorption of water in white clover (*T. repens*) and tall fescue (*Festuca arundinacea*). They found that the legume had poor water use efficiency and was a poor competitor for water, as compared to the grass. This may explain why a greater drop in legume components, as compared to Matua, was observed during the summer months.

Nitrogen treatment effect on Matua prairie grass component

Although not significant in May of 1999, the effect of residual nitrogen on Matua was evident (Fig. 8). In June, however, no evidence of residual nitrogen effect on Matua was observed. This can be attributed to the lowest amount of rainfall being recorded for the month of June, as compared to any other month in 1999 and the 30 year average. In July, September, and October, nitrogen fertilization increased percentage Matua (Fig. 8). The increase in Matua observed in July and September can be attributed to the residual nitrogen from the September 1998 application, while the increase in percentage Matua observed in October was due to the most recent nitrogen application (September, 1999).

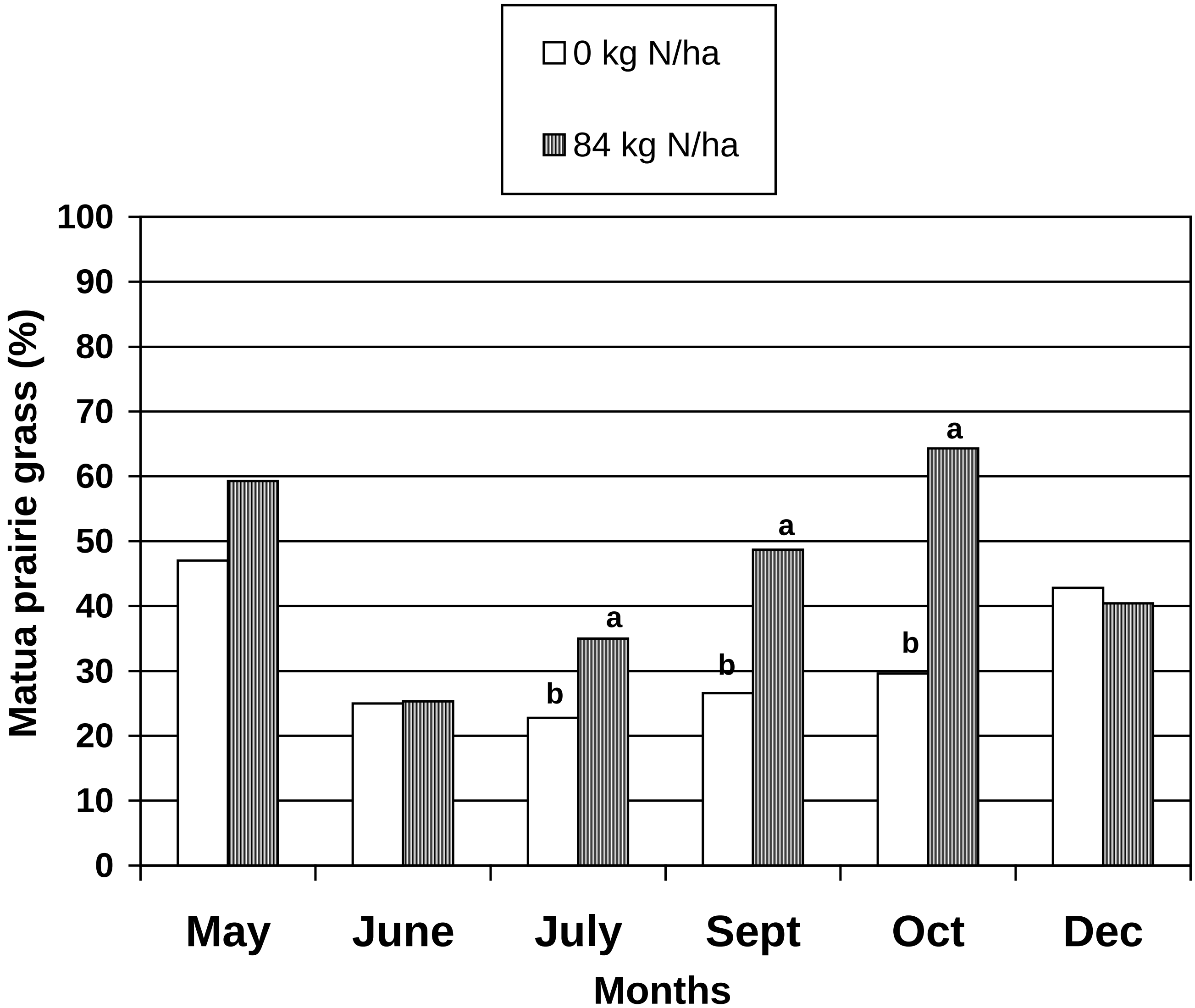

Fig. 8. The effect of nitrogen treatments on percentage Matua prairie grass by months: 1999. Means for bars within months followed by the same letters are not significantly different ($P < 0.05$) (Tukey-Kramer HSD).

Harvest date effect ($P < 0.0001$)
Nitrogen treatment * harvest date interaction ($P < 0.0001$)

Nitrogen fertilization increased percentage Matua over the untreated control by 45 and 52 percent in September and October, respectively. The lack of differences in percentage Matua due to nitrogen treatments during the months of May, June, and December, and the increase in percentage Matua observed in the fertilized stands during July, September, and October resulted in a nitrogen treatment x harvest date interaction.

Previous research has found Matua to be very responsive to nitrogen fertilization (Cameron et al., 1969; Vartha, 1977). Vartha (1977) found that Matua yielded up to 12,000 kg/ha/year when grown with nitrogen fertilization, and Matua out yielded other grass species grown in the same experimental conditions, when compared. Cameron et al. (1969) found that fertilized stands of prairie grass yielded approximately 4,100 kg/ha, while unfertilized controls yielded approximately 850 kg/ha.

Nitrogen treatment effect on legume percentage

Although nitrogen fertilization in September 1998 tended to reduce the percent of treatment legumes in the stands in 1999, the effect was not significant (Fig 9). However, nitrogen fertilization in September 1999 led to a significant decrease ($P<0.05$) in the percentage legumes present in October, as compared to unfertilized stands (nitrogen treatment x harvest date interaction). The percentage treatment legumes, on average, in the unfertilized stands were 13 percent, as compared to 3 percent in the nitrogen fertilized stands.

The general reduction in treatment legumes due to nitrogen fertilization can be expected. The suppressive effect of nitrogen fertilization has been documented (McAuliffe et al., 1958). The nitrogen fixation ability of legumes is suppressed by nitrogen fertilization (McAuliffe et al., 1958). Generally, legumes have an advantage in nitrogen deficient environments, while grasses tend to have an advantage in nitrogen fertilized environments (Camlin, 1981) due to the ability of grasses to more efficiently absorb and utilize applied nitrogen (Nuttall et al., 1980; Thornley et al., 1995).

Nitrogen fertilization could also be used as a method to control the excessive legume component, since the percentage treatment legumes were reduced as a result of nitrogen fertilization. Nitrogen fertilization tends to suppress legumes and gives grasses a competitive advantage (McAuliffe et al., 1958). Although one of the purposes of incorporating legumes in a grass sward is to reduce nitrogen fertilizer application, it may be practical to apply a moderate amount of nitrogen once every year or two in order to suppress legumes if they become excessive.

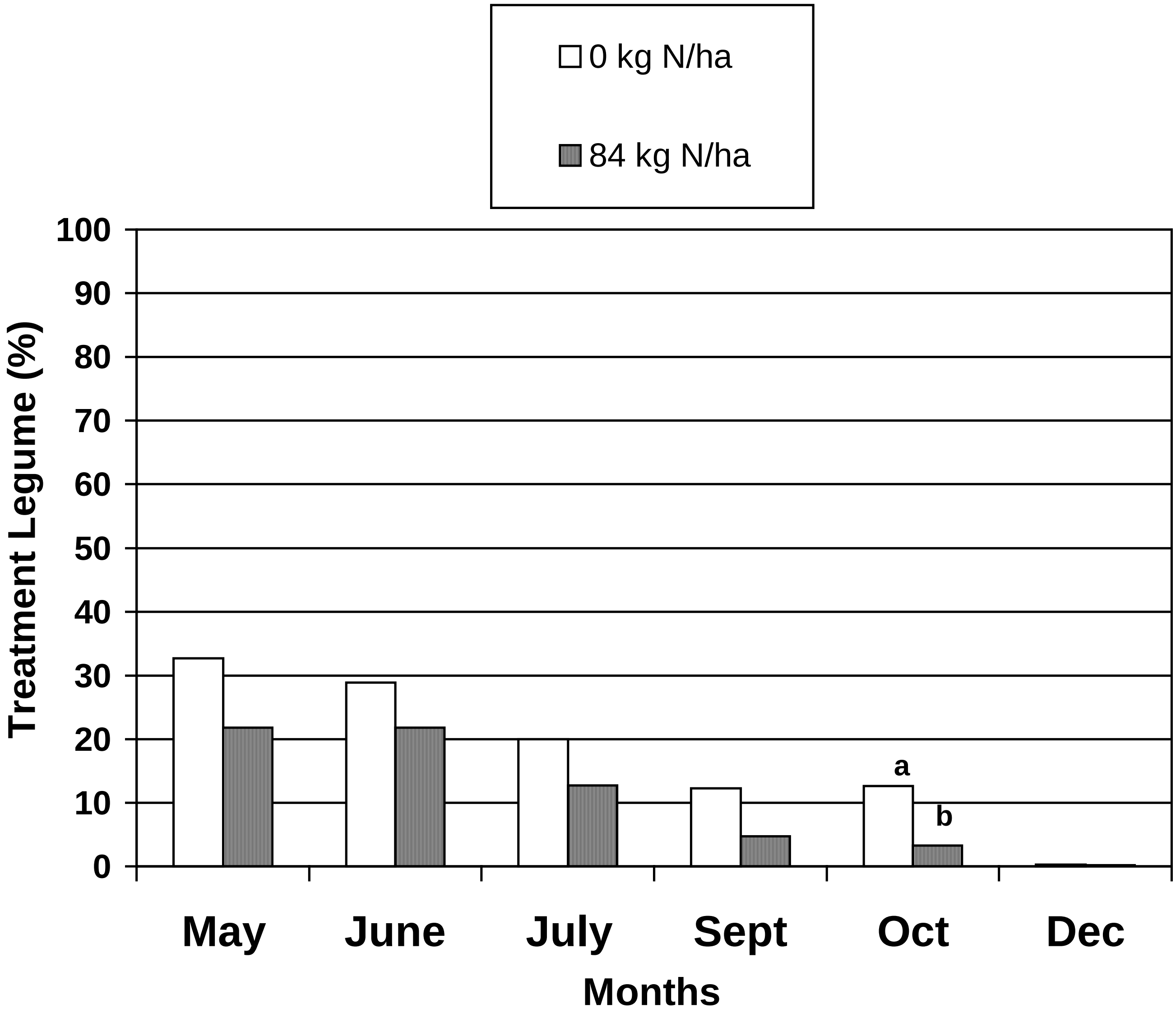

Fig. 9. The effect of nitrogen treatments on percentage treatment legume by months: 1999. Means for bars within months followed by the same letters are not significantly different ($P < 0.05$) (Tukey-Kramer HSD).

Harvest date effect ($P < 0.0001$)
Nitrogen treatment * harvest date interaction ($P < 0.001$)

Other components

Legume treatments had no effect on percentage other grasses, other legumes, weeds, and dead material in 1998 (Appendix A, Tables 1 and 2). In November 1998, nitrogen treatments had no effect on percentage Matua, treatment legume, other legume, and weeds. However, there was an effect on other grasses and dead material components (Appendix A, Table 3). In 1999, legume and nitrogen treatments had an effect on other legumes and dead material, but no effect on other grasses and weeds (Appendix A, Tables 4 and 5).

Total dry matter yield

In 1998, legume treatments had no effect on yield (Fig. 10). From June through September, yield ranged from 792 to 1,540 kg/ha (harvest date effect). In November of 1998, no effect of legume treatments on yield was observed; however, the effect of nitrogen on yield was evident (Fig. 11). Nitrogen fertilization increased yield by 47 percent, from 1,843 kg/ha where no nitrogen was applied to 2,711 kg/ha where 84 kg/ha nitrogen was applied.

In 1999, legume treatments influenced yield only in the months of May and June (Fig. 12) (legume treatment x harvest date interaction). In May, ladino clover and red clover treatments had higher ($P<0.05$) yields (1,797 and 2,032 kg/ha, respectively), as compared to alfalfa, annual lespedeza, and Matua grown alone. In June, only the ladino clover treatment increased ($P<0.05$) yield, as compared to the other legume treatments. In the remaining months in 1999, there was no effect of legume treatment on yield, and yields ranged widely, from 374 kg/ha to 1515.5 kg/ha (harvest date effect). In May and June, some treatment legumes comprised over 50 percent of the stands. In July and September, legumes comprised less than 40 percent of the stands, while in October and December legume components dropped to less than 20 percent of the stands. These amounts of legumes could explain the influence that legume treatments had on yield.

In 1999, there was an effect of nitrogen fertilization on yield (Fig. 13). In May, which is 8 months after the prior fall's nitrogen application, although not significant, a residual effect of nitrogen on yield was evident. In June, there was no increase in yield due to nitrogen fertilization, but this may be explained by the considerably below average precipitation during that month. In July and September, again almost a year after the initial nitrogen application, an increase in yield due to nitrogen fertilization was observed ($P<0.05$). However, the response to nitrogen fertilization was greatest in the month of October (1,033 and 1,672 kg/ha for 0 and 84 kg/ha nitrogen rates, respectively), which was immediately after the September 1999 application. The October yield in

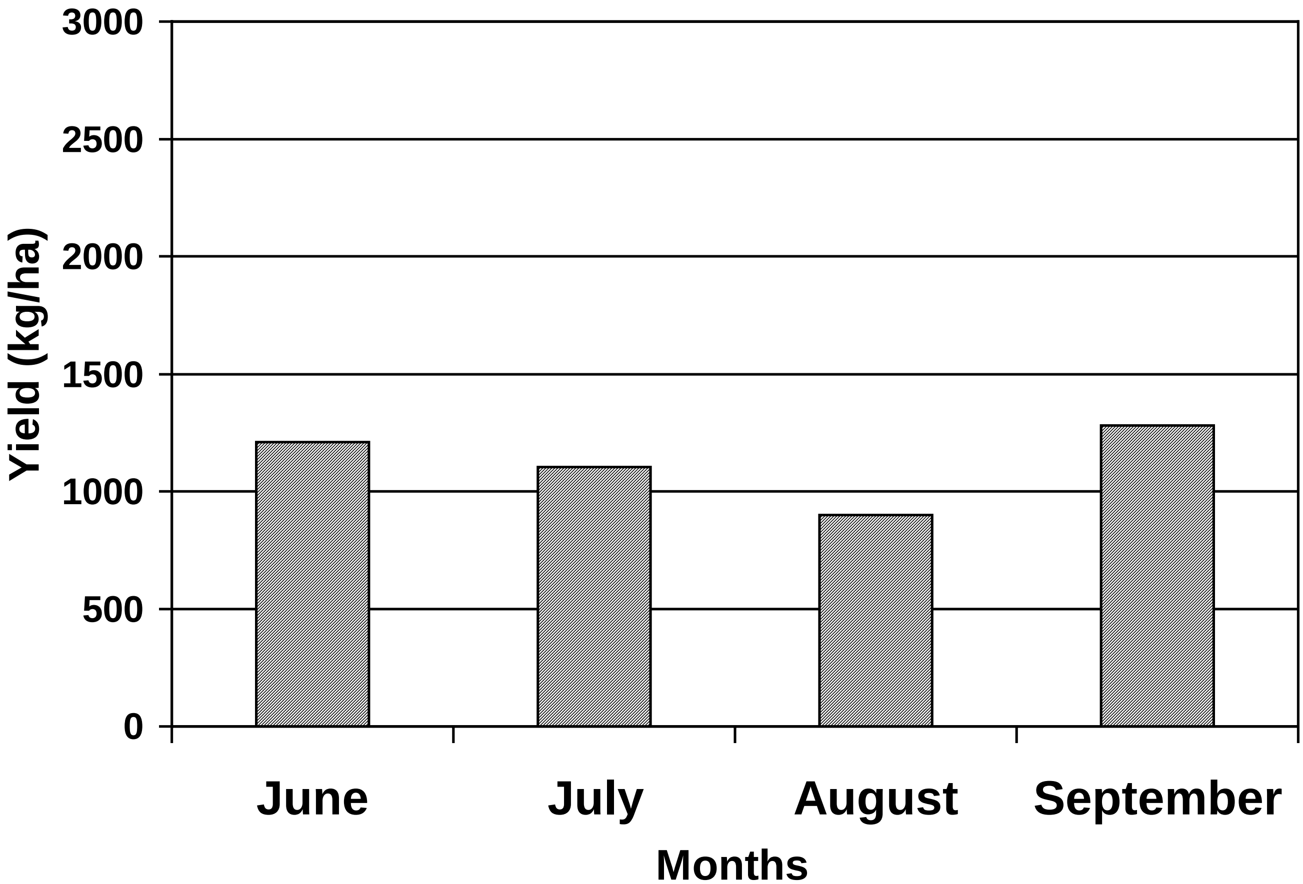

Fig. 10. Mean total dry matter yield (kg/ha) by months: 1998.

Legume treatment effect not significant.
Harvest date effect ($P = 0.001$).

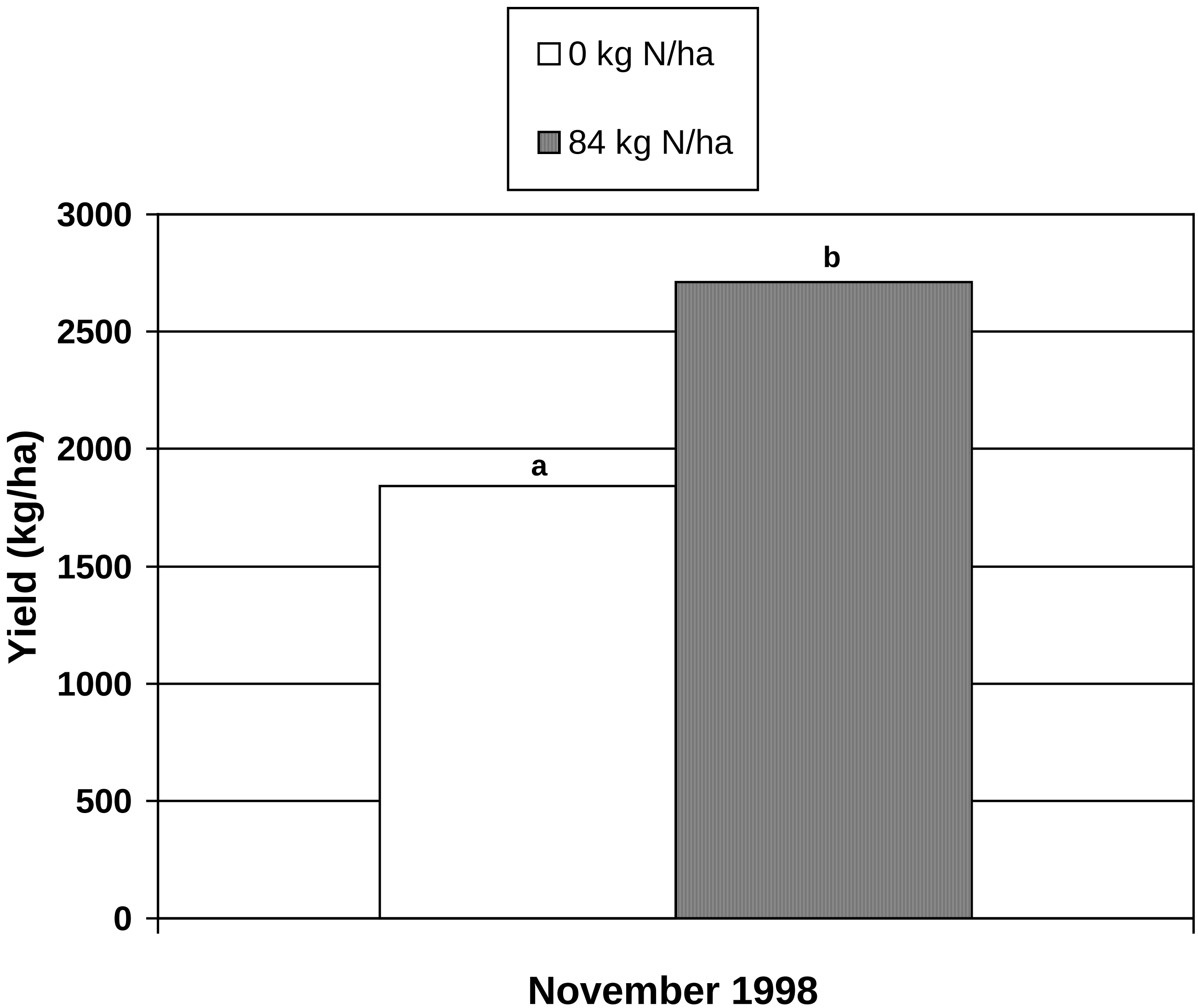

Fig. 11. The effect of nitrogen treatments on yield (kg/ha): November 1998. Means for bars followed by the same letters are not significantly different ($P<0.05$) (Tukey-Kramer HSD).

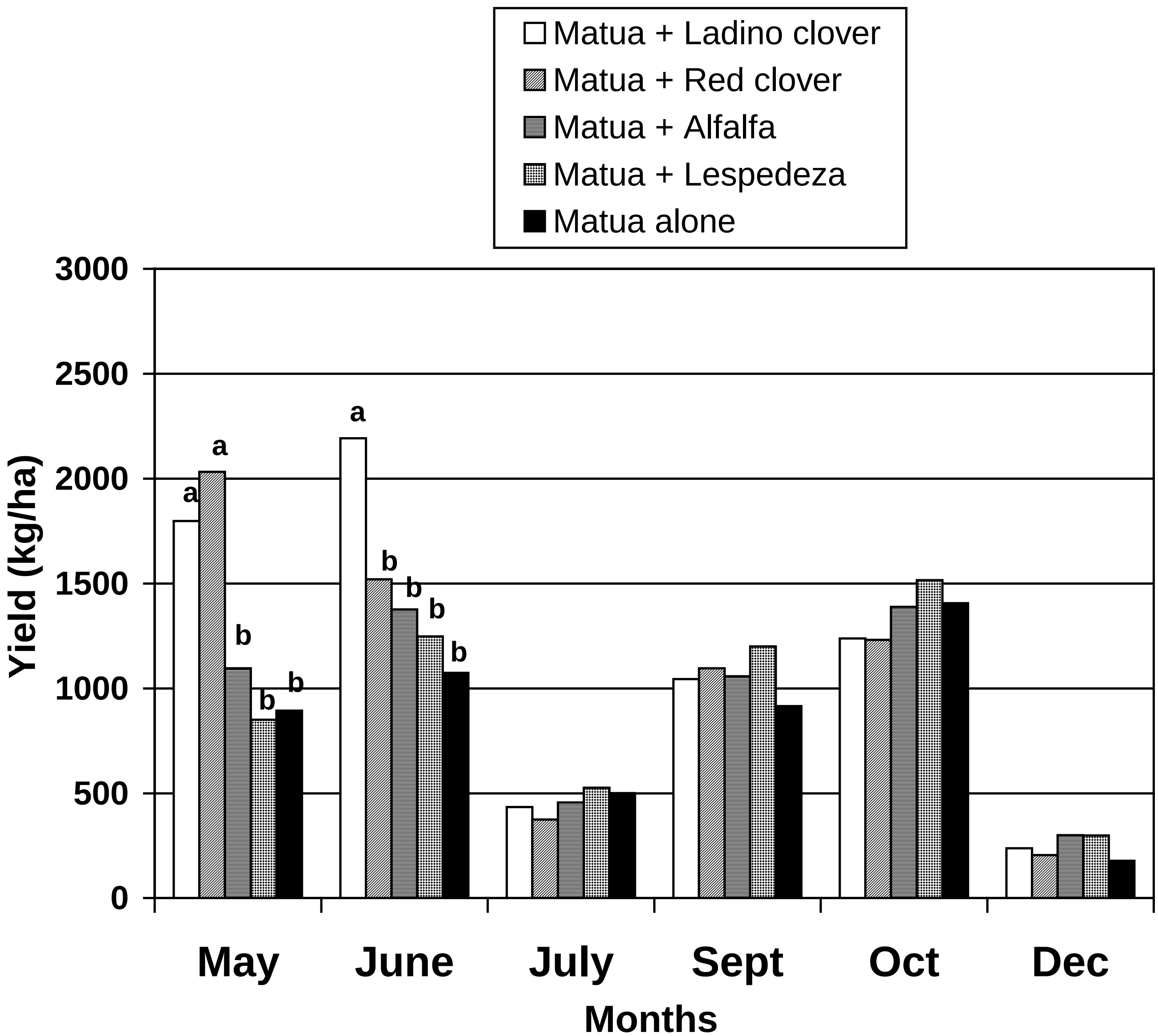

Fig. 12. The effect of legume treatments on yield (kg/ha) by months: 1999. Means for bars within months followed by the same letters are not significantly different (P < 0.05) (Tukey-Kramer HSD).

Harvest date effect (P < 0.0001)
Legume treatment * harvest date interaction (P < 0.0001).

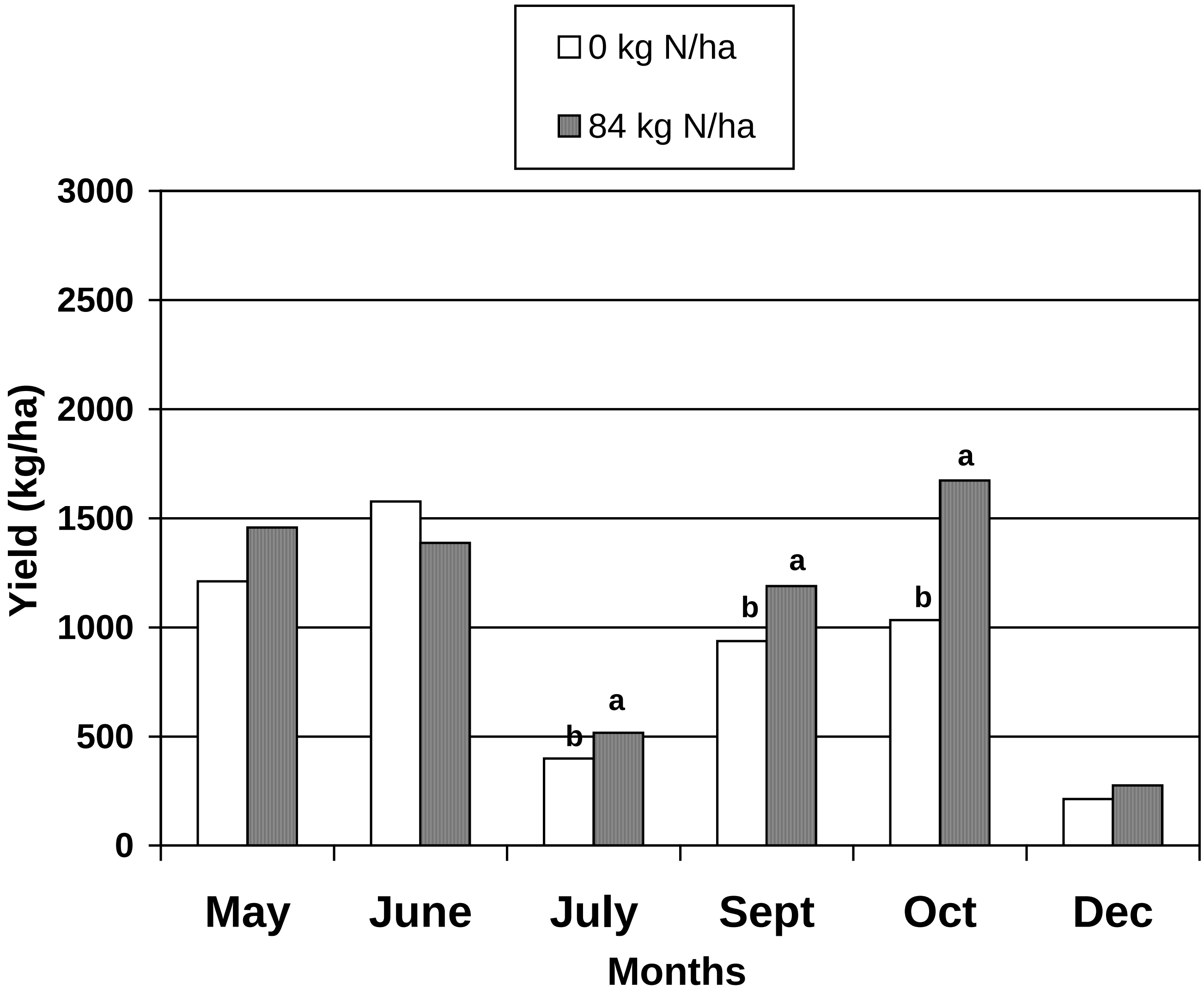

Fig. 13. The effect of nitrogen treatments on yield (kg/ha) by months: 1999. Means for bars within months followed by the same letters are not significantly different ($P < 0.05$) (Tukey-Kramer HSD).

Harvest date effect ($P < 0.0001$)
Nitrogen treatment * harvest date interaction ($P < 0.001$)

the nitrogen fertilized treatment was higher than in any other month in 1999. The lack of differences due to nitrogen treatment observed in May, June, and December, and the increases observed in July, September, and October in the fertilized stands resulted in a nitrogen treatment x harvest date interaction. Also, in June, the nitrogen fertilized stands had a numerically lower yield, but was not significant.

Annual total dry matter yields were not influenced by legume treatments in either 1998 or 1999 (Table 1). Annual total dry matter yields averaged 1363.9 and 984.4 in 1998 and 1999, respectively. The lower yield observed for 1999 may be explained by the lower amount of rainfall observed in 1999, as compared to 1998 or the 30 year average (Fig. 1).

In regard to Matua's ability to produce higher yield in the fall and its response to nitrogen fertilization, our results were similar to the results of other research. Jung et al. (1994) obtained higher yields in the fall as compared to spring. Fall yields observed by Jung et al. (1994) averaged 7 to 8 Mg/ha as compared to average spring yields of 4.0 Mg/ha. Cameron et al. (1969) found that *B. unioloides* was highly responsive to a single fall nitrogen application, where nitrogen fertilized stands yielded 4,094 kg/ha as compared to unfertilized stands which yielded 853 kg/ha. Vartha (1977) also compared the total dry matter yields of Matua to ryegrass (*Lolium perenne*), timothy (*Phleum pratense*), and orchardgrass (*Dactylis glomerata*). Each grass species received nitrogen on a monthly basis. Vartha (1977) found that Matua had annual yields of over 8 Mg/ha and had higher yields than the other grass species.

Table 1. Mean annual total dry matter yield (kg/ha), by year: 1998 and 1999.

Year	Legume treatment	Yield (kg/ha)	Average
1998	ladino clover	1225.8	1363.9
	Red clover	1455.4	
	Alfalfa	1279.2	
	Annual lespedeza	1514.1	
	None	1345.2	
1999	ladino clover	1157.3	984.4
	Red clover	1076.2	
	Alfalfa	946.0	
	Annual lespedeza	939.7	
	None	802.9	

Legume treatment effect not significant.

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Chapter IV

Chemical Composition of Matua Prairie Grass-Legume Mixtures with and without Nitrogen Fertilization

ABSTRACT

An experiment was conducted at Whitethorne, VA to evaluate the nutritive value of Matua prairie grass/legume mixtures. Ladino clover (*Trifolium repens*), red clover (*Trifolium pratense)*, alfalfa (*Medicago sativa*), and annual lespedeza (*Lespedeza stipulacea*) were seeded into a Matua prairie grass stand in May of 1998. Nitrogen was applied each fall at a rate of either 0 or 84 kg/ha. Samples were obtained on a monthly basis during the 1998 and 1999 growing seasons. Botanical composition, yield, and forage quality (fiber components, CP, and IVDMD) were evaluated. During 1998, few differences in fiber components, CP, and IVDMD, due to legume treatments, were found as a result of the low percentage of legumes in the stand. However, by 1999, differences in percentage fiber components were observed as a result of the greater legume component of the forage. Generally, the ladino clover and red clover treatments resulted in lower ($P<0.05$) NDF, ADF, hemicellulose, and cellulose as compared to the annual lespedeza treatment or Matua prairie grass grown alone. An increase ($P<0.05$) in CP was observed in the ladino clover and red clover treatments in May and June of 1999. Alfalfa did impact the chemical composition of the Matua prairie grass/legume mixtures, however, to a lesser extent than the clover treatments, and was more comparable to the annual lespedeza treatment or Matua prairie grass grown alone. Also, IVDMD was similarly influenced by legume treatments. The impact of nitrogen fertilization on fiber components, CP, and IVDMD had mixed results. In general, during the spring and summer months, when a residual effect from the prior fall's nitrogen application resulted in legume suppression, the nutritive value of the forage declined. However, in the fall, immediately after nitrogen application, a decrease ($P<0.05$) in ADF was observed in 1998, and increases ($P<0.05$) in CP and IVDMD were observed in nitrogen fertilized stands in both years. Overall, ladino clover and red clover improved the nutritive value of the Matua prairie grass/legume mixed forage.

INTRODUCTION

The importance of the incorporation of legumes into a grass pasture is well known. Legumes have the potential to increase the overall quality and digestibility of forages and also increase the crude protein content of the grass component of the mixture (Schultz and Stubbendieck, 1983). Improvements in livestock production have been realized when legume components in forages were increased (Fairey and Lefkovitch, 1990).

In a study conducted by LaCasha et al. (1999), Matua prairie grass (Matua) (*Bromus willdenowii*) hay was evaluated as a potential feed source for horses, and compared to alfalfa (*Medicago sativa*) and bermudagrass (*Cynodon dactylon*) hays in a horse digestion and palatability study. Matua was intermediate in quality when compared to the alfalfa and bermudagrass forages and was found to have 13.5, 62.4, 36.1, and 12 percent crude protein, neutral detergent fiber, acid detergent fiber, and total nonstructural carbohydrates, respectively. Mineral content of Matua was also evaluated and was found to have Ca, Mg, and P levels of 0.49, 0.27, and 0.18 percent, respectively. Apparent digestibility of dry matter, crude protein, neutral detergent fiber, acid detergent fiber, and in vitro dry matter digestibility were also evaluated and found to be 51, 74, 47, 20, and 58 percent, respectively. Matua was intermediate in voluntary dry matter intake during the digestion trial. However, during the subsequent palatability study, the authors found that voluntary dry matter intake of the three hays was influenced greatly by the type of hay the horses had been fed in the previous digestion trial. The authors concluded that Matua is an acceptable forage for horses and should meet nutritional requirements of yearling horses in terms of protein and most minerals.

The objectives of this experiment were to investigate the quality of Matua in pure stands versus mixed with legumes, and to investigate influence of a single fall nitrogen application on the quality of these mixtures.

METHODS AND MATERIALS

In May of 1998, treatments consisting of four legumes and two levels of nitrogen (0 and 84 kg/ha applied each September, after sampling) were imposed. The treatment legumes consisted of ladino clover (*Trifolium repens*), red clover (*Trifolium pratense)*, alfalfa (*Medicago sativa*) (hay type), and annual lespedeza (*Lespedeza stipulacea*). Legumes were drilled into a four year old stand of Matua sod at the rate of 2.52, 5.60, 11.20, and 19.04 kg/ha, for ladino clover, red clover, alfalfa, and annual lespedeza, respectively. Treatments, including a control with no legume treatment, were arranged in a randomized split block design and were replicated four times. All treatment plots were 1.83 m by 7.62 m. After the legumes were established (approximately June 1998), a sampling interval of approximately 28 days was used. Samples were obtained in June, July, August, September, and November of 1998, and May, June, July, September, October, and December of 1999. October of 1998 and August of 1999 forages were not harvested due to a lack of forage production from drought or to allow for natural reseeding of Matua to maintain adequate stands. Forages sampled in December of 1999 were not analyzed to determine quality, because of an inadequate amount of forage sample.

As described in Chapter 3, samples were obtained from two 0.25-m^2 quadrats, per treatment within replication, on a monthly basis for botanical composition and yield determination. The different components of these same samples were combined, dried at 65°C in a forced air oven, and ground to pass through a 1 mm mesh screen in a stainless steel Wiley mill (Thomas Wiley, Laboratory Mill Model 4, Arthur H. Thomas Co., Philadelphia, PA.). The samples were analyzed for dry matter (DM) (AOAC, 1990), neutral detergent fiber (NDF) (Van Soest and Wine, 1967), and acid detergent fiber (ADF) (Van Soest, 1963). Hemicellulose was calculated by difference (Van Soest and Wine, 1967). Lignin and cellulose were also determined (Goering and Van Soest, 1970). In vitro dry matter digestibility (IVDMD) was determined by using the first stage of the two-stage method of Tilley and Terry (1963) as an estimate of ruminal digestibility of the forage. Kjeldahl acid digestion technique (AOAC, 1990) was used to digest the samples. Total N was determined colorimetrically with an autoanalyzer by flow injection analysis (Lachat Instruments Inc., 1996). Total nitrogen was used to calculate crude protein (CP) (AOAC, 1990). All chemical composition values are reported on a dry matter basis.

Data analysis

Statistical analysis was performed using the JMP software (a product of SAS Institute) (JMP, 1996). Data for November 1998 were analyzed separately from the rest of the 1998 harvests, since it was the only harvest in 1998 to have received a nitrogen treatment. For June through September 1998 data, analysis of variance was calculated, testing the effects of block, legume treatment, harvest month, and all interactions. For November 1998 data, analysis of variance was calculated, testing the effects of block, legume treatment, nitrogen treatment, and all interactions. For 1999 data, analysis of variance was calculated, testing the effects of block, legume treatment, nitrogen treatment, harvest month, and all interactions. Means were then compared to find significant differences. The Student's t test was performed if comparing only two means, and the Tukey-Kramer Honestly Significant Difference (HSD) test was performed if comparing multiple means. Significance was declared at the $P < 0.05$ level.

RESULTS AND DISCUSSION

Effect of Legume Treatments on Fiber Components

There were no significant differences in fiber components in June, July and September 1998, as the result of the small percentage of legumes present in the forage components. During these months, legumes comprised less than 35 percent of the forage components. However, in August 1998, NDF, ADF, hemicellulose, and cellulose values were higher ($P<0.05$) in the alfalfa/Matua mixture and Matua grown alone than in the red clover/Matua mixture, while no differences were found among the other legume treatments (Table 1) (legume treatment x harvest date interaction). During the establishment year (1998), alfalfa rarely exceeded more than 5 to 10 percent of the botanical composition. This explains why fiber components of alfalfa/Matua mixture were similar to Matua grown alone. In August, differences in lignin were found. The annual lespedeza treatment had a higher ($P<0.05$) lignin content than the other legume treatments. During 1998, fiber components were generally higher during the months of June and August than in the remainder of the growing season (harvest date effect).

In November of 1998, mixtures of Matua with alfalfa or annual lespedeza had higher ($P<0.05$) NDF values than Matua mixtures with ladino clover or red clover, and no differences were found among the other treatments (Table 2). Percent hemicellulose was greater ($P<0.05$) in the alfalfa treatment than in the ladino clover and red clover treatments. Also, cellulose values in the annual lespedeza treatment and Matua grown alone were higher ($P<0.05$) than in the ladino clover treatment. No differences in ADF and lignin values were observed.

In 1999, differences in fiber components due to legume treatments were observed (Table 3). In May, the annual lespedeza treatment and Matua grown alone had higher ($P<0.\ 05$) NDF values (59.9 and 59.2 percent, respectively), as compared to alfalfa (50.7 percent), ladino clover (39.6) and red clover (43.6 percent) treatments. In June, NDF values were higher ($P<0.05$) in the annual lespedeza legume treatment and Matua grown alone (59.6 and 60.1 percent, respectively) than the ladino clover and red clover treatments (41.1 and 46.5 percent, respectively). In July, the alfalfa and annual lespedeza treatments and Matua grown alone had higher ($P<0.05$) percentages NDF (58.9, 57.6, and 59.7 percent, respectively) than the ladino clover

Table 1. Legume treatment effect on fiber components, DM basis, of Matua prairie grass/legume mixtures by months, 1998.

Component[1]	Legume treatment	Month			
		June	July	Aug	Sept.
		---------------%---------------			
NDF*	Ladino clover	59.4	59.4	61.0ab[2]	54.6
	Red clover	61.0	58.0	58.8b	56.9
	Alfalfa	60.2	61.1	64.5a	56.7
	Annual lespedeza	63.2	61.2	62.0ab	54.7
	None	62.1	62.3	64.5a	59.4
ADF*	Ladino clover	35.4	34.1	34.4ab	32.9
	Red clover	35.4	33.7	33.6b	32.8
	Alfalfa	34.6	35.5	35.8a	33.1
	Annual lespedeza	37.0	35.5	35.4ab	33.7
	None	36.2	35.5	35.9a	35.1
Hemicellulose*	Ladino clover	24.1	25.4	26.6ab	21.8
	Red clover	25.6	24.2	25.2b	24.1
	Alfalfa	25.6	25.5	28.7a	23.6
	Annual lespedeza	26.2	25.8	26.6ab	21.0
	None	25.9	26.8	28.6a	24.3
Cellulose*	Ladino clover	29.7	29.1	29.1ab	27.1
	Red clover	29.9	28.8	28.3b	27.5
	Alfalfa	29.8	30.4	30.3a	27.7
	Annual lespedeza	31.7	30.3	29.5ab	27.5
	None	31.0	30.4	30.4a	29.5
Lignin* ŧ	Ladino clover	3.4	3.1	3.4b	3.8
	Red clover	2.8	3.2	3.5b	3.3
	Alfalfa	2.4	3.1	3.4b	3.3
	Annual lespedeza	2.8	2.7	4.2a	4.2
	None	3.1	3.2	3.4b	3.5

[1]Abbreviations: Neutral detergent fiber (NDF), Acid detergent fiber (ADF).
[2]Means within months followed by the same letters are not significantly different ($P < 0.05$) (Tukey-Kramer HSD).
*Harvest date effect ($P<0.05$).
ŧ Legume treatment x harvest date interaction ($P<0.05$).

Table 2. Legume treatment effect on fiber components, DM basis, of Matua prairie grass/legume mixtures: November 1998.

Component[1]	Legume treatment	
		----%----
NDF	Ladino clover	50.4b[2]
	Red clover	49.6b
	Alfalfa	58.2a
	Annual lespedeza	57.8a
	None	56.6ab
ADF	Ladino clover	31.8
	Red clover	31.9
	Alfalfa	33.5
	Annual lespedeza	36.1
	None	35.0
Hemicellulose	Ladino clover	19.7b
	Red clover	18.2b
	Alfalfa	25.0a
	Annual lespedeza	22ab
	None	22.6ab
Cellulose	Ladino clover	24.1b
	Red clover	25.4ab
	Alfalfa	27.5ab
	Annual lespedeza	28.9a
	None	28.4a
Lignin	Ladino clover	3.0
	Red clover	3.8
	Alfalfa	3.4
	Annual lespedeza	4.8
	None	3.3

[1]Abbreviations: Neutral detergent fiber (NDF), Acid detergent fiber (ADF).
[2]Means followed by the same letters are not significantly different ($P < 0.05$) (Tukey-Kramer HSD).

Table 3. Legume treatment effect on fiber components, DM basis, of Matua prairie grass/legume mixtures by months, 1999.

Component[1]	Legume treatment	May	June	July	Sept	Oct
		----------	----------	%	----------	----------
NDF*t	Ladino clover	39.6c[2]	41.1c	50.6b	63.8a	56.2
	Red clover	43.6c	46.5bc	55.6ab	61.2ab	59.0
	Alfalfa	50.7b	54.0ab	58.9a	60.3ab	59.5
	Annual lespedeza	59.9a	59.6a	57.6a	54.1b	57.1
	None	59.2a	60.1a	59.7a	58.1ab	58.2
ADF*t	Ladino clover	26.5c	30.1c	33.2ab	35.7	31.7
	Red clover	27.8c	32.4bc	31.7b	35.5	33.2
	Alfalfa	29.5b	33.6ab	35.7a	34.9	34.8
	Annual lespedeza	33.7a	35.1a	35.3a	33.3	33.7
	None	31.8ab	35.0a	35.3a	34.0	33.9
Hemicellulose*t	Ladino clover	13.1c	11.0c	17.3b	28.1a	24.5
	Red clover	15.8c	14.1bc	23.8a	25.7ab	25.7
	Alfalfa	21.2b	20.5ab	23.2a	25.5ab	24.7
	Annual lespedeza	26.3a	24.5a	22.3a	20.8b	23.4
	None	27.4a	25.0a	24.4a	24.1ab	24.3
Cellulose*t	Ladino clover	23.0c	24.6c	26.2bc	29.8	25.4
	Red clover	23.4c	26.2bc	25.7c	28.5	26.9
	Alfalfa	25.0bc	27.6ab	28.8ab	28.8	27.8
	Annual lespedeza	28.9a	29.5a	28.4abc	26.6	26.9
	None	27.7ab	29.3a	29.4a	27.8	27.5
Lignin*	Ladino clover	1.7b	3.7	5	3.7	4.3
	Red clover	2.3ab	4.3	3.9	4.7	4.2
	Alfalfa	2.5ab	3.7	5.1	4.2	5.0
	Annual lespedeza	2.7a	3.4	4.2	4.7	4.8
	None	2.0ab	3.7	3.9	4.3	4.4

[1]Abbreviations: Neutral detergent fiber (NDF), Acid detergent fiber (ADF).
[2]Means within months followed by the same letters are not significantly different (P < 0.05) (Tukey-Kramer HSD).
*Harvest date effect (P<0.05).
tLegume treatment x harvest date interaction (P<0.05).

treatment (50.6 percent). However, by September, only the ladino clover and annual lespedeza treatments differed ($P<0.05$) (63.8 and 54.1 percent, respectively). In October, no differences in percentage NDF were found. The differences between the highest and lowest mean NDF values were 34.3, 31.6, 15.2, and 15.2 percent, for May, June, July, and September, respectively (harvest date effect). During May and June, over 50 percent of the forage components were ladino clover and red clover, as reflected by the greatest reduction in NDF values (legume treatment x harvest date interaction).

Similar differences, such as those in the NDF values, were observed during each month for the ADF, hemicellulose, and cellulose values (Table 3). In terms of lignin, however, only in May the annual lespedeza treatment contained higher ($P<0.05$) lignin than the ladino clover treatment (2.7 and 1.7 percent, respectively). In general, the annual lespedeza treatment and Matua grown alone tended to have higher fiber component values than the ladino clover and red clover treatments.

Incorporation of a cool season legume in a grass sward can be expected to lower the fiber component values, as a result of the legume's high amount of cell content as compared to cell wall (Van Soest, 1973). In general, ladino clover and red clover treatments influenced the chemical composition of the Matua/legume mixture the most. The fiber components most influenced by the ladino clover and red clover treatments include NDF, ADF, hemicellulose, and cellulose. Ladino clover decreased ($P<0.05$) NDF and ADF values by as much as 33 and 17 percent, respectively, in May 1999. The higher quality measure observed for the ladino clover treatment can be attributed to its structural and morphological characteristics. Ladino clover has stolons (above ground stems) which remain close to the ground (Sucking, 1975) escaping defoliation. Therefore, the components of the plant that are harvestable are leaflets and petioles, which do not have the same amount of structural components as the stolons (Van Soest, 1982). Alfalfa, in some instances, did impact the chemical composition and improve the quality of the forage, but at an intermediate level.

Lignin was also influenced by the legume treatments, but to a lesser extent. However, in some instances the annual lespedeza treatment had a higher lignin content than the other legume treatments. Annual lespedeza, being a warm season legume, can be expected to contain more lignin and be lower in quality when compared to cool season legumes (Ball et al., 1996). The overall quality of the annual lespedeza treatment, however, was comparable to Matua grown alone.

El Hadj (2000) observed similar results, where the incorporation of a legume into a grass sward lowered fiber components. The author investigated the effects of the incorporation of red clover, alfalfa, sericea lespedeza (*Lespedeza cuneata*), and annual lespedeza on the nutritive value of Caucasian bluestem (Bothriocloa caucasica) and switchgrass (Panicum virgatum), two warm season grass species. Similarly, the legume treatments had no effect on ADF during the establishment year. However, the alfalfa and red clover treatments had lower NDF than the Caucasian bluestem grown alone. By the second growing season of the study, the incorporation of alfalfa resulted in lower NDF and ADF in both types of grasses, as compared to the other legume treatments. Red clover also lowered NDF and ADF as compared to the other legume treatments, but only in the switchgrass stands.

Effect of Nitrogen Treatments on Fiber Components

During November 1998, no differences in NDF, hemicellulose, and cellulose values were observed due to nitrogen treatments, while percent ADF was higher ($P<0.05$) in the unfertilized stands, as compared to the stands that received nitrogen fertilization (Table 4).

An interaction between nitrogen treatment and legume treatments was observed in November of 1998 (Table 5). In the ladino clover and red clover treatments, NDF values increased as a result of nitrogen fertilization, while NDF values decreased as a result of nitrogen fertilization in the other legume treatments. However, nitrogen fertilization had a different effect on ADF values. The ADF values in all legume treatments decreased as a result of nitrogen fertilization, with the greatest response occurring in the annual lespedeza and alfalfa treatment.

In May, June, and July, and again in October of 1999, no differences in NDF and ADF values, due to nitrogen fertilization, were observed (Table 6). However, in September, higher ($P<0.05$) NDF and ADF values were observed in unfertilized stands, as compared to the stands that received nitrogen fertilization (harvest date effect). Differences in cellulose values were observed during the months of June and September. In June, a higher ($P<0.05$) percent cellulose was observed in the fertilized stands; while in September, the opposite effect from nitrogen fertilization was observed (nitrogen treatment x harvest date interaction). The higher cellulose values observed in June can be attributed to the residual effect of the September 1998 nitrogen application on the legume components. No differences in hemicellulose and lignin values were observed, as a result of nitrogen fertilization, during 1999.

Table 4. Nitrogen treatment effect on fiber components, DM basis, of Matua prairie grass/legume mixtures: November 1998.

Component[1]	Nitrogen treatment	
	------------kg/ha ------------	
	0	84
	-----------%----------	
NDF	55.9	53.1
ADF	35.7a[2]	31.6b
Hemicellulose	21.1	21.9
Cellulose	28.5	25.2
Lignin	4.0	3.3

[1]Abbreviations: Neutral detergent fiber (NDF), Acid detergent fiber (ADF).
[2]Means followed by the same letters are not significantly different ($P < 0.05$) (Tukey-Kramer HSD).

Table 5. Legume and nitrogen treatment interaction effects on fiber components, DM basis, of Matua prairie grass/legume mixtures: November 1998.

Component[1]	Legume treatment	Nitrogen treatment	
		0 kg/ha	84 kg/ha
		----------------%---------------	
NDF*	Ladino clover	47.3	53.5
	Red clover	48.6	50.6
	Alfalfa	60.6	55.8
	Annual lespedeza	61.8	53.8
	Matua prairie grass	61.2	51.9
ADF*	Ladino clover	32.6	31.0
	Red clover	33.3	30.4
	Alfalfa	36.1	31.0
	Annual lespedeza	40.3	31.9
	Matua prairie grass	36.3	33.7

[1]Abbreviations: Neutral detergent fiber (NDF), Acid detergent fiber (ADF).

*Nitrogen treatment x legume treatment interaction ($P<0.05$).

Table 6. Nitrogen treatment effect on fiber components, DM basis, of Matua prairie grass/legume mixtures by months, 1999.

Component[1]	Nitrogen treatment	Month				
		May	June	July	Sept	Oct
	--kg/ha--	----------------------	----------	%	----------	----------------------
NDF*t	0	49.2	49.1	55.2	61.7a[2]	58.1
	84	52.0	54.6	57.7	57.3b	57.9
ADF*t	0	29.9	32.4	33.9	35.9a	33.8
	84	29.8	33.9	34.6	33.4b	33.2
Hemicellulose*t	0	19.2	16.7	21.3	25.7	24.3
	84	22.3	20.8	23.2	23.9	24.7
Cellulose*t	0	25.7	26.5a	27.0	29.5a	27.2
	84	25.5	28.2b	28.3	27.1b	26.6
Lignin*	0	2.4	3.9	4.6	4.5	4.4
	84	2.1	3.6	4.3	4.2	4.7

[1]Abbreviations: Neutral detergent fiber (NDF), Acid detergent fiber (ADF).
[2]Means within months followed by the same letters are not significantly different ($P < 0.05$) (Tukey-Kramer HSD).
*Harvest date effect ($P<0.05$).
[t]Nitrogen treatment x harvest date interaction ($P<0.05$).

During 1999, nitrogen treatment x harvest date interactions were also observed for NDF, ADF, and hemicellulose. NDF was higher in the fertilized stands in May, June, and July, while in September and October, NDF was higher in the unfertilized stands. ADF was higher in the fertilized stands in June and July, and higher in the unfertilized stands in May, September, and October. Hemicellulose was higher in the unfertilized stands only in September, and higher in the fertilized stands during the remainder of the growing season.

Nitrogen fertilization impacted the chemical composition and subsequent nutritional quality of the forage. Our data indicated a depression in percentage legume where nitrogen was applied, compared with no nitrogen. McAuliffe et al. (1958) similarly observed a depression of legume components due to nitrogen fertilization, as a result of inhibited nitrogen fixation and stimulation of the grass component. The suppression of legumes by nitrogen fertilization could partially explain nitrogen treatment x legume treatment interactions observed.

Nitrogen fertilization led to a decrease in the fiber components consisting of NDF, ADF, and cellulose. However, the extent at which the nitrogen treatments affected the quality differed from the legume treatments. Similarly, El Hadj (2000) also found that nitrogen fertilization of a Caucasian bluestem stand resulted in a decrease in NDF, but only during the first year of their experiment.

Generally, the fiber component values of Matua grown in a pure stand observed in our experiment were similar to those observed by LaCasha et al. (1999). LaCasha et al. (1999) found the fiber components of Matua to be higher than alfalfa but lower than bermudagrass. The incorporation of legumes with Matua in our experiment resulted in intermediate fiber component values between the values for Matua by itself and alfalfa, as reported by LaCasha et al. (1999).

Effect of Legume Treatments on Crude Protein

June through September of 1998, legume treatments had no effect on CP. Average CP was 12.4, 11.2, 11.2, and 19.2 percent for June, July, August, and September, respectively. In November of 1998, no differences in CP percent, due to legume treatments, were observed (Table 7).

During May of 1999, the ladino clover and red clover treatments had higher ($P<0.05$) CP values (Table 8) than the annual lespedeza treatment and the Matua grown alone. In June, the ladino clover and red clover treatments had higher ($P<0.05$) CP than the Matua grown alone.

Table 7. Legume and nitrogen treatment effects on crude protein content, DM basis, of Matua prairie grass/legume mixtures: November 1998.

	------%------
Legume treatment	
Ladino clover	11.5
Red clover	13.1
Alfalfa	10.0
Annual lespedeza	9.3
None	9.8
Nitrogen treatment	
0 kg/ha	9.5a[1]
84 kg/ha	11.9b

[1] Means followed by the same letters are not significantly different ($P < 0.05$) (Tukey-Kramer HSD).

Table 8. Legume and nitrogen treatment effects on crude protein content[*tt], DM basis, of Matua prairie grass/legume mixtures by months, 1999.

	Month				
	May	June	July	Sept	Oct
	---------------------%------------------------				
Legume treatment					
Ladino clover	20.0a[1]	16.7a	21.2	16.7	18.6
Red clover	18.7a	16.3a	22	15.8	13.7
Alfalfa	16.0ab	14.9ab	16.3	16.9	15.4
Annual lespedeza	11.8b	12.4ab	17.1	17.2	14.9
None	13.2b	11.2b	16.2	18.9	14.5
Nitrogen treatment					
0 kg/ha	16.9	15.3	18	14.5a	13a
84 kg/ha	15.0	13.5	19.1	19.7b	17.9b

[1] Means within months followed by the same letters are not significantly different ($P < 0.05$) (Tukey-Kramer HSD).

[*]Harvest date effect ($P<0.05$).

[t]Nitrogen treatment x harvest date effect ($P<0.05$).

[t] Legume treatment x harvest date effect ($P<0.05$).

The differences observed between the highest and lowest mean CP values were 41 and 33 percent during May and June, respectively. During the remaining months in 1999, no effect of legume treatments on CP values was observed. The higher proportion of legume component resulted in the greater CP values observed during May and June of 1999 (harvest date effect). ladino clover and red clover comprised over 50 percent of the forage components during these two months.

A legume treatment x harvest date interaction was observed for CP during 1999. In May, the ladino clover treatment had higher CP than annual lespedeza treatment or Matua grown alone. In June, the ladino and red clover treatments had higher percent CP than the Matua grown alone. In July, September, and October no differences were observed.

El Hadj (2000) also observed increases in CP content of grass stands as a result of incorporation of legumes. The author found that the incorporation of red clover and alfalfa resulted in higher crude protein as compared to Caucasian bluestem or switchgrass grown alone, while sericea lespedeza and annual lespedeza increased CP at an intermediate amount.

Overall, the CP content of the Matua/legume mixed forage varied widely, when compared to the Matua hay evaluated by LaCasha et al. (1999). Matua grown in pure stands (without legumes) generally had CP values similar to that reported by LaCasha et al. (1999) (13.5 percent). However, the incorporation of legumes in our experiment increased the CP percentage, when compared to the Matua hay reported by LaCasha et al. (1999). This can be expected since legumes tend to have higher percentage CP than grasses. LaCasha et al. (1999) found that alfalfa hay had 20 percent CP, which was greater than the CP value for Matua hay.

Effect of Nitrogen Treatments on Crude Protein

There was an effect of nitrogen application on CP values in November of 1998 (Table 7). Nitrogen fertilized stands had higher ($P<0.05$) CP (11.9 percent) than unfertilized stands (9.5 percent). During May through July of 1999, nitrogen fertilization had no effect on CP values (Table 8). However, nitrogen fertilization effect on CP values in September and October of 1999 was observed (harvest date effect). The CP values were greater ($P<0.05$) in fertilized stands (19.7 and 17.9 percent) as compared to unfertilized stands (14.5 and 13 percent), for September and October, respectively. The increase in CP percent in September, due to nitrogen fertilization, was a residual effect from the previous fall's nitrogen application (September 1998), while the greater CP percent observed in October was due to the recent nitrogen application, which was immediately after the September 1999 harvest. A nitrogen treatment x harvest date interaction was observed for CP in

1999. Generally, CP was higher in unfertilized stands in May and June; while in July, September, and October, CP was higher in fertilized stands.

Fairey and Lefkovitch (1990) found that nitrogen fertilization of a smooth bromegrass (*Bromus inermis*)/alfalfa mixture resulted in an overall increase in total nitrogen content of the mixed forage. However, McAuliffe et al. (1958) observed mixed results from nitrogen fertilization of ladino clover/tall fescue mixtures. The authors found that, at low rates of nitrogen fertilization, total nitrogen content of the mixed forage was decreased as a result of the inhibition of nitrogen fixation in the legume component. However, at higher rates of nitrogen fertilization, the total nitrogen content of the forage increased as the applied nitrogen was substituted for fixed nitrogen by the forage components.

Generally, the Matua grown without nitrogen fertilization had CP values similar to that reported by LaCasha et al. (1999) (13.5 percent). However, nitrogen fertilization of the Matua stands in our experiment increased the CP percentage, when compared to the CP content of the Matua hay reported by LaCasha et al. (1999).

Effect of Legume Treatments on In Vitro Dry Matter Digestibility

Legume treatments had no effect on IVDMD values during June, July, and September of 1998 (Table 9). However, in August of 1998, the red clover treatment had higher ($P<0.05$) IVDMD (59.0 percent) than the annual lespedeza treatment (52.2 percent), while no differences were observed among the other treatments. August had the lowest percentages of IVDMD during 1998 (harvest date effect), which could be expected due to the general decline in the nutritional value of the forage as the proportion of cool season forages to warm season forages shifted. During November of 1998, legume treatments did not affect IVDMD values (Table 10).

By 1999, the legume treatments had an impact on IVDMD (Table 11). In May, the ladino clover treatment had considerably higher ($P<0.05$) IVDMD (72.6 percent) than the annual lespedeza treatment (62.6 percent), while no differences were observed among the other legume treatments. In June, the ladino clover treatment had higher ($P<0.05$) IVDMD (67.7 percent) than the other treatments (range: 58.2 to 60.8 percent). In July, the ladino clover treatment had a higher ($P<0.05$) IVDMD value (59.5 percent) than the alfalfa treatment (51.9 percent). No differences between IVDMD values were observed for the September and October harvests due to treatments.

Table 9. Legume treatment effect on In Vitro Dry Matter Digestibility*, DM basis, of Matua prairie grass/legume mixtures by months, 1998.

Legume treatment	Month			
	June	July	August	September
	----------------------------%------------------------------------			
Ladino clover	66.2	66.3	57.3ab[1]	64.6
Red clover	63.2	65.6	59.0a	65.8
Alfalfa	66.2	65.4	53.9ab	64.5
Annual lespedeza	64.4	64.6	52.2b	62.4
None	65.2	64.6	54.8ab	61.9

[1] Means within months followed by the same letters are not significantly different ($P < 0.05$) (Tukey-Kramer HSD).
*Harvest date effect ($P<0.05$).

Table 10. Legume and nitrogen treatment effects on In Vitro Dry Matter Digestibility, DM basis, of Matua prairie grass/legume mixtures: November 1998.

	------%------
<u>Legume treatment</u>	
Ladino clover	64.9
Red clover	63.4
Alfalfa	57.9
Annual lespedeza	59.3
None	61
<u>Nitrogen treatment</u>	
0 kg/ha	58.5a[1]
84 kg/ha	64.1b

[1] Means followed by the same letters are not significantly different ($P < 0.05$) (Tukey-Kramer HSD).

Table 11. Legume and nitrogen treatment effects on In Vitro Dry Matter Digestibility[*t t], DM basis, of Matua prairie grass/legume mixtures by months, 1999.

	Month				
	May	June	July	Sept	Oct
	---------------------%------------------------				
Legume treatment					
Ladino clover	72.6a[1]	67.7a	59.5a	58.7	68.4
Red clover	66.2ab	60.8b	57.5ab	60.1	63.9
Alfalfa	66.3ab	59.9b	51.9b	59.2	61.3
Annual lespedeza	62.6b	58.2b	54.7ab	61.1	66.3
None	65.4ab	56.8b	57.5ab	62.1	65.9
Nitrogen treatment					
0 kg/ha	67.2	63.3a	56.4	57.8a	61.3a
84 kg/ha	66.0	58.3b	54.9	62.6b	68.9b

[1] Means within months followed by the same letters are not significantly different ($P < 0.05$) (Tukey-Kramer HSD).
[*] Harvest date effect ($P<0.05$).
[t] Nitrogen treatment x harvest date effect ($P<0.05$).
[t] Legume treatment x harvest date effect ($P<0.05$).

The seasonal distribution of cool season legumes might have impacted the nutritive value of the forage, as observed by a wide range of IVDMD values for the various treatments. The cool season legumes that were present in the spring and early summer at a high level in the forage components (over 50 percent for ladino clover and red clover) may have resulted in the highest IVDMD values.

A legume treatment x harvest date interaction was observed in 1999. In May, IVDMD was higher in the ladino clover treatment than the annual lespedeza treatment. In June, IVDMD was higher in the ladino clover treatment than the other legume treatments. In July, the ladino clover treatment had higher IVDMD than the alfalfa treatment. No differences in IVDMD due to legume treatment were observed in September or October.

In this experiment, the incorporation of legumes in a stand of Matua resulted in an increase in IVDMD. LaCasha et al (1999) compared the IVDMD of Matua, alfalfa, and bermudagrass hays. The authors found that Matua had IVDMD of 58 percent, and was intermediate to the IVDMD of alfalfa and bermudagrass, which had IVDMD of 67 and 46 percent, respectively. Beuselinck et al. (1992) compared the IVDMD of birdsfoot trefoil (*Lotus corniculatus*) to tall fescue. The authors found that birdsfoot trefoil generally had higher IVDMD than tall fescue. The higher IVDMD of legumes could explain why the incorporation of legumes into a grass stand would increase the IVDMD of the mixed forage.

Effect of Nitrogen Treatments on In Vitro Dry Matter Digestibility

In November of 1998, nitrogen treatment increased ($P<0.05$) IVDMD values (Table 10). Nitrogen fertilization also had an effect on IVDMD values in June, September, and October of 1999 (Table 11). In June, unfertilized stands had higher ($P<0.05$) IVDMD (63.5 percent) than fertilized stands (58.3 percent). However, the opposite effect was seen later in the growing season (nitrogen treatment x harvest date interaction). In September and October, the fertilized stands had higher ($P<0.05$) IVDMD values (62.6 and 68.9 percent, respectively) than unfertilized stands (57.8 and 61.3 percent, respectively).

A nitrogen treatment x legume treatment interaction was also observed in 1999, as a result of the previous fall's nitrogen application (Table 12). In May, nitrogen fertilization of the ladino clover, red clover, and alfalfa treatments resulted in a decrease in IVDMD, while nitrogen fertilization of the annual lespedeza treatment and Matua grown alone increased IVDMD. In June, nitrogen fertilization resulted in an increase in IVDMD in all of the legume treatments. In July,

Table 12. Legume and nitrogen treatment interaction effects on In Vitro Dry Matter Digestibility*, DM basis, of Matua prairie grass/legume mixtures by months, 1999.

Month	Legume treatment	Nitrogen treament (kg/ha)	
		0	75
		----------%-----------	
May	Ladino clover	74.9	70.4
	Red clover	68.9	63.5
	Alfalfa	67.5	65.0
	Annual lespedeza	60.8	64.4
	Matua prairie grass	63.8	67.0
June	Ladino clover	70.4	64.9
	Red clover	65.5	56.0
	Alfalfa	60.2	59.6
	Annual lespedeza	61.0	55.4
	Matua prairie grass	58.8	54.7
July	Ladino clover	59.7	59.3
	Red clover	55.8	53.4
	Alfalfa	51.2	52.6
	Annual lespedeza	57.6	51.8
	Matua prairie grass	57.4	57.5
Sept	Ladino clover	55.2	62.2
	Red clover	58.2	61.9
	Alfalfa	55.2	63.3
	Annual lespedeza	57.6	64.5
	Matua prairie grass	63.0	61.2
Oct	Ladino clover	68.0	68.8
	Red clover	59.6	68.1
	Alfalfa	55.1	67.5
	Annual lespedeza	60.3	72.2
	Matua prairie grass	63.8	68.0

*Nitrogen treatment x legume treatment interaction ($P<0.05$).

nitrogen fertilization of the ladino clover, red clover, and annual lespedeza treatments resulted in a decrease in IVDMD, while fertilization of the alfalfa treatment and Matua grown alone increased IVDMD. In September, nitrogen fertilization increased IVDMD in all the legume treatments, with the exception of a decrease in IVDMD observed in the Matua grown alone. In October of 1999, the month immediately after the September 1999 nitrogen application, nitrogen fertilization resulted in an increase in IVDMD in all legume treatments.

The effect of nitrogen fertilization on IVDMD was different, depending on the harvest date. The differences in effects observed due to nitrogen fertilization could be a result of the detrimental effect that nitrogen fertilization has on legumes (McAuliffe et al., 1958). In our experiment, nitrogen fertilization led to a decline in the percentage legumes in 1999. In the spring and early summer, IVDMD was higher ($P<0.05$), by as much as 8 percent, in unfertilized stands, which may partially be explained by the impact that nitrogen fertilization has on legumes. McAuliffe et al. (1958) found that even at low rates, nitrogen fertilization was detrimental to legumes by reducing the ability of legumes to fix atmospheric nitrogen. Nuttall et al. (1980) and Thornley et al. (1995) also concluded that nitrogen fertilization would lead to a reduction of the amount of legumes in a stand of grass/legume mixed forages. Since cool season legumes, especially ladino and red clover, were found to increase IVDMD, a reduction in those legumes would also lead to a reduction in IVDMD. However, in the fall months, IVDMD was higher ($P<0.05$) by as much as 11 percent in the nitrogen fertilized stands. Nitrogen fertilization in our experiment resulted in IVDMD values to be intermediate between the values for pure Matua and alfalfa hays, reported by LaCasha et al. (1999).

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Chapter V

Summary

Pure stands of Matua prairie grass (Matua), and in mixture with four legumes, were evaluated to determine their compatibility, quality, and yield in southwestern Virginia. The influence of a single fall nitrogen application on the Matua/legume mixtures was also investigated. During the 1998 growing season, the legume establishment year, legume treatments had no effect on percentage Matua or total dry matter yield. However, by 1999, the legume treatments influenced the percentage Matua and total dry matter yield. The ladino clover and red clover had the greatest impact by reducing the percentage Matua in the stands. Alfalfa also reduced the percentage Matua in the stands, but not nearly as much as the ladino clover and red clover treatments, while annual lespedeza had no effect on percentage Matua. Ladino clover and red clover were present at very high proportions, in some instances, at a rate of over 50 percent of the forage components. Therefore, Matua and the treatment legumes exhibited an inverse relationship; that is, the higher the percentage legume resulted in a lower percentage Matua being present in the stand. Total dry matter yield was also increased as a result of the presence of a high percentage legume, specifically ladino clover and red clover.

Nitrogen fertilization in the fall of 1998 had a residual influence on the percentage Matua and percentage legumes observed in 1999. However, the greatest responses to nitrogen fertilization were observed immediately following the fall 1999 nitrogen application. In general, nitrogen fertilization resulted in an increase in the percentage Matua and a decrease in the percentage legume component. Nitrogen fertilization also resulted in a substantial increase in the total dry matter yield.

Both monthly precipitation and the seasonal distribution of the cool season legumes influenced the amount of forage components during the growing seasons. In addition, Matua's high fall forage production potential influenced the percentage Matua present and total dry matter production at various times during the growing season.

The legume treatments influenced the chemical composition, as well as the botanical composition of the forage. In 1998, due to the minimal amounts of legumes present, few differences in chemical composition were found. By 1999, more differences were observed in fiber components due to legume treatments, with the greatest differences occurring during the spring in the ladino clover and red clover treatments. These two legumes were present at very high amounts, as a result the greatest decrease ($P<0.05$) in NDF, ADF, hemicellulose, and cellulose values, and the greatest increase ($P<0.05$) in CP and IVDMD values were observed.

In terms of botanical composition, yield, and forage quality, the fall nitrogen applications had mixed results. In 1999, the forage sampled from plots that received nitrogen fertilization the previous fall had a lower percentage of legume components, which resulted in a lower nutritive value than forage from the plots that were not fertilized. In June, cellulose was higher ($P<0.05$) in the unfertilized treatment when compared to the fertilized treatment. During May through July, fiber components tended to be numerically higher, although not significant, in fertilized treatments. In addition to fiber components, a similar effect of nitrogen treatment on IVDMD values occurred. IVDMD was higher ($P<0.05$) in the unfertilized treatment in the spring of 1999. However, in fall months, as a result of the overall decline in percent cool season legumes due to their seasonal distribution, nitrogen fertilization resulted in an improvement in the nutritive quality of the forage. This was reflected by the decrease ($P<0.05$) in fiber component values and an increase ($P<0.05$) in CP and IVDMD values.

Ladino clover and red clover appeared to be incompatible with Matua in this experiment, as they resulted in a large decrease in the Matua component. However, these two legumes resulted in the greatest overall improvement of the nutritive value of the grass/legume mixed forage. Alfalfa seemed to be more compatible with Matua and also improved the nutritive value of the forage, but at an intermediate amount, as compared to the clovers. Annual lespedeza was also compatible with Matua, as it did not lead to a reduction in Matua. However, annual lespedeza generally did not lead to an improvement in the nutritive value of the forage, as fiber components, CP, and IVDMD values in the annual lespedeza treatment were comparable to the Matua grown alone. Also, the annual lespedeza resulted in higher ($P<0.05$) lignin values in August of 1998 and May of 1999. Overall, alfalfa was the least competitive with Matua of the legumes that resulted in an improvement in nutritive quality. However, additional research investigating the compatibility with legumes would be warranted, especially with the incorporation of livestock. Since livestock are selective grazers the grass/legume balance may be shifted.

Appendix

Table 1. The effect of legume treatments on specific plot components* by months: 1998.

Component	Legume Treatments	Months			
		June	July	Aug	Sept
		-------------------%	-------------------		
Other Grasses (%)	Ladino clover	44.8	43	59.3	25.9
	Red clover	55.4	37.3	53.7	34.1
	Alfalfa	61.8	54.7	43.7	35.5
	Lespedeza	53.4	48.6	55.4	28.5
	Matua	51.7	51.4	48.2	43.6
Other Legumes (%)	Ladino clover	3.3	0	0.2	0
	Red clover	2	0.3	0.3	0
	Alfalfa	0.1	1.7	0	0
	Lespedeza	0.4	0.5	0.3	0
	Matua	0	2.7	0.3	0
Weeds (%)	Ladino clover	16.8	13.8	4.2	3
	Red clover	4.1	6.8	8.4	6
	Alfalfa	11.8	5	0.3	1.3
	Lespedeza	1.2	4	0.2	0.7
	Matua	3.8	9.9	0.3	4
Dead Material (%)	Ladino clover	10.2	11.4	20.9	35.8
	Red clover	11.2	13.4	15.2	38
	Alfalfa	6.5	12.4	24.3	35.2
	Lespedeza	13.5	12.9	21.3	22.5
	Matua	11.5	15	25.6	33.3

*These components (within month and legume treatment) will total 100 percent if Matua prairie grass and treatment legumes are included.

Table 2. The effect of legume treatments on specific plot components[*]: November 1998.

Component	Legume Treatments	
		-----%-----
Other Grasses (%)	Ladino clover	27.7
	Red clover	30.2
	Alfalfa	30
	Lespedeza	31.5
	Matua	36.9
Other Legumes (%)	Ladino clover	1.3
	Red clover	0.4
	Alfalfa	0.7
	Lespedeza	0
	Matua	0.1
Weeds (%)	Ladino clover	0.3
	Red clover	0.2
	Alfalfa	0.7
	Lespedeza	0.8
	Matua	0
Dead Material (%)	Ladino clover	51.6
	Red clover	50.8
	Alfalfa	57
	Lespedeza	62.3
	Matua	57.3

[*]These components (within legume treatments) will total 100 percent if Matua prairie grass and treatment legumes are included.

Table 3. The effect of nitrogen treatments on all plot components*: November 1998.

Component	Nitrogen treatment	-----%-----
Matua prairie grass (%)	0 kg/ha	4.9
	84 kg/ha	7
Other grasses (%)	0 kg/ha	20.2b[1].
	84 kg/ha	42.3a
Treatment legume (%)	0 kg/ha	9.6a
	84 kg/ha	2.7b
Other legumes (%)	0 kg/ha	0.7
	84 kg/ha	0.3
Weeds (%)	0 kg/ha	0.5
	84 kg/ha	0.3
Dead Material (%)	0 kg/ha	64.2a
	84 kg/ha	47.4b

*These components include Matua prairie grass and treatment legumes, and will total 100 percent (within nitrogen treatments).

[1] Means followed by the same letters are not significantly different ($P < 0.05$) (Tukey-Kramer HSD).

Table 4. The effect of legume treatments on specific plot components* by months: 1999.

Component	Legume Treatments	May	June	July	Sept	Oct	Dec
		----------	----------	----------	%-	----------	----------
Other Grasses (%)	Ladino clover	3.5	9.7	8.2	35.9	9.6	3.4
	Red clover	4.6	8.6	23.9	31.2	12.6	6.2
	Alfalfa	7.2	14	21.2	26.8	2.1	0
	Lespedeza	4.4	7.5	12.9	17.6	4.3	0.2
	Matua	3.4	11.1	20.6	21.3	1.3	2.3
Other Legumes (%)	Ladino clover	1.5	0b[1]	0	1.2b	0	0
	Red clover	1.7	4.6a	0	5.9b	3.8	0
	Alfalfa	4.3	18.1ab	3.1	5.8b	4.9	0
	Lespedeza	0.8	14.5ab	0	3.8b	1.5	0.3
	Matua	0.2	12.7ab	0	21.9a	1.7	0
Weeds (%)	Ladino clover	0.8	2	2.1	1.5	3.6	0
	Red clover	0.2	1.1	6.5	5.6	2	0
	Alfalfa	0.7	3.9	1.1	4.9	0.6	0
	Lespedeza	1.6	1.8	1.1	1	1.5	0
	Matua	0.5	2.8	6.8	1.1	6.4	0
Dead Material (%)	Ladino clover	9.2b	10.5b	34.6	18.2	27.7	52.8
	Red clover	7.9b	21.4ab	20.6	17	33.9	53.9
	Alfalfa	12.4ab	26.8ab	38.7	18.7	42.1	61.2
	Lespedeza	18.3a	38.1a	38.5	13.3	28.2	51.9
	Matua	15.4ab	38.1a	34	17	38.6	58.8

*These components (within month and legume treatment) will total 100 percent if Matua prairie grass and treatment legumes are included.

[1] Means within months followed by the same letters are not significantly different (P < 0.05) (Tukey-Kramer HSD).

Table 5. The effect of nitrogen treatments on specific plot components* by months: 1999.

Component	Nitrogen treatment	Months					
		May	June	July	Sept	Oct	Dec
		---------------------------	-------------	-------------	%	-------------	-----------------------------
Other grasses (%)	0 kg/ha	4.2	10.7	14.8	28.4	5.9	3.7
	84 kg/ha	5	9.7	19.9	24.7	6.5	1.2
Other legumes (%)	0 kg/ha	2.7	14.1a[1]	1.2	7.3	3.8	0.1
	84 kg/ha	0.7	5.9b	0	8.1	1	0
Weeds (%)	0 kg/ha	0.8	1.9	4.4	2.6	3.1	0
	84 kg/ha	0.8	2.8	2.7	3	2.2	0
Dead Material (%)	0 kg/ha	12.8	19.4b	36.8	22.9a	45a	53.2
	84 kg/ha	12.5	34.5a	29.8	10.8b	22.7b	58.3

*These components (within month and nitrogen treatment) will total 100 percent if Matua prairie grass and treatment legumes are included.

[1] Means within months followed by the same letters are not significantly different ($P < 0.05$) (Tukey-Kramer HSD).

Vita

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