Performance of birdsfoot trefoil, white clover, and other legume-grass mixtures under irrigation in the Intermountain West USA

J. W. MACADAM and T. C. GRIGGS
Utah State University, 4820 Old Main Hill, Logan, Utah 84322-4820 USA
jenmac@cc.usu.edu

Abstract
Two trials were designed to provide baseline data on the productivity and quality of irrigated pastures in the Intermountain West USA. An initial clipping trial (1997-1999) screened a number of temperate grass-legume mixtures well-adapted to the soils and climate of the Intermountain West, and a successive grazing trial (2001-2003) evaluated a subset of these mixtures under rotational grazing. The most productive and best utilised grass in mixtures was meadow brome (*Bromus riparius*), followed by tall fescue (*Lolium arundinaceum*) and cocksfoot (*Dactylis glomerata*). Perennial ryegrass (*Lolium perenne*) and Kentucky bluegrass (*Poa pratensis*) mixtures tended to become legume-dominated (up to 44% under grazing), and were therefore high in quality but a potential bloat threat. The bloat-safe legume birdsfoot trefoil (*Lotus corniculatus*) proved to be productive, well-utilised, and as persistent as other legumes in mixtures under grazing.
Keywords: grass, grazing, Intermountain West USA, legume, mixtures, pasture

Introduction
The Intermountain West USA is a semi-arid (150 to 600 mm annual precipitation), high-elevation (1200 to 2000 m) region lying roughly between 37 and 43° N latitude. Soils are calcareous and neutral to alkaline, and irrigation water is often moderately saline. Beef producers in this region usually lease federal rangeland for at least part of the year, but there is increasing public pressure to de-stock rangeland and increase lease fees to fully cover costs to federal agencies. At the other end of the spectrum, confinement dairy producers are faced with rising feed costs, animal health issues, and increasingly restrictive environmental regulations. Irrigated pastures can increase beef cattle production compared with range-based production, and increase the profits of dairy production compared with confinement operations in the Intermountain West. The objectives of these trials were to determine the productivity, botanical composition stability, and nutritive value of irrigated pasture mixtures for grazing-based livestock production, with the goal of increasing the rate of gain for beef production or lowering the costs of dairy production.

Burns and Standaert (1985) compared steer gains/ha on grass-legume mixtures with those on grass monocultures, and calculated the N value of legumes as 170-270 kg N/ha. Local livestock producers had reported severe bloat on established perennial ryegrass-white clover pastures because perennial ryegrass is not persistent and white clover (*Trifolium repens*) becomes dominant, so legumes selected for these studies included bloat-safe species (Lees 1984), and a harvest management treatment designed to discourage legume dominance of mixtures.

Methods
Clipping trial (1997-1999)
The six grasses used in the trial were 'Regar' meadow brome, 'Dawn' cocksfoot, 'Martin' tall fescue, 'Barmaco' and 'Moy' diploid perennial ryegrasses and 'Ginger' Kentucky bluegrass. Legumes used were 'Windsor' cicer milkvetch (*Astragalus cicer*), 'Norcen' birdsfoot trefoil, 'Archer' lucerne (*Medicago sativa*), and 'Grasslands Pitau' white clover. Grasses were planted in monoculture or in binary mixtures with each legume. These 30 treatments were either harvested throughout the growing season (May to October) to simulate rotational grazing, or were cut in spring for hay at the grass early-heading stage and managed to simulate rotational grazing for the balance of the growing season.

All treatments were fertilised to simulate the return of nutrients that would occur under rotational grazing. Each 1.5 x 6 m plot was fertilised after each harvest with a 17-5-10 N-P_2O_5-K_2O chemical fertilizer at a rate calculated at N equal to 3.7% of dry matter (DM) removal for that harvest and mixture. Each grass monoculture or grass-legume mixture grew at a different rate, so treatments were harvested based on regrowth height to further simulate rotational grazing. Plots containing perennial ryegrass or Kentucky bluegrass were clipped to 4 cm after regrowth to 15 cm; all other mixtures were clipped to 7.5 cm after regrowth to 25 cm. Two 0.2 m^2 quadrats were clipped to these same heights in randomly selected locations in each plot at each harvest to determine herbage DM production. Grasses and legumes from the quadrats from one replicate were hand separated, while sampled DM from the other four replicates was dried, weighed, ground to pass a 1-mm screen, and scanned using near-infrared reflectance spectrometry (NIRS). Botanical

Table 1 Three-year means of total season herbage DM production (t/ha) and botanical composition of binary grass-legume mixtures in the clipping trial (1997-1999).

	Total DM	Grass DM	Legume DM	% Legume
Mixtures averaged across legumes				
'Dawn' cocksfoot	8.3[c]	7.7[b]	0.7[d]	7[e]
'Ginger' Kentucky bluegrass	9.2[b]	6.3[c]	2.9[b]	27[c]
'Regar' meadow brome	8.8[b]	7.7[b]	1.1[c]	12[d]
'Barmaco' perennial ryegrass	8.2[c]	4.3[e]	3.9[a]	41[a]
'Moy' perennial ryegrass	8.8[b]	5.1[d]	3.7[a]	36[b]
'Martin' tall fescue	10.0[a]	9.2[a]	0.8[d]	8[e]
SE	0.25	0.21	0.12	0.90
Mixtures averaged across grasses				
'Norcen' birdsfoot trefoil	9.7[c]	7.5[a]	2.1[c]	22[c]
'Windsor' cicer milkvetch	8.4[d]	6.6[c]	1.8[d]	21[c]
'Archer' lucerne	10.1[b]	7.1[b]	3.0[b]	28[b]
'Grasslands Pitau' white clover	11.6[a]	7.6[a]	4.0[a]	35[a]
Monoculture grasses	4.8[e]	4.7[d]	0.1[e]	2[d]
SE	0.23	0.23	0.13	1.00

Different letters within columns indicate significantly different values at $P \leq 0.05$.

Table 2 Three-year means of nutritive value of binary grass-legume mixtures in the clipping trial (1997-1999).

	% DM			% NDF
	IVTDMD	CP	aNDF	NDFD
Mixtures averaged across legumes				
'Dawn' cocksfoot	89[b]	18[c]	45[b]	77[a]
'Ginger' Kentucky bluegrass	88[c]	20[b]	45[b]	74[c]
'Regar' meadow brome	89[b]	21[a]	47[a]	77[a]
'Barmaco' perennial ryegrass	91[a]	22[a]	36[d]	75[b]
'Moy' perennial ryegrass	90[b]	21[a]	38[c]	73[c]
'Martin' tall fescue	86[d]	19[b]	48[a]	72[d]
SE	0.2	0.4	0.5	0.5
Mixtures averaged across grasses				
'Norcen' birdsfoot trefoil	89[b]	21[b]	43[b]	74[a]
'Windsor' cicer milkvetch	89[b]	20[c]	43[b]	75[a]
'Archer' lucerne	88[b]	22[b]	43[b]	73[a]
'Grasslands Pitau' white clover	91[a]	24[a]	39[c]	76[a]
Monoculture grasses	88[b]	14[d]	48[a]	75[a]
SE	0.3	0.4	0.4	0.7

Different letters within columns indicate significantly different values at $P \leq 0.05$.
IVTDMD = *in vitro* true dry matter digestibility
CP = crude protein
aNDF = amylase-treated neutral detergent fibre
NDFD = neutral detergent fibre digestibility

composition was determined using NIRS calibrated for percent legume in mixtures, and nutritive value was calibrated by wet chemistry analyses for crude protein (CP), amylase-treated neutral detergent fibre (aNDF) and *in vitro* true dry matter digestibility (IVTDMD; 48-h incubation and neutral detergent second stage). Digestibility of fibre (NDFD) was calculated from IVTDMD and NDF.

Rotational grazing trial (2001-2003)

Mixtures consisted of 'Norcen' birdsfoot trefoil or 'Grasslands Pitau' white clover with 'Paddock' meadow brome, 'Ambassador' cocksfoot, 'Fuego' tall fescue, or 'Madera' perennial ryegrass. Fenced plots were 330 m^2 (0.033 ha) and were grazed based on grass regrowth height with a sufficient number of dairy heifers to remove the forage in 1 day to the same heights as those in the clipping trial. Plots were either grazed season-long or a spring hay crop was taken when grasses reached early heading stage. Accumulated forage was determined before and after each grazing using a calibrated rising plate meter.

Table 3 Three-year means of total-season herbage DM production (t/ha) and percent utilisation of binary grass-legume mixtures in the grazing trial (2001-2003). Data are from 50 rising plate meter readings taken in each plot before (accumulated) and after (removed) grazing. Accumulated forage includes ungrazed stubble, and forage removed includes forage that disappeared due to grazing, trampling, etc.

	Season-long rotational stocking			Spring hay plus rotational stocking		
	Accumulated	Removed	% Utilisation	Accumulated	Removed	% Utilisation
Mixtures averaged across legumes						
'Paddock' meadow brome	9.1[a]	7.3[a]	79[b]	8.9[a]	6.8[a]	79[a]
'Ambassador' orchardgrass	9.0[a]	7.5[a]	83[a]	6.4[d]	4.9[c]	75[a]
'Madera' perennial ryegrass	6.5[b]	4.3[b]	66[c]	7.0[c]	4.8[c]	68[b]
'Fuego' tall fescue	8.8[a]	6.7[a]	76[b]	8.1[b]	5.6[b]	69[b]
SE	0.20	0.22	0.91	0.20	0.22	0.91
Mixtures averaged across grasses						
'Norcen' birdsfoot trefoil	8.8[a]	6.9[a]	76[a]	7.7[a]	5.7[a]	73[a]
'Grasslands Pitau' white clover	7.9[b]	6.0[b]	75[a]	7.5[a]	5.4[a]	71[a]
SE	0.16	0.17	0.67	0.16	0.17	0.67

Different letters within columns indicate significantly different values at $P \leq 0.05$.

Table 4 Three-year means of total-season herbage DM production (t/ha) and percent botanical composition of accumulated forage in rotationally stocked binary grass-legume mixtures in the grazing trial (2001-2003).

	Season-long rotational stocking			Spring hay plus rotational stocking		
	Grass	Legume	% Legume	Grass	Legume	% Legume
Mixtures averaged across legumes						
'Paddock' meadow brome	7.9[b]	1.3[b]	13[b]	7.0[a]	1.9[b]	22[b]
'Ambassador' orchardgrass	8.8[a]	0.2[c]	2[c]	6.0[b]	0.5[c]	6[c]
'Madera' perennial ryegrass	3.9[c]	2.5[a]	39[a]	3.9[c]	3.1[a]	44[a]
'Fuego' tall fescue	7.7[b]	1.1[b]	13[b]	6.4[b]	1.7[b]	22[b]
SE	0.19	0.13	1.60	0.19	0.13	1.60
Mixtures averaged across grasses						
'Norcen' birdsfoot trefoil	7.2[a]	1.7[a]	21[a]	4.9[b]	2.8[a]	37[a]
'Grasslands Pitau' white clover	7.0[a]	0.9[b]	13[b]	6.7[a]	0.8[b]	10[b]
SE	0.14	0.11	1.30	0.14	0.11	1.30

Different letters within columns indicate significantly different values at $P \leq 0.05$.

Table 5 Three-year means of nutritive value of binary grass-legume mixtures in the grazing trial (2001-2003).

	%			% NDF
	IVTDMD	CP	aNDF	NDFD
Mixtures averaged across legumes				
'Paddock' meadow brome	87[b]	21[b]	47[b]	73[a]
'Ambassador' orchardgrass	86[c]	19[c]	49[a]	73[a]
'Madera' perennial ryegrass	89[a]	21[a]	40[c]	73[a]
'Fuego' tall fescue	84[d]	18[d]	49[a]	68[b]
SE	0.12	0.17	0.25	0.19
Mixtures averaged across grasses				
'Norcen' birdsfoot trefoil	87[a]	21[a]	45[b]	71[b]
'Grasslands Pitau' white clover	87[a]	19[b]	48[a]	73[a]
SE	0.11	0.13	0.24	0.15

Different letters within columns indicate significantly different values at $P \leq 0.05$.
IVTDMD = *in vitro* true dry matter digestibility
CP = crude protein
aNDF = amylase-treated neutral detergent fibre
NDFD = neutral detergent fibre digestibility

In both trials, irrigation plus precipitation equaled 30 mm per week throughout the growing season, totalling about 800 mm over the 6-month grazing season. Data were analysed using the SAS Mixed Procedure. Since these two trials were carried out successively rather than concurrently, data cannot be statistically compared.

Results and Discussion

Clipping trial (1997-1999)

Among the mixtures in the clipping trial (Table 1), those containing tall fescue were the most productive. The meadow brome and cocksfoot components of mixtures were also relatively productive, while the yield of perennial ryegrass and Kentucky bluegrass mixtures was dependent on the legume component. The mixtures containing the two bloat-causing legumes (lucerne and white clover) were the most productive, representing 28-35% of DM, while the bloat-safe legumes (birdsfoot trefoil and cicer milkvetch) comprised about 20% of mixtures under clipping. The nutritive value of all mixtures was high under clipping, while monoculture grasses had lower CP and higher NDF (Table 2). Legume dominance of perennial ryegrass mixtures produced lower NDF values.

Birdsfoot trefoil and white clover were further studied in the grazing trial because white clover was the more productive of the two bloat-causing legumes, and was physically more integrated with companion grasses than lucerne. Birdsfoot trefoil was the more productive of the two bloat-safe legumes, and was more persistent in the clipping trial than in earlier research studies (Blumenthal & McGraw 1999). All treatments were clipped according to grass regrowth height, and no effort was made to allow birdsfoot trefoil to reseed itself. Logan, Utah is at about 40° N latitude so it is likely significant seed production occurred, but seedling recruitment was not quantified.

Rotational grazing trial (2001-2003)

In the grazing trial (Table 3), perennial ryegrass mixtures were significantly less productive and less well utilised under season-long grazing than mixtures containing other grasses. Perennial ryegrass may be less winter-hardy than the other grasses used in this trial, but it also tends to be less dormant. The autumn climate in Utah is often sunny and warm, but irrigation water becomes unavailable, so plants may be harmed as much by drought stress as by intolerance to cold temperatures. When a spring hay crop was taken, grazed mixtures containing meadow brome were the most productive and were well-utilised (Table 3). Mixtures containing birdsfoot trefoil were significantly more productive under season-long grazing than mixtures containing white clover, but utilisation was similar.

Under grazing, cocksfoot was the least compatible with legumes (2-6%), while both meadow brome and tall fescue maintained about the same amount of legume: 13% under season-long grazing, and 22% when a spring hay crop was taken (Table 4). The initial hypothesis that allowing grasses to reach early heading stage before first harvest each year would reduce legumes, was not found to be the case. Under grazing, proportion of birdsfoot trefoil was higher when a spring hay crop was taken than under season-long grazing. Differences were most pronounced in summer (data not shown), perhaps because root development (and thus avoidance of a water deficit) was improved by delaying the first harvest. The potential for legume dominance in grazed mixtures containing perennial ryegrass is apparent in Table 4. The IVTDMD was higher and NDF lower for these perennial ryegrass-based mixtures (Table 5).

The most interesting result of the grazing trial was the productivity of birdsfoot trefoil under grazing. Birdsfoot trefoil was nearly as productive as lucerne in mixtures under clipping and more productive than white clover under season-long grazing (Table 3). Although data collection has not continued and the site is currently less intensively grazed, both the birdsfoot trefoil and white clover planted in 2000 have persisted well under grazing through to 2006. The performance of 'Norcen' and a rhizomatous birdsfoot germplasm (ARS-2620) was compared at a number of sites in the USA (Beuselinck *et al*. 2005). While Norcen performed best in a humid cold climate (Madison, Wisconsin), the rhizomatous birdsfoot trefoil produced much larger and heavier crowns and rhizomes in Logan, Utah than in other locations. Herbage of this rhizomatous germplasm and the selection 'Grasslands Creeping,' a prostrate spreading type from AgResearch New Zealand (Widdup *et al*. 2004), has higher concentrations of condensed tannins than are found in Norcen and many other birdsfoot trefoil cultivars (Wen *et al*. 2004). Higher tannin levels in the herbage increase rumen undegradable protein levels, increasing animal gain and reproductive health, and reducing methane and ammonia production in the rumen (Ramírez-Restrepo & Barry 2005; Woodward *et al*. 2004). Given the livestock productivity advantages of the bloat-safe legume birdsfoot trefoil, a well-utilised component of rotationally stocked grass-legume mixtures, we recommend birdsfoot trefoil mixtures with meadow brome or tall fescue for this region.

ACKNOWLEDGEMENTS

Support for these studies was provided by the Utah Agricultural Experiment Station, Utah State University, Logan, Utah.

REFERENCES

Beuselinck, P.R.; Brummer, E.C.; Viands, D.K.; Asay, K.H.; Smith, R.R.; Steiner, J.J.; Brauer, D.K. 2005. Rhizomatous *Lotus corniculatus*: V. Genotypic and environmental effects on growth. *Crop Science 45*: 1736-1740.

Blumenthal, M.J.; McGraw, R.L. 1999. Lotus adaptation, use, and management. pp. 97-119 *In*: Trefoil: the science and technology of *Lotus*. CSSA Special Publication No. 28. Ed. P.R. Beuselinck. ASA, CSSA, Madison, WI, USA.

Burns, J.C.; Standaert, J.E. 1985. Productivity and economics of legume-based vs. nitrogen-fertilized grass-based pasture in the United States. pp 56-71 *In*: Forage legumes for energy-efficient animal production. Proceedings of a Trilateral Workshop Held in Palmerston North, New Zealand, April 30-May 4, 1984. Eds. Barnes, R.F.; Ball, P.R.; Brougham, R.W.; Marten, G.C.; Minson, D.J. USDA-ARS, Washington, D.C., USA.

Lees, G.L. 1984. Cuticle and cell wall thickness: relation to mechanical strength of whole leaves and isolated cells from some forage legumes. *Crop Science 24*: 1077-1081.

Ramírez-Restrepo, C.A.; Barry, T.N. 2005. Alternative temperate forages containing secondary compounds for improving sustainable productivity in grazing ruminants. *Animal Feed Science and Technology 120*: 19-201.

Wen, L.; Williams, J.E.; Kallenbach, R.L.; Roberts, C.A.; Beuselinck, P.R.; McGraw, R.L. 2004. Cattle preferentially select birdsfoot trefoil in mixtures of tall fescue and birdsfoot trefoil. Online. Forage and Grazinglands doi:10.1094/FG-2004-0924-01-RS.

Widdup, K.H.; Rumball, W.; Rolston, M.P.; Archie, B.J. 2004. Productivity of *Lotus corniculatus* and *L. pedunculatus* cultivars with and without tall fescue under sheep grazing. *Proceedings of the New Zealand Grassland Association 66*: 273-278.

Woodward, S.L.; Waghorn, G.C.; Laboyrie, P.G. 2004. Condensed tannins in birdsfoot trefoil (*Lotus corniculatus*) reduce methane emissions from dairy cows. *Proceedings of the New Zealand Society of Animal Production 64*: 160–164.