The potential of legume-shrub mixtures for optimum forage production in southwestern Saskatchewan: A greenhouse study

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Schellenberg, M. P. and Banerjee, M. R. 2002. **The potential of legume-shrub mixtures for optimum forage production in southwestern Saskatchewan**: **A greenhouse study**. Can. J. Plant Sci. **82**: 357–363. Grazing in fall and early winter decreases the cost of beef production in southwestern Saskatchewan. This grazing system can be improved by utilizing legume and native shrub species, which exhibit high nutritive value in the fall. To realize the system's full potential, a better understanding of optimum mixtures of legumes and shrubs is required. A greenhouse study was conducted to optimize mixtures of legumes and shrubs for economical pasture production. The first goal was to obtain better understanding of synergy from mixtures of legumes and native shrubs. The second goal was to estimate the changes in soil quality caused by growing legumes and shrubs in monocultures or mixtures. Legume species studied were: alfalfa (*Medicago sativa* L.) (Alf), purple prairie clover [*Petalostemon purpureum* (Vert.) Rydb] (Pr Cl) and American vetch (*Vicia americana* Muhl.) (Vetch); shrubs were: winterfat [*Krascheninnikovia lanata* (Pursh) Guldenstaedt] (Wf) and Gardner's saltbush [*Atriplex gardneri* (Moq.) D. Dietr.] (Sb). Treatments consisted of five monocultures, six mixtures and a control. Data on plant biomass, forage quality and soil quality parameters indicate that legume and shrub mixtures of Alf + Wf and/or Alf + Sb can potentially provide diversified forage sources, extended grazing periods and higher or similar yields with enhanced or similar forage quality than when grown separately.

Key words: Legume, native shrub, forage production, forage quality, winterfat, saltbush

Schellenberg, M. P. et Banerjee, M. R. 2002. **Potentiel des mélanges de légumineuses et de plantes arbustives pour la production optimale de fourrages dans le sud-ouest de la Saskatchewan : étude en serre**. Can. J. Plant Sci. **82**: 357–363. Dans le sud-ouest de la Saskatchewan, on réduit le coût de production du bœuf en laissant les bêtes paître en automne et au début de l'hiver. On pourrait améliorer la paissance en recourant à des légumineuses et à des espèces arbustives indigènes riches en éléments nutritifs à l'automne. Pour tirer le meilleur parti d'un tel régime cependant, il faut d'abord établir les meilleures combinaisons de légumineuses et de plantes arbustives. Les auteurs ont entrepris une étude en serre en vue d'identifier les meilleurs mélanges de légumineuses et de plantes arbustives pour des pâturages rentables. Leur premier objectif était de mieux comprendre la synergie des mélanges de légumineuses et d'espèces arbustives indigènes. Ils voulaient aussi déterminer comment la qualité du sol change quand les légumineuses et les plantes arbustives sont cultivées seules ou en association. Pour leur étude, les chercheurs ont retenu les légumineuses suivantes : la luzerne (*Medicago sativa* L.), le petalostemon pourpre [*Petalostemon purpureum* (Vert.) Rydb] et la vesce d'Amérique (*Vicia americana* Muhl.). Les plantes arbustives retenues étaient *Krascheninnikovia lanata* (Pursh) Guldenstaedt et l'arroche de Gardner [*Atriplex gardneri* (Moq.) D. Dietr.]. Les chercheurs ont procédé à cinq monocultures, à six cultures mixtes et à une culture témoin. Les données sur la biomasse végétale, la qualité du fourrage et les paramètres de la qualité du sol indiquent que les mélanges luzerne + *K. lanata* et/ou luzerne + arroche peuvent diversifier les cultures fourragères, prolonger la période de paissance et fournir un rendement similaire ou supérieur en fourrages de qualité plus grande ou analogue aux mêmes espèces cultivées séparément.

Mots clés: Légumineuses, plantes arbustives indigènes, production de fourrage, qualité des fourrages, *Krascheninnikovia lanata*, arroche de Gardner

Late-season grazing has been considered as a method of decreasing the cost of beef production in the southern prairie region of Canada. The nutritive value of available forage in fall and winter generally restricts the grazing season. Grasses are usually the main forage source even though they are not the only source of herbage during that period. The nutritive value of native shrubs and forbs (Smoliak and Bezeau 1967; Cook 1972; Dietz 1972) is higher than that of grasses. The cost of beef production can be reduced by up to 56% by over-wintering cattle on winter pasture (Extension Agrologist, J. Graham, personal communication). Thus, it would be beneficial for livestock producers to have a high-quality, late-season pasture with low input cost. One method of improving late-season grazing is to utilize native shrub and legume species that maintain high nutritional quality in the fall. In order to develop a potential forage source using shrub and legume species requires an understanding of their performance in mixtures.

Abbreviations: **Alf**, alfalfa; **Pr Cl**, purple prairie clover; **Vetch**, American vetch; **Wf**, winterfat; **Sb**, saltbush

In recent years, winterfat [*Krascheninnikovia lanata* (Pursh) Guldenstaedt] and Gardner's saltbush [*Atriplex gardneri* (Moq.) D. Dietr.], two native shrubs of southwestern Saskatchewan, have gained considerable attention from both producers and researchers. Winterfat is salt and drought tolerant (Van Dersal 1938; Stubbendieck et al. 1986) and highly palatable and nutritious (Romo et al. 1997; Abouguendia 1998). This species provides excellent forage to livestock and wildlife, and is used for wildlife habitat reclamation (Bai et al. 1998). Winterfat retains enough protein and minerals to meet the nutritional requirements of livestock feeding on winter range (Smoliak and Bezeau 1967). There is also considerable interest in using this shrub for restoration and improvement of rangelands on the Canadian Prairies (Hou and Romo 1997).

Saltbush has similar nutritional qualities as winterfat (Smoliak and Bezeau 1967; Banerjee et al. 1999). Saltbush can also be used as winter forage by livestock and is fairly palatable to cattle (Smoliak et al. 1993). Although saltbush is found on badlands and eroded soils throughout the Canadian Prairies, the most productive Gardner's saltbush are found on south-facing slopes in sandy soils with cobblestones in association with blue grama grass (Banerjee et al. 1999). Le Houerou (1992) reported that plantations of saltbush appeared to be one of the best ways to rehabilitate desertified areas and restore them to production in spite of a number of constraints in their establishment, management and utilization.

The native legumes, American vetch (*Vicia americana* Muhl.) and purple prairie clover [*Petalostemon purpureum* (Vert.) Rydb], and alfalfa (*Medicago sativa* L.) are known to have high nutritional value as well as being adapted to the semiarid region. American vetch is a highly palatable forb, while prairie clover is also considered an important palatable component of prairie hay (Hermann 1966). In the Canadian Prairies, the popularity of alfalfa as a forage crop has increased significantly and it is found growing in southwest Saskatchewan under natural conditions. Growing a monoculture of alfalfa alone is not widely accepted among producers due to fear of ruminant bloat. Other non-bloat species such as sainfoin (*Onobrychis viciaefolia*) and cicer milkvetch (*Astragalus cicer)* have been observed to be short lived and not well adapted to the semiarid conditions found in southwestern Saskatchewan (personal observation). A pasture consisting of a shrub and legume mixture may well be suited to this purpose. Thus, a pasture with the ideal mixture would produce more forage and livestock as well as provide late-season grazing at low production cost.

In many countries, growing trees and shrubs together for improving soil fertility has gained considerable attention. In central Africa, where rainfall is limited, soil fertility, especially N-supplying capacity, has increased and higher crop yields have been obtained following different shrub fallows (Barrios et al. 1996a, b; Buresh and Tian 1996). Although shrub contribution to soil quality has never been investigated in the semiarid portion of the Canadian Prairies, growing native shrubs with legumes may potentially improve soil quality or soil health in the region.

Table 1. Physical and chemical characteristics of South Farm soil used in the legume-shrub pot study

Characteristics	Analysis
Texture	Sandy loam
Sand (%)	65.4
Silt (%)	21.1
Clay (%)	13.5
pH	6.6
EC (dS^{-1})	0.5
Total C (g kg^{-1})	19.3
Organic C (g kg^{-1})	18.4
Organic C as % of total C	95.1
Total N (g kg^{-1})	2.0
NH_4-N (µg g^{-1})	3.0
NO_3-N (µg g^{-1})	1.8
C:N	9.8
Extractable P (µg g^{-1})	5.8
Extractable K (µg g^{-1})	457.5
Extractable S (µg g^{-1})	3.7

The objectives of this investigation were: to test mixtures of legumes and shrubs for potential production of pasture to extend the grazing season; to obtain a better understanding about the forage quality of the mixtures; and to monitor the potential changes in soil quality caused by growing legume/shrub mixtures. To control environmental variability of temperature, soil moisture and wind, a greenhouse study was selected as the method for initial investigation.

MATERIALS AND METHODS

A pot study was conducted in the greenhouse (16 h photoperiod, 8 h dark; 24°C during the day and 18°C during the night) to determine optimal mixtures of legumes and shrubs using a Brown soil (Swinton silt loam) obtained from an experimental forage field near Swift Current, SK (Table 1). Legume species studied were: Alfalfa (Alf), purple prairie clover (Pr Cl) and American vetch (Vetch); shrubs were winterfat (Wf) and Gardner's saltbush (Sb). The 12 treatments consisted of five monocultures, six mixtures and a control. The treatments were: (i) Alf, (ii) Pr Cl, (iii) Vetch, (iv) Wf, (v) Sb, (vi) Alf + Wf, (vii) Alf + Sb, (viii) Pr Cl + Wf, (ix) Pr Cl + Sb, (x) Vetch + Wf, (xi) Vetch + Sb, and (xii) Control (no seedlings). The experiment was laid out in a completely randomized design with three replications to give a total of 36 pots. Each 17.5-cm (2 L) clay pot contained 2 kg of soil. Legume [inoculated with appropriate inoculant (Smith at al. 1988)] and shrub seedlings (2-wk old) were taken from the greenhouse nursery at the Semiarid Prairie Agricultural Research Centre (SPARC) and transplanted into the appropriate pots on3 September 1998. Four plants were transplanted into each pot. For monocultures, each pot contained four plants of a single species, and for the mixture treatments, two plants per selected species. Establishment and growth of legume/shrub plants in the pots at different growth stages were visually observed. Plant biomass was harvested at five different times (25 November 1998; 27 January 1999; 22 March 1999; 4 May 1999 and 14 June 1999), depending on the full bloom stage of alfalfa with plants clipped to a height of 5 cm. Plant biomass was

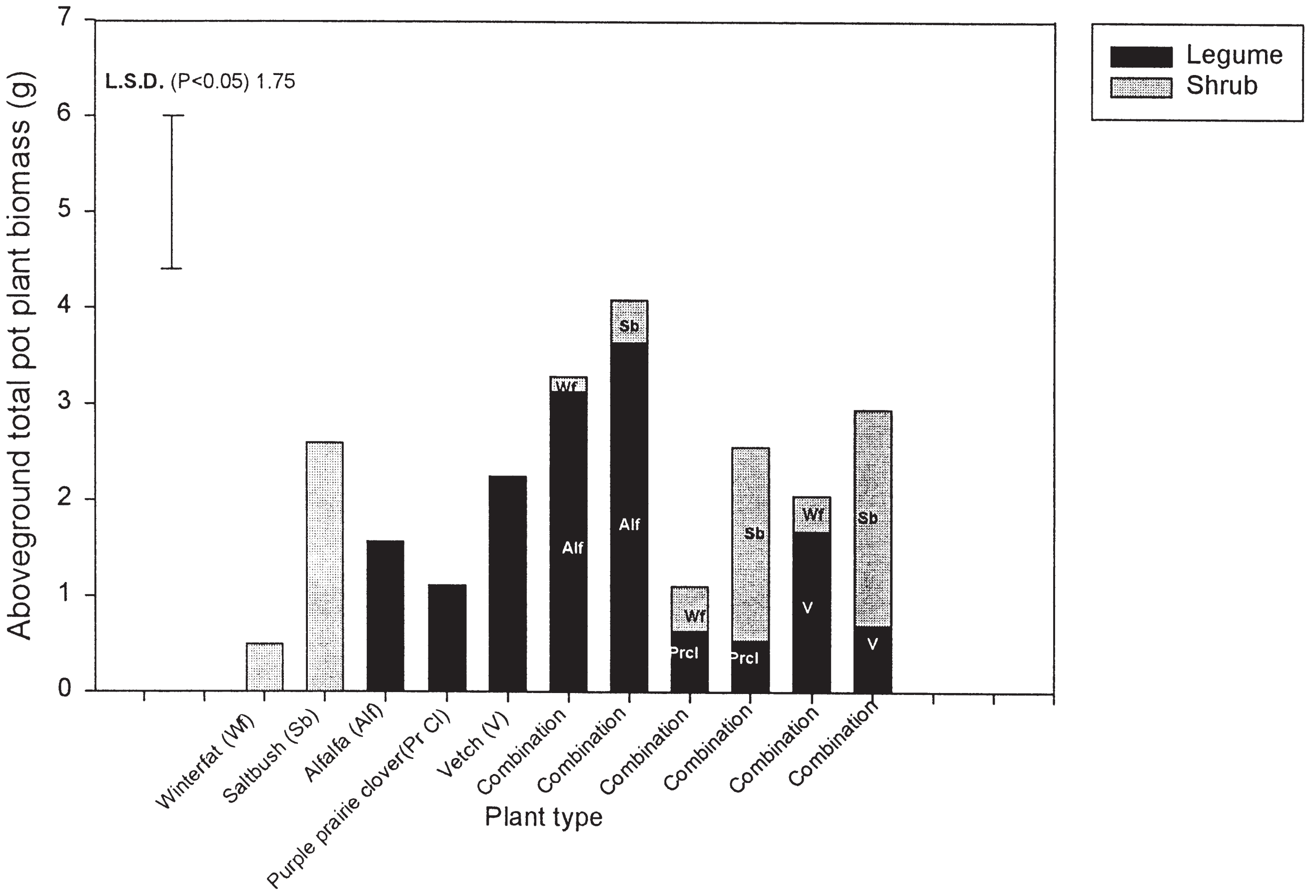

Fig. 1. Oven-dry weight of aboveground plant biomass.

measured as dry matter weights after bulking the five consecutive harvests. Forage quality analysis (CP, P and Ca) was also done on the bulked samples. At the end of fifth harvest, soils were destructively sampled to assess the changes in soil parameters.

Soil and Plant Analyses

Total C and N in soil were determined by an automated combustion technique (Carlo Erba™, Milan, Italy). Soil organic C was determined by the same combustion method after removal of carbonates with phosphoric acid (Campbell et al. 1995). Soil NH_4-N was determined by the method of Gentry and Willis (1988). Soil NO_3-N, extractable P and Extractable K were determined using the technique of Hamm et al. (1970), and extractable S was determined by the method of Hamm et al. (1973). For plant analysis, oven-dry plant materials were prepared using one digesting mixture (H_2SO_4/Se/Na_2SO_4) for N and P, and another digesting mixture ($HClO_4$/HNO_3) for Ca.. Total N was analyzed by the Association of the Official Analytical Chemists (1984) method, total P was measured by using the Varley (1966) technique and total Ca was measured by using an Hitachi Polarized Zeeman atomic absorption spectrophotometer. Crude protein concentration in plant was calculated by the factor (total N $\times$ 6.25). Protein, P and Ca percent content were calculated using weighted means based on the oven-dry biomass weight contribution to total biomass of each species.

Statistical Analyses

Statistical analyses of the data were performed using analysis of variance and means comparisons of the treatment effects (SAS Institute, Inc. 1989). When a significant *F* value was obtained, least significant difference (Fisher LSD) was determined. Orthogonal contrasts were used to compare group means (Steel and Torrie 1980) when a significant *F* value was obtained for the treatment effect.

RESULTS AND DISCUSSION

Based on the five bulked cuts, the mixture treatments increased ($P \leq 0.05$) plant biomass production an average of 1.8 times the yield from monoculture (Fig. 1, Table 2). Compared with the monoculture, yield of Alf + Wf increased ($P \leq 0.05$), while Alf + Sb was similar ($P \leq 0.05$). A multi-year experiment carried out in southwest Saskatchewan has indicated that yields from mixtures of legume and grass were always higher than growing grass alone (Leyshon 1978). Enhanced growth of grasses could be related to greater available N supplied by legumes, which are N-fixing plants. A similar synergistic phenomenon might have

Table 2. Means averaged across treatments for monoculture and mixtures for above ground biomass, % protein, % Ca, and % P

Grouping	Biomass (g)	% protein	% Ca	% P
Monoculture	1.46	17.5	16.8	0.24
Mixture	2.64	17.7	17.4	0.26
SEM[z]	0.23	0.9	0.7	0.01
Contrast				
Monoculture vs. mix	S[y]	NS	NC[x]	NS

[z] Standard error mean.
[y]Significant ($P < 0.05$), NS, not significant ($P < 0.05$).
[x]Not calculated due to non-significant treatment effect.

occurred between the legume (alfalfa) and the shrubs. In the Alf + Wf and Alf + Sb treatments, the greater alfalfa yields compensated for the reduction in shrub yields to produce yields that were higher than or similar to the combined production of the respective monocultures (Fig. 1). This might have been due to light competition in the smaller pot surface area because of the more upright vigorous growth of alfalfa compared to the relatively shorter and bushier winterfat or saltbush plants. With the shrubs' contribution to the total mixture production, mixture production was greater than winterfat and alfalfa grown as monocultures. Harper (1977) stated that successful capture of resources by plants is dependant on their distance from neighbours and their size. A possible method to improve the shrub component access to resources and thus production may be simply to increase spacing in the field or pot. Waddington and Steppuhn (1996) and Steppuhn and Waddington (1996) reported a 40% increase in alfalfa production when soil moisture was increased using tall wheatgrass windbreaks that trap snow and decrease evapo-transpiration. In a field situation the alfalfa, winterfat and saltbush may also be able to serve as windbreaks. Thus, growing a mixture of shrub (Wf or Sb) and legume (Alf) has the potential to maximize production, as the legume provides available N to the shrub, and the more upright plant architecture of shrubs and legume reduces wind speed, conserves moisture and traps snow. By fall, the shrubs would provide a greater barrier to wind and snow with retention of leaves, while alfalfa loses a large proportion of its leaves. The other mixtures (Pr Cl + Wf, Pr Cl + Sb, Vetch + Wf and Vetch + Sb) did not increase the plant dry matter yield over their respective monocultures' combined biomass production. On the other hand, the Pr Cl + Sb and Vetch + Sb mixture produced more shrub (saltbush) compared to the respective legumes with Vetch + Sb producing more biomass than the monocultures.

Of the legumes tested, alfalfa was the most competitive in a mixture that reduced the shrub biomass to a minor com-

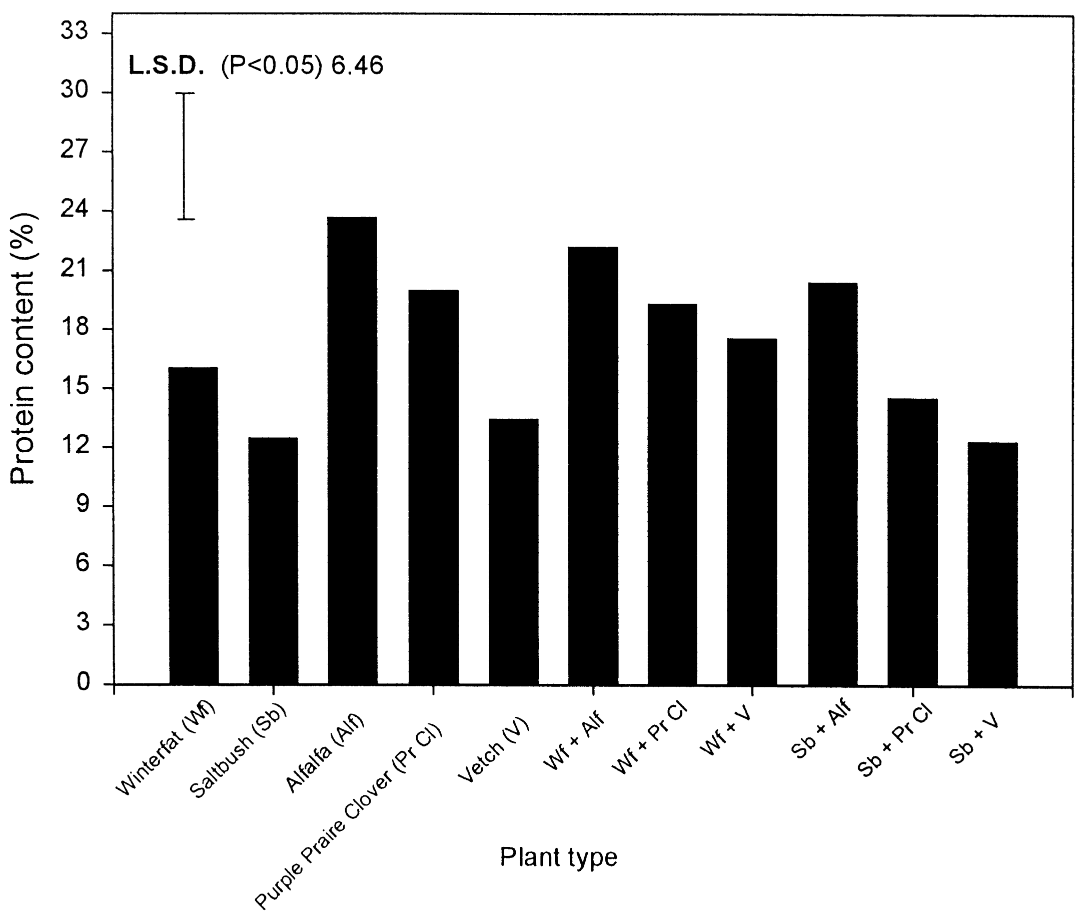

Fig. 2. Percent protein in plant biomass calculated using weighted means based on oven-dry weight contribution of each species.

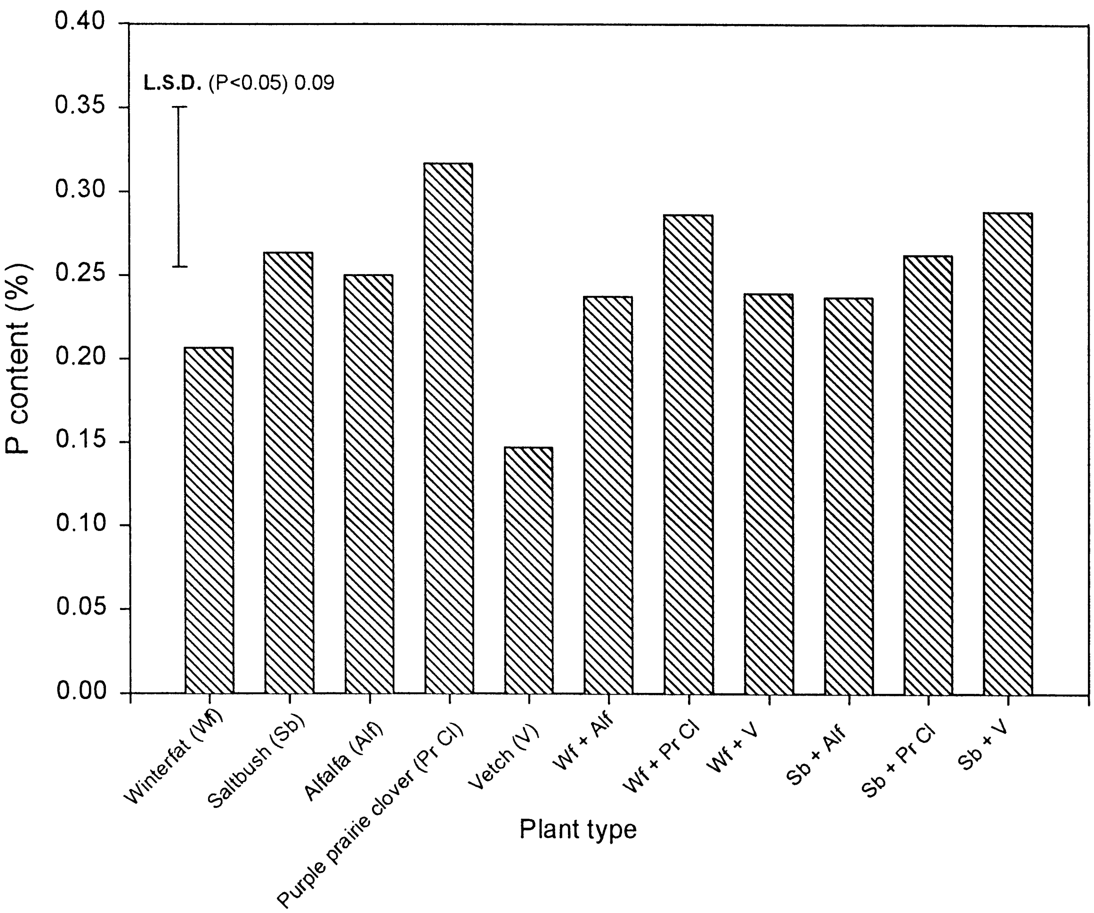

Fig. 3. Percent P in plant biomass calculated using weighted means based on oven-dry weight contribution of each species.

ponent of the total (Fig. 1). While vetch and prairie clover were less productive than alfalfa, they were also less competitive, which allowed greater production from shrubs. Therefore, vetch and prairie clover may be desirable components in a mixture where shrubs are required.

Forage quality (protein, P and Ca contents) was greater than, or nearly maintained at the same level, in the Alf + Wf and Alf + Sb treatments compared to the combined forage quality of their respective monoculture treatments (Figs. 2, 3 and 4). Protein, P, and Ca contents all increased ($P > 0.05$) for the mixes as opposed to the monocultures. The mixtures, therefore, may provide enough protein, P and Ca for livestock, but less crude fibre than principal grasses of comparable growth stage (Smoliak and Bezeau 1967). Thus, they may be used as a potential winter pasture forage with good fall nutritive values (Cook 1972; Abouguendia 1998), which will help in extending the grazing period, resulting in decreased operational costs and greater returns to the livestock producers (Adams et al. 1996). Further study in the field is required to verify the aforementioned benefits.

The treatment effects on the soil (Table 3) were influenced by the vegetation and the greenhouse environment where the study was made. Mineralization without additions from plants may account for losses from the original soil (Tables 1 and 3). However, the net effect of plants, through N extraction or addition, on total N was not large enough to be detected among treatments at the conclusion of the experiment. Only soil organic C was significantly ($P < 0.05$) greater than the control, which suggests additions to the soil through root mass or root exudates. The fact that these results were produced in a greenhouse raises the question of their application in the field, and identifies the need for field studies to validate the observations. The tap-rooted saltbush looks promising for adding organic C to soil, and further research could be valuable in light of increasing interest in C sequestration.

CONCLUSIONS

The study indicates that a pasture with a mixture of legume and shrubs (Alf + Wf and/or Alf + Sb) can potentially provide a diversified forage source, extended grazing periods, higher yields than when grown separately, with enhanced or similar forage quality. However, long-term field study is needed before the true benefit can be established satisfactorily.

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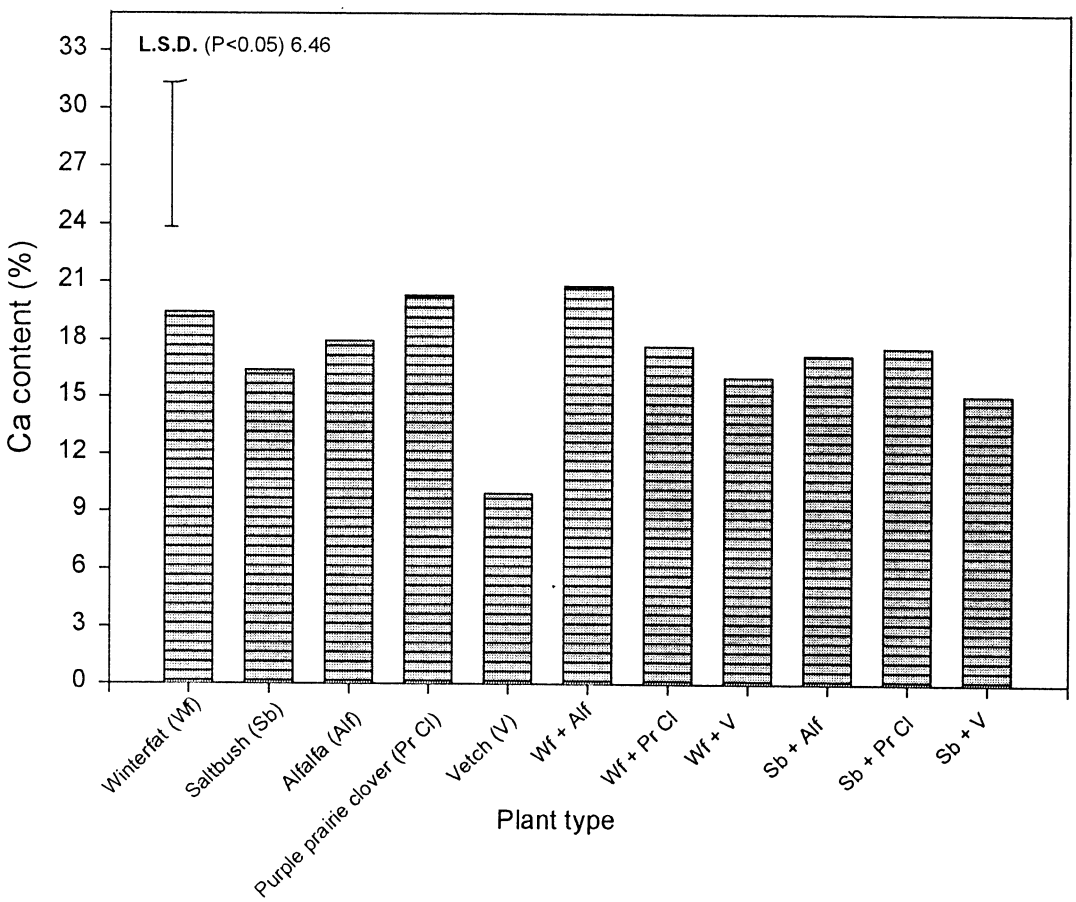

Fig. 4. Percent Ca in plant biomass calculated using weighted means based on oven-dry weight contribution of each species.

Table 3. Soil parameter after the 5th harvest in the legume-shrub pot study

Treatment	Total C ($g\ kg^{-1}$)	Organic C ($g\ kg^{-1}$)	Organic C (% of total C)	Total N ($g\ kg^{-1}$)	C:N
Control	15.7	15.6	98	1.6	9.7
Alfalfa	15.4	15.1	98	1.5	9.9
Winterfat	16.9	16.6	98	1.6	10.4
Saltbush	19.9	18.9	95	1.7	11.3
Alf + Wf	16.2	15.8	97	1.6	10.1
Alf + Sb	17.1	16.6	97	1.6	10.2
LSD[z] ($P \le 0.05$)	2.7	2.4	NS[y]	NS	1.0

[z]Least significant difference.
[y]Not significant ($P > 0.05$).

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