GRASS, LEGUMES, AND GRASS-LEGUME MIXTURES: YIELD, NUTRITIVE VALUE, AND SOIL WATER USE

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ABSTRACT

Forages play a major role in Wyoming's economy. However, forage yields in the state have been dwindling and below the national average over the past few years. A field study was conducted from 2013 to 2015 in Sheridan, WY to evaluate grass-legume mixture seeding ratios and nitrogen (N) fertilizer rates for improved forage yield and nutritive value and efficient soil water use. In 2014, forage dry matter (DM) was highest (5980 kg ha^{-1}) in meadow bromegrass receiving the highest N rate (100% meadow bromegrass + 112 kg N ha^{-1}). In general, forage DM in mixture treatments were relatively lower than their respective sole stand treatments in 2014. An opposite trend in forage DM was observed in 2015. The highest yield (8580 kg ha^{-1}) was observed in 25% alfalfa + 25% birdsfoot trefoil + 50% meadow bromegrass treatment. Average forage yield was higher in 2015 (6854 kg ha^{-1}) than 2014 (4611 kg ha^{-1}). Soil water depletion (SWD) between April 4 and August 15, 2015 ranged from 301 to 318 mm. Birdsfoot trefoil monoculture (100% birdsfoot trefoil) depleted the highest amount (318 mm) of soil water. Water use efficiency (WUE) ranged between 44 kg DM mm^{-1} water (100% sainfoin; 50% sainfoin + 50% meadow bromegrass treatments) to 74 kg DM mm^{-1} water (30% alfalfa + 70% meadow bromegrass treatment). Nutritive value of the legumes was higher than meadow bromegrass and this resulted in higher nutritive value in meadow bromegrass-legume mixtures than sole meadow with or without N application. Forage crude protein (CP) in birdsfoot trefoil was as high as 231 and 296 g kg^{-1} in 2014 and 2015, respectively which was almost similar to that of sole alfalfa (286 and 292 g kg^{-1} in 2014 and 2015, respectively). These results showed that birdsfoot trefoil either grown in mixtures with alfalfa and meadow bromegrass or as monoculture has the potential as a good substitute for alfalfa in Wyoming. With the added benefits of non-bloating and resistance to the alfalfa weevil, birdsfoot trefoil will be suitable as a forage crop both for grazing and haying for Wyoming producers, and perhaps for neighboring states.

Key words: Grass-legume mixture ratios, forage yield and nutritive value, soil water depletion, water use efficiency

INTRODUCTION

Forages are the most important agricultural produce in terms of value in Wyoming, contributing $371 million in cash returns in 2014 (USDA-NASS, 2015). However, the yield of forage crops especially alfalfa, the widely grown forage crop, has been consistently below the national average (USDA-NASS, 2015). There are numerous options to improve forage yield, albeit with different impacts. Using species mixtures and improved management practices,

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particularly water and nutrient management, just to mention a few, are some of the main options available for improving forage yield. Nutrient management in the form of fertilizer application has been the major approach for increasing forages yields. However, fertilizers have numerous negative environmental impacts, and are expensive. Growing forage legumes in mixtures with grasses has therefore been long considered a viable alternative to N fertilization of pure grass stands.

Establishing grass-legume mixtures, however, does not only require selection of adapted species that are compatible, but also optimum proportions and number of species. This is important because species number and proportions have profound effects on yield, nutritive value, and profitability. Sainfoin and birdsfoot trefoil are resistant to the alfalfa weevil (Hybner, 2013; Ratciffe and Elgin Jr., 1987), non-bloating, high yielding, and high nutritive value perennial forages that have a potential as alternatives to alfalfa (MacAdam and Griggs, 2013). Research in Utah (MacAdam and Griggs, 2006) has shown that meadow bromegrass is well adapted to Western U.S. and performs well under irrigation. This presents an opportunity to evaluate its performance with potential perennial forage legumes.

This study therefore assessed the effects of different ratios of one grass (meadow bromegrass), and three legumes (alfalfa, sainfoin, and birdsfoot trefoil) mixtures on forage yield and nutritive value. Additionally, compatibility of the forage species as well as depletion of soil water and efficiency of water use were assessed.

PROCEDURES

The study was established in September 2013 at the University of Wyoming Sheridan Research and Extension Center, Sheridan, WY. The experiment consisted of 15 treatments arranged in a randomized complete block with four replicates. The treatments comprised a perennial cool season grass (meadow bromegrass, cultivar ‘Fleet’), three legumes (alfalfa, cultivar ‘WL 363 HQ’; sainfoin, cultivar ‘Shoshone’; and birdsfoot trefoil, cultivar ‘Norcen’), three rates of N fertilization (0, 56, and 112 kg N ha^{-1}) and five ratios of grass:legume mixtures (100:0, 50:50, 70:30, 50:25:25, and 50:16.7:16.7:16.7). Urea was used as the source of N (46% N) which was applied in two splits only to pure grass stands twice in 2014 (April and October) and once (April) in 2015.

Treatment ratios were calculated based on pure live seed and recommended seeding rates. The calculated actual seed needed for each pure stand were 22, 39, 11, and 22 kg ha^{-1} for alfalfa, sainfoin, birdsfoot trefoil, and meadow bromegrass, respectively. The actual amount of seed needed for each pure stand was taken as 100% in calculating the mixture ratios. Plots were clipped three times in 2014 and twice in 2015. Clipped sampled were oven-dried and dry weights of samples were taken and expressed as weight per unit quadrat area. This was then used to calculate forage DM yield (kg ha^{-1}). Soil moisture was monitored between April 4 and August 15, 2015 using a neutron probe (Hydroprobe Model 503DR, CPN International, Inc., Martinez, CA, USA). Soil water depletion was calculated by subtracting the total water transpired from total water input (irrigation + precipitation + residual soil moisture at the beginning of the growing season). Water use efficiency was calculated by diving forage DM yield by the total water transpired. Forage nutritive value was evaluated using near infrared reflectance spectroscopy (NIRS, Foss InfraXact analyzer, Silver Spring, MD).

RESULTS AND DISCUSSION

Forage DM varied among treatments in both 2014 and 2015 (Table 1). Meadow bromegrass receiving the highest N rate (100% meadow bromegrass + 112 kg N ha^{-1}) produced the highest DM (5980 kg ha^{-1}). In general, forage DM in mixture treatments were relatively lower than their respective sole stand treatments. An opposite trend in forage DM was observed in 2015. The highest yield (8580 kg ha^{-1}) was observed in 25% alfalfa + 25% birdsfoot trefoil + 50% meadow bromegrass treatment (Table 1; Figure 1). Average forage yield was higher in 2015 than 2014. This was not surprising because forages were expected to be well-established in 2015. Soil water depletion ranged from 301 to 318 mm (Table 1). Birdsfoot trefoil monoculture (100% birdsfoot trefoil) depleted the highest amount (318 mm) of soil water. Water use efficiency ranged between 44 kg DM mm^{-1} water (100% sainfoin; 50% sainfoin + 50% meadow bromegrass treatments) to 74 kg DM mm^{-1} water (30% alfalfa + 70% meadow bromegrass treatment).

Table 1. Forage dry matter (DM), soil water depletion (SWD), and water use efficiency (WUE) as influenced by N application and grass-legume mixture ratios

Treatment†	**2014**	**2015**	**SWD***	**WUE***
	DM kg ha^{-1}		**(mm)**	**(kg DM mm^{-1})**
100AF	5210	6100	317	50
50AF+50MB	4670	6820	306	60
30AF+70MB	4790	8220	301	74
25AF+25SF+50MB	3630	7340	305	52
100SF	5240	4680	310	44
50SF+50MB	3670	5110	308	44
30SF+70MB	4530	5980	307	57
25AF+25BFT+50MB	3840	8580	305	67
100BT	5430	6670	318	49
50BFT+50MB	3860	6580	306	54
30BT+70MB	5000	6560	305	57
16AF+16SF+16BT+50MB	3610	8080	312	63
100MB+N0	4260	6580	306	57
100MB+N56	5440	7680	301	67
100MB+N112	5980	7830	314	69
Average	**4611**	**6854**	-	-
P value	0.001	0.0005	0.013	0.005
HSD§ (0.05)	2140	2980	16.7	26.6

†% of AF = alfalfa; BT = birdsfoot trefoil; SF = sainfoin; MB = meadow bromegrass; N0 = 0 kg N ha^{-1}; N56 = 56 kg N ha^{-1}; N112= 112 kg N ha^{-1}

*Soil water was monitored using a neutron probe

§Tukey's Honestly Significant Difference test (P > 0.05)

Forage nutritive value was higher in legumes (alfalfa, birdsfoot trefoil, and sainfoin) than meadow bromegrass (Table 2). This resulted in higher forage nutritive value in grass-legume mixtures than sole grass treatments. However, the nutritive value of birdsfoot trefoil was comparable to alfalfa in 2015 supporting the previous findings in Utah (MacAdam and Griggs, 2013). For example, crude protein in birdsfoot trefoil was as high as 231 and 296 g kg^{-1} in 2014 and 2015, respectively which was similar to that of sole alfalfa (286 and 292 g kg^{-1} in 2014 and 2015, respectively). Sainfoin although produced forage of higher nutritive value compared to the meadow bromegrass, alfalfa and birdsfoot trefoil were of generally higher nutritive value than sainfoin. Nitrogen application to sole meadow bromegrass stands did not improve nutritive value.

Table 2. Effects of N application and grass-legume mixture ratios on acid detergent fiber (ADF), neutral detergent fiber (NDF), and crude protein (CP) in two years, 2014 and 2015

	2014			**2015**		
Treatment†	**ADF**	**NDF**	**CP**	**ADF**	**NDF**	**CP**
	g kg^{-1}					
100AF	226	333	286	233	348	292
50AF+50MB	270	394	214	317	528	187
30AF+70MB	276	400	206	326	532	181
25AF+25SF+50MB	278	403	190	328	509	185
100SF	259	372	194	291	381	204
50SF+50MB	286	412	182	336	523	152
30SF+70MB	283	413	180	341	540	146
25AF+25BFT+50MB	272	400	206	317	516	191
100BT	247	352	231	242	322	296
50BT+50MB	282	418	190	331	528	179
30BT+70MB	291	430	183	335	527	170
16AF+16SF+16BT+50MB	267	389	210	305	474	209
100MB+N0	300	450	175	370	611	126
100MB+N56	291	440	180	374	608	126
100MB+N112	289	439	187	364	600	136
P value	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
HSD§ (0.05)	19.3	28.8	23.2	30.2	51.3	24.4

†% of AF = alfalfa; BT = birdsfoot trefoil; SF = sainfoin; MB = meadow bromegrass; N0 = 0 kg N ha^{-1}; N56 = 56 kg N ha^{-1}; N112= 112 kg N ha^{-1}
§Tukey's Honestly Significant Difference test ($P > 0.05$)

Figure 1. A 25% alfalfa + 25% birdsfoot trefoil + 50% meadow bromegrass plot in August 2015

CONCLUSION AND REMARKS

Meadow bromegrass maintained a good balance with legumes when grown in mixtures. This resulted in a general increase in forage DM and nutritive value in meadow bromegrass-legume mixtures than sole meadow bromegrass receiving as high as 112 kg N ha^{-1}. In general, grass-legume mixtures had lower SWD than sole legumes. On the other hand, legumes when mixed with grass improved WUE. Results showed that birdsfoot trefoil has the potential to use as a good substitute for alfalfa in Wyoming. With the added benefits of non-bloating and resistance to the alfalfa weevil, birdsfoot trefoil will be suitable as a forage crop both for grazing and haying for Wyoming producers and perhaps for producers in neighboring states. Preliminary economic analysis (data not shown) showed that birdsfoot trefoil grown both in mixtures with meadow bromegrass and as a sole stand will be profitable in Wyoming.

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Forage mixtures containing legumes out-yield monocultures, fix atmospheric nitrogen, and have lower carbon footprints. However, evidence-based information on creating forage mixtures by directâ€¦Â For high performance grazing systems, identification of suitable bloat-free legumes and methods for direct seeding into old grass and legume stands will be essential strategies. Our review includes information on the benefits of mixed pastures and seeks possible methods of introducing bloat-free forage legumes into existing pastures in western Canada for rapid improvement in productivity and quality while positively influencing animal, soil, and environmental health. Grassâ€legume seed mass ratios and nitrogen rates affect forage accumulation, nutritive value, and profitability. AT Adjesiwor, MA Islam, VD Zheljazkov, JP Ritten, A Garcia y Garcia. Crop Science 57 (5), 2852-2864, 2017. 11. 2017. Nitrogen application in sainfoin under rainâ€fed conditions in Wyoming: Productivity and cost implications. HY Sintim, AT Adjesiwor, VD Zheljazkov, MA Islam, AK Obour. Agronomy Journal 108 (1), 294-300, 2016. 8. 2016.Â Improving Weed Control in Dry Bean Using Narrow Planting. KD LeQuia, ML Thornton, DW Morishita, AT Adjesiwor. GRASS, legumes, and grass-legume mixtures: yield, nutritive value, and soil water use. AT Adjesiwor, MA Islam. The system can't perform the operation now. Keywords: Matua, prairie grass, yield, quality, legumes, compatibility, botanical composition. COMPATIBILITY, YIELD, AND QUALITY OF MATUA PRAIRIE GRASS, Bromus willdenowii (Kunth), WITH LEGUMES. Jennifer F. Guay. ABSTRACT.Â 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.Â resulted in some improvements in total dry matter yield and nutritive value of the forage, without the detrimental suppression of Matua prairie grass. iii. Acknowledgments. If properly inoculated, legumes have the capacity to use atmospheric nitrogen, eliminating the need to apply nitrogen from commercial sources. Legumes also supply a considerable amount of nitrogen to the grass portion of the mixture. Alfalfa. Alfalfa is the most frequently grown forage legume and the highest-yielding perennial forage crop grown in many countries. It produces more protein per unit area than other forage legumes and can be grown alone or in combination with various grass species. For high yields and persistence, alfalfa requires well-drained soil, a pH above 6.1, adequate fertility and proper harvest management. Well-managed alfalfa normally persists for 3 or more years.