Influence of alfalfa in bromegrass-alfalfa mixtures on forage yield, protein yield, fertilizer N requirements, net returns and energy performance

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ABSTRACT. Field experiments were conducted at Lacombe and Eckville in central Alberta from 1993 to 1995 to determine the influence of alfalfa in bromegrass-alfalfa mixtures on forage yield, protein yield, fertilizer N requirements, net returns and energy performance. Ammonium nitrate was applied at 0, 50, 100, 150 and 200 kg N ha1 rates to five smooth bromegrass (Bromus inermis Leyss.)-alfalfa (medicago sativa Leyss.) compositions (pure bromegrass; 2:1, 1 :l and 1:2 ratio of bromegrass: alfalfa; and pure alfalfa). In the zero-N treatment, dry matter yield (DMY) and protein yield (PY) were lowest in pure bromegrass stands. The DMY and PY increased substantially when alfalfa was grown in association with bromegrass. There was a marked increased in DMY and PY from N applied in pure bromegrass stands, but the increases were much less in the mixed stands. The net returns above fertilizer and forage harvesting costs were much greater from mixed stands than from pure bromegrass. In pure bromegrass stands, the net returns increased with increasing N rates up to 200 kg N ha1 but equivalent net returns were usually attained without fertilizer N in bromegrass-alfalfa mixtures as low as 2:l. The amount of hay produced per unit of energy input and energy output/energy input ratio were greater for bromegrass-alfalfa mixture than for pure bromegrass or for alfalfa alone. In conclusion the results indicate that seeding of alfalfa in mixed stands with bromegrass can reduce the use of N fertilizer by more than 100 kg N ha-1 without any detrimental effect on forage yields, forage quality and net returns to producers. However, the short-lived nature of alfalfa may be *a* serious limitation to bromegrass-alfalfa mixtures. Therefore, producers must also adopt management practices that increase the longevity of the alfalfa stands.

INTRODUCTION

Perennial forages are an important feed source for beef cattle throughout the Canadian prairies. Second to moisture, yields of forage grasses grown in pure stands are often limited by plant-available N (Malhi et al. 1986, 1992; Ukrainetz and Campbell 1988). However, when grasses are grown in mixture with legumes, forage yield and protein content are usually higher compared to monoculture cropping (Dilz and Mulder 1962; Hamilton et al. 1969; Ta and Faris 1987a). The legumes fix large amounts of N (Heichel et al. 1984); grasses grown in association with legumes utilize some of this fixed N (Ta and Faris 1987b), which enhances overall forage dry matter and protein yields, while reducing the need for applied N fertilizer.

The amount of fertilizer N needed for optimum dry matter and protein yield depends upon the percentage of legume in the grass-legume mixture, soil-climatic characteristics of the region, and the prevailing economic conditions (Campbell et al. 1986; Malhi et al. 1986; Zentner et al. 1989; Malhi et al. 1997). The objectives of this study were to determine the optimum economic N rates for various bromegrass-alfalfa compositions for dry matter and protein yield, and to determine the effectiveness of alfalfa in mixtures with bromegrass in reducing the requirements of fertilizer N and non-renewable energy use for optimum forage and protein yield.

MATERIAL AND METHODS

Field experiments were conducted from 1993 to 1995 at Lacombe and Eckville in central Alberta. The soil at Lacombe was a Black Chernozem and that at Eckville was a Gray Luvisol. The surface soil (O-15 cm) at Lacombe had a pH of 6.1 (1:2 soil : water), 103 g kg-' organic matter and a clay texture, whereas at Eckville the soil had pH 5.9, 45 g kg-' organic matter and a clay texture. The long-term average annual precipitation of this area is 450 mm, of which about 270 mm is received during the growing season (May to August period). Growing season precipitation at Lacombe for 1993,1994, and 1995 was 277,307, and 281 mm, respectively.

The experimental design was 5 by 5 factorial with four replications in a randomized complete block, There were five bromegrass-alfalfa compositions (pure bromegrass; 2:1, 1 :l and 1:2 ratio of bromegrass: alfalfa; and pure alfalfa) and five rates of N fertilizer (0, 50, 100, 150 and 200 kg N ha-1) The N fertilizer (ammonium nitrate) was broadcast on the soil surface in early spring (mid to late April) of each study year. The mixtures of smooth bromegrass (cv. 'Carlton') and alfalfa (cv. 'Algonquin') were seeded in the summer of 1992 in rows 15 cm apart with 12 rows per plot (1.8 m by 6.0 m). For the 2:l ratio, there were 2 rows of bromegrass and 1 row of alfalfa in an alternating fashion. For the 1:l mixture, alternate rows of bromegrass and alfalfa were established. The sequence was 1 row of bromegrass and 2 rows of alfalfa for the 1:2 mixture. Each plot received a blanket application of 33 kg P,125 kg K, and 30 kg S ha-1 annually.

The plots were harvested for hay during the 1993, 1994, and 1995 growing seasons, with a first cut in early July and second cut in early September. The harvested area per plot was 5.4 m2 (i.e., 6 central rows 6 m long). The dry matter yield (DMY) was determined on subsamples dried at 65°C. The subsamples from all plots were ground through a 1-mm sieve, digested in hot sulphuric acid and then analyzed for total N and P using a Technicon AutoAnalyzer II (1977). Protein concentration was estimated by multiplying total N concentration by 6.25.

Net returns (i.e., income minus costs of N fertilizer, fertilizer application, forage harvesting, and interest) were calculated for all experimental treatments using 1998 input cost levels (Saskatchewan Agriculture and Food 1998). The cost of N fertilizer was held constant at $0.77 kg-1N. Market price of the forages was estimated two ways, first using a fixed value for each forage type (grass and legume) regardless of its nutritional quality, which is a typical pricing structure used by producers selling hay, and second using a relationship that estimates forage value based on its nutritional composition (Campbell et al. 1986). In the first instance, fixed prices of $70 t-1 DM for first-cut and $77 t-1 DM for second-cut bromegrass, and $90 t-l DM for first-cut and $99 t-1DM for second-cut alfalfa were assumed. For grass-legume mixtures these prices were weighted by the respective compositions of bromegrass and alfalfa in each mixture. In the second (or quality adjusted) instance, forage prices ($ t1 DM) were estimated as 17.81 + 28.5*%P + 32.06*%N in the forage (Campbell et al. 1986). The energy performance of the forage mixture and N fertilizer treatments was determined using methods described by Zentner et al. (1998).

Data on DMY, protein concentration (PC), protein yield (PY), net return (NR) , and energy performance were subjected to analysis of variance. The least significant difference

(LSD at P10.05) test was used to make comparisons among treatments (Little and Hills 1978).

RESULTS AND DISCUSSION

Dry Matter Yield

Without fertilizer N, DMYs were lowest in pure bromegrass stands at both sites (Figure 1). The DMY increased when alfalfa was grown in association with bromegrass. The mixtures produced two times or more DMY than did bromegrass alone. The advantage of legume-grass mixtures in increasing forage yield agrees with the results reported by Dilz and Mulder (1962) Hamilton et al. (1969), and Ta and Faris (1987).

In pure bromegrass stands, there was a marked increase in DMY from fertilizer N up to the highest rate of 200 kg N ha-' used in the study. Forage yields also increased with N fertilization in mixed stands, but the magnitude of yield increase from applied N was much less than the pure bromegrass. Bromegrass with alfalfa (1 :I mixture at Eckville and all mixtures at Lacombe) in the zero-N treatment produced forage yields equivalent to pure bromegrass with N fertilizer applied at about 150 kg N ha-1 or higher.

In the second cut, pure bromegrass without N fertilizer produced 1048 kg DMY ha-' (average of two sites). The second cut forage yield was only 27% of that of the first cut. However, in mixed stands the forage yields of Cut 2 were essentially similar to Cut 1. In pure bromegrass, the DMY of Cut 2 increased with N fertilization but forage yields were still relatively much lower as compared to Cut 1. This suggests that forage yield distribution over the season would be more uniform with mixed stands than with bromegrass alone.

Protein *Concentration in Forage*

There was a significant increase in the concentration of protein in forage when bromegrass was grown in a mixture with alfalfa as compared to bromegrass alone (Figure 2). The PC in forage was highest in pure alfalfa stands. As alfalfa can fix substantial amount of N from the atmosphere (Heichel et al. 1984), it had higher PC in forage than bromegrass.

In pure bromegrass stands, the PC in Cut 1 forage increased substantially with N fertilization, but in mixed stands the increase in PC from applied N was slight. In Cut 2, the PC in forage decreased with N application. This was possibly due to a dilution effect from increased forage yield with applied N and little plant-available N present in soil.

Protein Yield

Like DMY, the PYs were also lowest in pure bromegrass stands in the zero-N treatment (Figure 3). The PY increased dramatically when alfalfa was grown in a mixture with bromegrass. The relative increase was greater with PY than with DMY, most likely due to increase in the concentration of protein in forage. For pure alfalfa stands, in spite of lower DMY than mixtures, the PY was greatest because of highest PC in alfalfa forage.

The PYs increased with increasing N rate, but increases were much greater for pure bromegrass stands than mixtures. There was also some increase in PY in the pure alfalfa stands. With the exception of pure bromegrass stands, the increase in PY from applied N in mixed or pure alfalfa stands was only in the first cut.

Economic Returns

Net returns from mixed stands and from alfalfa alone were much higher than from pure bromegrass at both test sites (Figure *4).* In pure bromegrass stands, net returns increased significantly with increasing N rates up to 200 kg N ha-'. In general, equivalent net returns for optimally fertilized pure bromegrass were obtained without any fertilizer N in bromegrass-alfalfa mixtures as low as 2:1. The economic benefit from applying N fertilizer to pure bromegrass was further enhanced when the effects on its nutritional composition were considered, mainly reflecting the improvement in protein concentration and protein yield (Tables 2 and 3). In contrast, the application of N fertilizer to bromegrass-alfalfa mixtures at rates greater than 50 kg N ha^{-1} seldom produced a significant economic benefit, while the application of N fertilizer to pure alfalfa was not economic under any situation.

Our results suggests that the economic optimum rates of N fertilizer for pure bromegrass are much higher than the currently used rates of 30 to 60 kg N ha-' for this region, in agreement with the general findings for the more moist regions of Saskatchewan (Zentner et al. 1989) and Alberta (Malhi et al. 1987). Further, our findings suggest that producers seeding alfalfa in a mixture with bromegrass can reduce the need for N fertilizer by more than 100 kg N ha" from that used in the pure bromegrass without any detrimental impact on forage production and net returns.

Non-Renewable Energy Performance

Non-renewable energy requirements at both test sites were lowest for check treatments, and increased in a linear fashion with increasing rates of applied N fertilizer (Figure 5), reflecting the high energy cost associated with its manufacture. The amount of energy expended on hay production increased about IO-fold as N rate increased to 200 kg ha". Total energy requirements also tended to be higher for the bromegrass-alfalfa mixtures than for pure bromegrass and for alfalfa alone. In contrast, the amount of hay produced per unit of energy input and the energy output/energy input ratio displayed the opposite trend, reflecting the higher total dry matter yields obtained with the bromegrass-alfalfa mixtures (Figure 1). The energy output/energy input ratios obtained in this study are much higher than those reported by Zentner et al. (1998) for wheat production; however, in their study crop residues were returned to the soil and many other production inputs and machine operations were considered.

These findings suggest that producers interested in maximizing energy use efficiency, or in minimizing the input of non-renewable energy in production of forage must do so by reducing the reliance on inorganic N fertilizer. Our results indicate that this can be achieved in a cost-effective and energy-efficient way by growing a properly inoculated legume in mixture with the grass.

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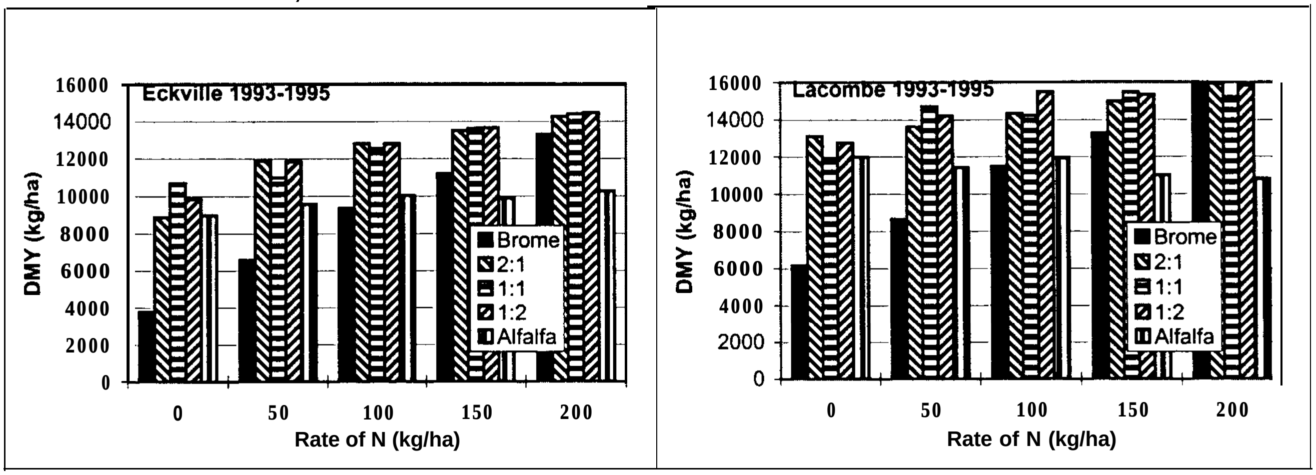
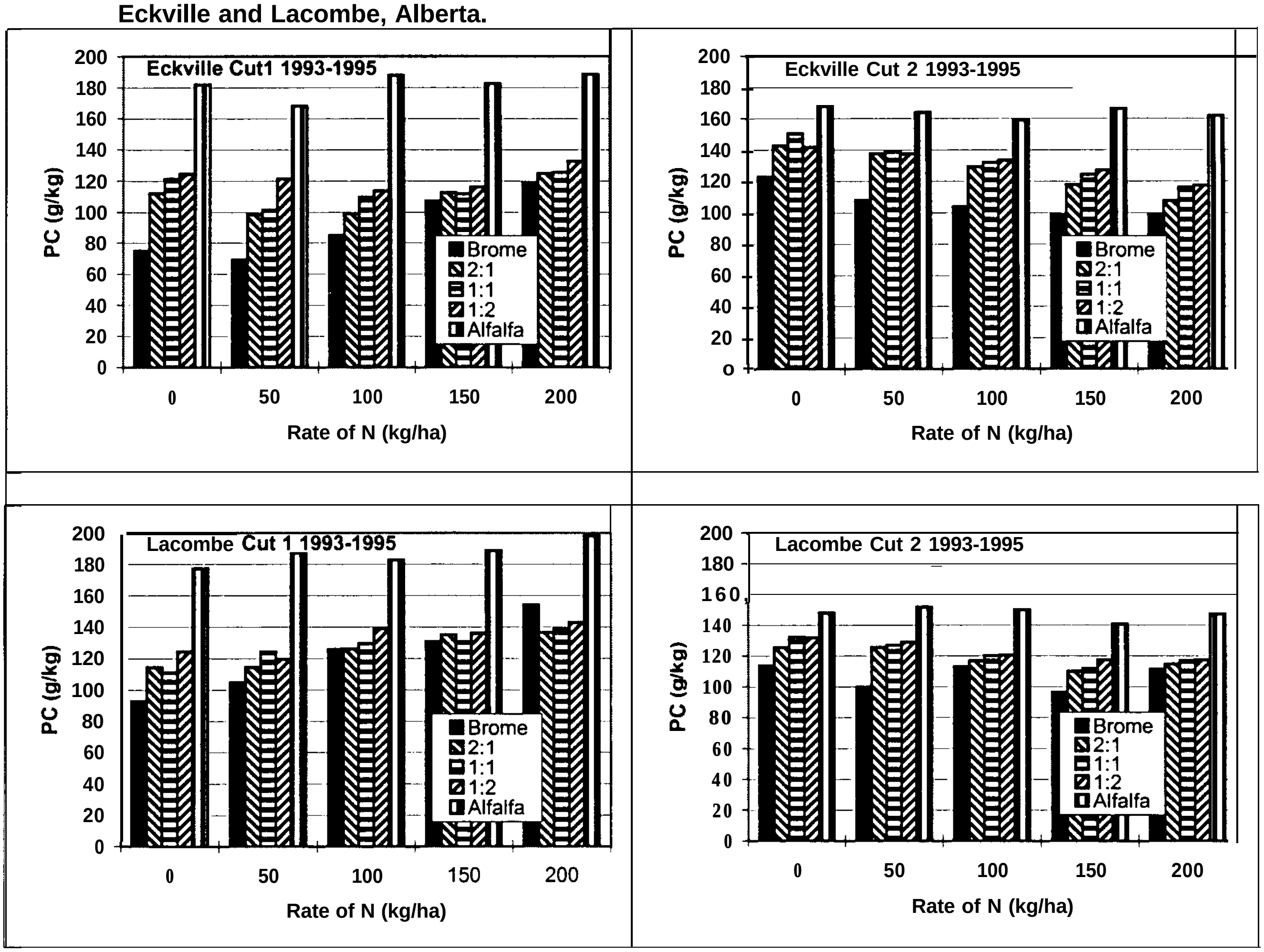
Fiqure 1. Dry matter Yield (DMY) for various bromegrass-alfalfa mixtures with N fertilization at Eckville and Lacombe, Alberta.



Fiqure 2. Protein concentration (PC) from various bromegrass-alfalfa mixtures with N fertilization at Eckville and Lacombe, Alberta.



Fiqure 3. Protein yield (PY) for various bromegrass-alfalfa mixtures with N fertilization at Eckville and Lacombe, Alberta.

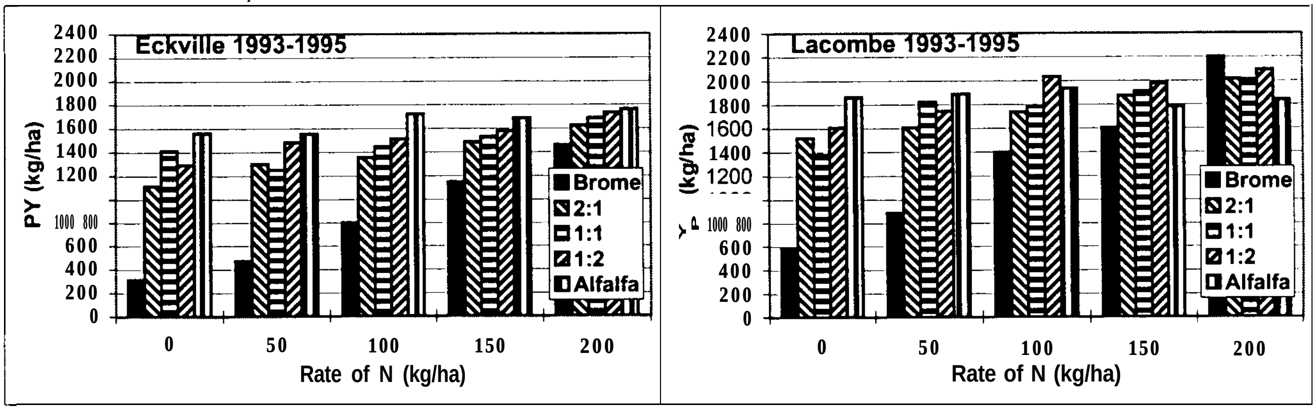
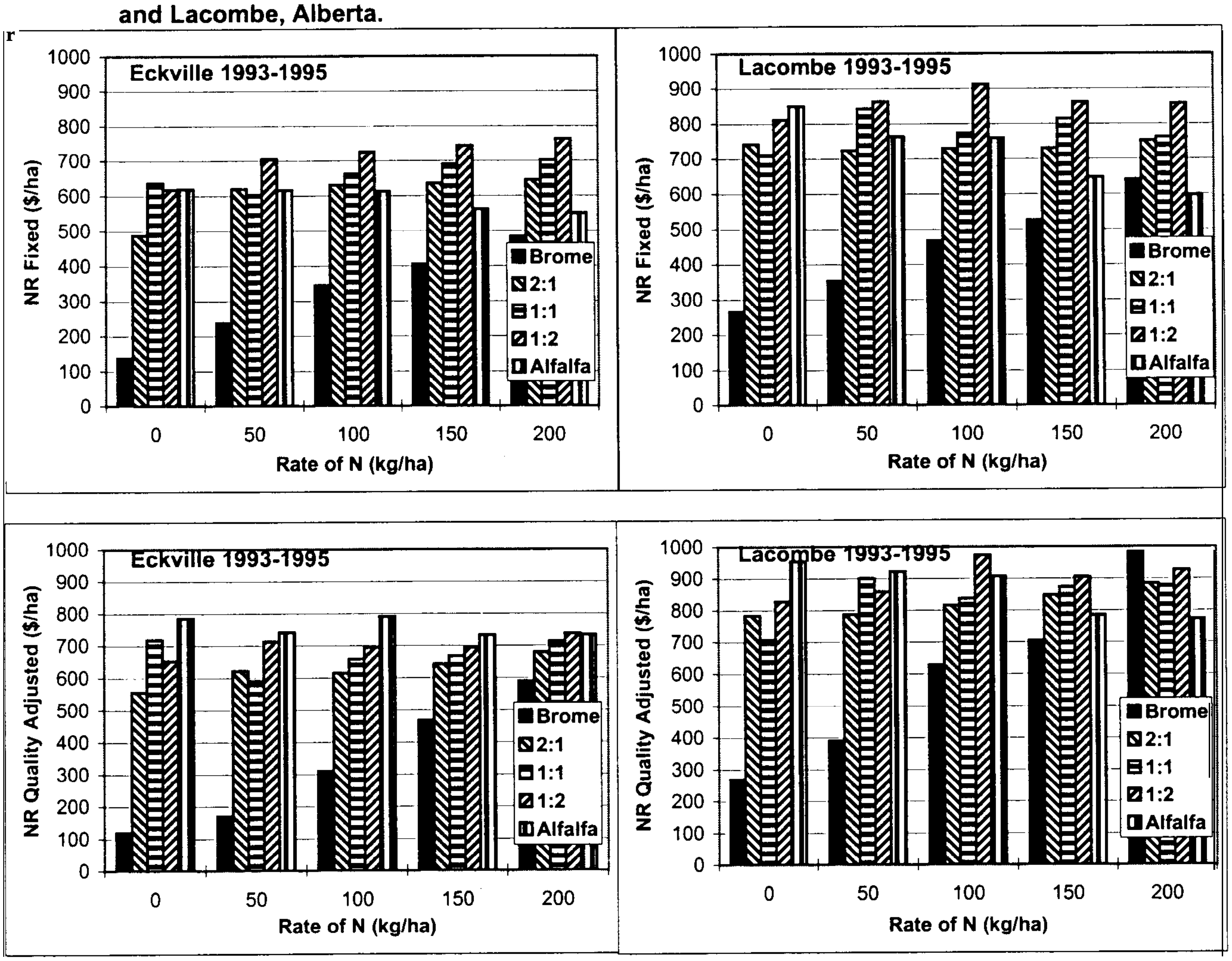


Figure 4. Net returns (NR) from various bromegrass-alfalfa mixtures with N fertilization at Eckville and Lacombe, Alberta.



Fiqure 5. Non-renewable energy inputs from various bromegrass-alfalfa mixtures with N fertilization at Eckville and Lacombe, Alberta.