Grass-Legume Mixtures for Diversified and Profitable Forage Production

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Abstract
Grass-legume mixtures can improve forage yields, nutritive value, and net economic benefits. A replicated experiment was conducted from 2013-2017 at the University of Wyoming Sheridan Research and Extension Center to determine forage yield, nutritive value, and gross margin for meadow bromegrass (*Bromus riparius* Rehm.), alfalfa (*Medicago sativa* L.), sainfoin (*Onobrychis viciifolia* Scop.), and birdsfoot trefoil (*Lotus corniculatus* L.) mixtures and monocultures. Treatments included 50-50% and 70-30% mixtures of meadow bromegrass with each legume and 50-25-25% mixture of meadow bromegrass with two legumes and 50-16.7-16.7-16.7% mixture of meadow bromegrass, alfalfa, sainfoin, and birdsfoot trefoil. Grass monocultures received 0, 50, and 100 pounds of nitrogen (N) per acre as urea. The study was established in 2013 and plots were harvested in mid-June, August, and October each year from 2014 to 2017. Harvested samples were used to estimate forage dry matter (DM) yield and nutritive value using the near infrared reflectance spectroscopy. Economic analysis was based on expenses involved in producing each crop according to different treatment and cumulative forage DM yields. Gross margin was calculated each year from the difference of cash inflow and variable operational cost. Total forage DM yield from mixtures was consistently higher than legume and grass monocultures. This was particularly evident in the 50-50% and 70-30% mixtures of meadow bromegrass with alfalfa and 70-30% mixture of meadow bromegrass with birdsfoot trefoil. Some of the grass-legume mixtures containing alfalfa and birdsfoot trefoil improved forage nutritive value to levels equivalent to good quality alfalfa. The 50-50% mixture of meadow bromegrass with alfalfa had the highest four-year total gross margin of $1497 per acre. There were no significant gains in profits for meadow bromegrass monoculture with or without N fertilizer. Overall, grass-legume mixtures, which include alfalfa and birdsfoot trefoil, have potential market value comparable to good quality, pure alfalfa.

Introduction
Hay production is a major contributor to US economy generating over $16 billion annually, 50% of which is from alfalfa (USDA NASS 2017). Productivity of alfalfa in the US in the last decade has been 3.4 tons per acre with a 0.004 ton per acre annual increase. In contrast, alfalfa hay price increased by $4 per ton each year. This indicates that there are opportunities to increasing production and income by diversifying forage crops. One way to realize this is through grass-legume mixtures. Studies indicate that grass-legume mixtures can improve forage yields, nutritive value, and net economic benefits (Dhakal 2005; Adjesiwor et al. 2017). Meadow bromegrass is one of the popular cool-season grasses found suitable for mixture. This species can grow upright and allows legumes to thrive in mixtures. Different combinations of meadow bromegrass and legumes including alfalfa, birdsfoot trefoil, and sainfoin can help alleviate challenges of producing monocrops that include costs of N fertilizers required to optimize yield, comparatively low nutritive value of grasses, and bloat disorder in livestock caused by alfalfa.

High forage nutritive value has been used as a benchmark for setting alfalfa and grass hay prices (USDA NASS 2018). Alfalfa hay with crude protein (CP) values of less than 16, 16-18, 18-20, 20-22, and greater than 22% is rated as utility, fair, good, premium, and supreme quality, respectively. While grass hay with CP concentrations less than 5, 5-9, 9-13, and greater than 13% is ranked as low, fair, good, and premium quality hay, respectively. Nutritive value of hay fed to cattle determines the net income from livestock farming. Livestock feed accounts for about 12% of the total farm operating cost (USDA NASS 2017). High quality hay enhances productivity of beef and dairy cattle. The objective of the study was to investigate whether diversified grass-legume mixtures can increase not only productivity but also profitability of the forage farming systems.

Methods and Study Site
The study was conducted during 2013 to 2017 at the University of Wyoming Sheridan Research and Extension Center (ShREC) in Wyoming to determine forage yield, nutritive value, and gross margin (GM) for meadow bromegrass, alfalfa, sainfoin, and birdsfoot trefoil mixtures and monocultures (Table 1). There were 50-50% and 70-30% mixtures of meadow bromegrass with each legume, 50-25-25% mixtures of meadow bromegrass with two legumes, and 50-16.7-16.7-16.7% mixture of meadow bromegrass with three legumes. Grass monocultures received 0, 50, and 100 pounds of N per acre. Seed rates and ratios were estimated based on

pure live seed (PLS) basis (Cosgrove and Collins 2003) and recommended seeding rates. The recommended seeding rates based on PLS for meadow brome grass, alfalfa, sainfoin and birdsfoot trefoil were 20, 20, 35, and 10 pounds per acre, respectively (Holzworth et al. 2003). Crops were harvested in mid-June, August, and October each year from 2014 to 2017. Harvested samples were used to estimate forage dry matter yield per acre and nutritive value using the near infrared reflectance spectroscopy. Economic analysis was based on expenses involved in producing each crop (Table 2) according to different treatment and cumulative forage dry matter yields. Each treatment was treated as an enterprise. Gross margins were calculated each year according to Equation GM=CI-VOC (Karellas et al. 2010), where CI is the cash inflow (US $) and VOC is the variable operational cost (US $).

Table 1. Description of grass-legume seed mass proportions and nitrogen (N) treatments

Treatments†	Proportions of seeds by weight				N rate
	MB	Alf	SF	BFT	
	----------%----------				lb/ac
Alf (100)	0	100	0	0	0
SF (100)	0	0	0	100	0
BFT (100)	0	0	100	0	0
MB-Alf (50-50)	50	50	0	0	0
MB-Alf (70-30)	70	30	0	0	0
MB-SF (50-50)	50	0	50	0	0
MB-SF (70-30)	70	0	30	0	0
MB-BFT (50-50)	50	0	0	50	0
MB-BFT (70-30)	70	0	0	30	0
MB-Alf-SF (50-25-25)	50	25	25	0	0
MB-Alf-BFT (50-25-25)	50	25	0	25	0
MB-Alf-BFT-SF (50-16.7-16.7-16.7)	50	16.7	16.7	16.7	0
MB-N0	100	0	0	0	0
MB-N50	100	0	0	0	50
MB-N100	100	0	0	0	100

†MB = meadow bromegrass; Alf = alfalfa; SF = sainfoin; BFT = birdsfoot trefoil, N0 = 0 pound N per acre; N50 = 50 pounds N per acre; N100 = 100 pounds N per acre.

Table 2. Operation costs and prices for grass and legume hay at University of Wyoming Sheridan Research and Extension Center during the years of 2014 to 2017.

	Price unit^{-1}			
Operation costs/hay prices	**2014**	**2015**	**2016**	**2017**
Fixed operation costs	US $			
Personnel cost (US $ per year)	224.00	224.00	224.00	224.00
Fuel costs for crop monitoring (US $ per year)	2.00	2.00	2.00	2.00
Overheads (Land rental charge, US $ per acre)†	61.52	61.52	61.52	61.52
Soil tests (US $ per sample)	14.00			
Variable operation costs				
Land preparation (US $ per acre)†	62.15	0	0	0
Herbicide (Glyphosate, US $ per pound a.i.)†	3.00	0	0	0
Herbicide application (US $ per acre)†	7.00	0	0	0
Alfalfa seeds (US $ per pound)†	4.51	0	0	0
Birdsfoot trefoil seeds (US $ per pound)†	5.26	0	0	0
Sainfoin seeds (US $ per pound)†	2.70	0	0	0
Meadow bromegrass seeds (US $ per pound)†	3.00	0	0	0
Planting grass (US $ per acre)†	16.36	0	0	0
Planting legumes (US$ per acre)†	15.36	0	0	0
Planting mixtures (US $ per acre)†	17.44	0	0	0
Urea fertilizer (US $ per pound N)†	0.66	0.66	0.85	0.85
Fertilizer application (US $ per pound)†	6.24	6.24	6.24	6.24
Irrigation (US $ per acre)‡	72.87	72.87	72.87	72.87
Hay swathing, raking, and rolling (US $ per acre)†	20.10	20.10	20.10	20.10
Hay hauling (US $ ton^{-1})‡	5.30	5.30	5.30	5.30
Interest on operating capital (4.8%)				
Taxes and insurance (1% of total investment)				
Hay prices per ton§				
Alfalfa	118.00	118.00	122.00	136.00
BFT	101.00	101.00	106.00	128.00
Sainfoin	101.00	101.00	106.00	128.00
Meadow bromegrass	101.00	101.00	106.00	128.00
Meadow bromegrass - legume mixture	101.00	101.00	106.00	128.00

†Adjesiwor et al. 2017; ‡Patterson 2015; §USDA NASS 2018

Results

Forage Yield and Nutritive Value

Monoculture and mixture treatments affected forage dry matter yield (Table 3). There was a trend of higher forage yield from mixtures compared to legume and grass monocultures. This was particularly evident in the 50-50% and 70-30% mixtures of meadow bromegrass with alfalfa and 70-30% mixture of meadow bromegrass with birdsfoot trefoil. Same applied to 50-25-25% mixture of meadow bromegrass, alfalfa, and sainfoin; 50-25-25% mixture of meadow bromegrass, alfalfa, and birdsfoot trefoil; and 50-16.7-16.7-16.7% mixture of meadow bromegrass, alfalfa, birdsfoot trefoil, and sainfoin. Sainfoin monoculture had lowest forage yield. Treatments also affected forage nutritive value. There was a trend of higher nutritive values in monoculture legumes and mixtures compared to monoculture meadow bromegrass (with or without N). In general, mixtures had similar nutritive value to monoculture legumes.

Table 3. Total forage dry matter (DM) yield and average nutritive value for grass-legume mixtures and nitrogen (N) treatments from different harvests at University of Wyoming Sheridan Research and Extension Center during 2015 to 2017.

Treatment†	DM yield				Forage nutritive value‡					
	2015	2016	2017	Total	CP	ADF	NDF	IVDMD	TDN	RVF
	----------tons per acre--------				----------%----------					
Alf (100)	3	5	4	12	24	28	47	69	70	168
SF (100)	2	1	1	4	19	29	47	62	70	172
BFT (100)	3	4	3	10	22	29	47	65	69	174
MB-Alf (50-50)	4	7	7	18	18	33	53	67	65	129
MB-Alf (70-30)	4	5	7	16	18	32	55	66	66	133
MB-SF (50-50)	3	3	3	9	14	34	56	64	65	122
MB-SF (70-30)	3	3	3	9	13	35	55	64	65	118
MB-BFT (50-50)	3	5	5	13	17	34	55	65	64	128
MB-BFT (70-30)	3	5	6	14	17	33	55	66	66	129
MB-Alf-SF (50-25-25)	4	4	6	14	16	34	53	68	65	125
MB-Alf-BFT (50-25-25)	5	7	6	18	18	33	54	68	67	131
Mb-Alf-BFT-SF (50-16.7-16.7-16.7)	4	5	6	15	17	32	52	67	66	133
MB-N0	3	3	2	8	12	37	60	65	62	104
MB-N50	4	4	2	10	13	37	60	67	63	101
MB-N100	4	5	4	13	14	35	60	66	63	113

†MB = meadow bromegrass; Alf = alfalfa; SF = sainfoin; BFT = birdsfoot trefoil, N0 = 0 pound N per acre; N50 = 50 pounds N acre; N100 = 100 pounds N per acre.
‡ CP = crude protein; ADF = acid detergent fiber; NDF = neutral detergent fiber; IVDMD = in vitro dry matter digestibility; TDN = total digestible nutrients; RFV = relative feed value.

Economic Benefits of Different Crops

Year and monoculture and mixture treatments influenced GM (Table 4). The 50-50% mixture of meadow brome with alfalfa had the highest four-year total GM of US $1497 per acre. This was similar to GM for 50-25-25% mixture of meadow bromegrass, alfalfa, and birdsfoot trefoil (US $1440 per acre) and 70-30% mixture of meadow bromegrass with alfalfa (US $1368 per acre). Sainfoin monoculture earned the lowest total GM of US $62. All treatments had an increase in GM in the year 2015 compared to 2014 when no enterprise had profits. In subsequent years, some mixtures maintained a consistent increase in profits, for example, the 50-50% mixture of meadow bromegrass with alfalfa (US $241 to $802 per acre) and 70-30% mixture of meadow bromegrass with alfalfa (US $313 to $753 per acre). There were no significant gains in profits for meadow bromegrass monoculture with or without N fertilizer from 2015 to 2017.

Table 4. Operation costs, revenue, and gross margin for different grass-legume mixtures and nitrogen (N) fertilizer rates determined during the years 2014 to 2017 at the University of Wyoming Sheridan Research and Extension Center.

Treatments†	Operation costs				Revenue				Gross margin‡				
	2014§	2015	2016	2017	2014§	2015	2016	2017	2014§	2015	2016	2017	Total
	----------US $ per acre----------												
Alf (100)	397	110	117	117	347	373	562	611	-51	264	445	495	1153
SF (100)	399	104	100	97	306	211	141	105	-93	107	41	7	62
BFT (100)	368	110	112	108	317	327	387	363	-51	217	275	255	696
MB-Alf (50-50)	375	111	127	132	273	352	683	934	-102	241	556	802	1497
MB-Alf (70-30)	371	115	119	130	280	428	511	883	-91	313	393	753	1368
MB-SF (50-50)	368	107	111	109	214	274	357	376	-153	167	246	268	528
MB-SF (70-30)	370	109	109	108	265	314	330	366	-106	204	221	258	577
MB-BFT (50-50)	346	110	118	121	226	327	501	683	-120	217	383	562	1042
MB-BFT (70-30)	362	110	120	124	292	323	550	757	-70	213	430	633	1206
MB-Alf-SF (50-25-25)	367	112	115	123	212	357	439	718	-155	245	325	596	1011
MB-Alf-BFT (50-25-25)	356	116	128	126	224	440	700	802	-132	324	572	676	1440
Mb-Alf-BFT-SF (50-16.7-16.7-16.7)	361	114	120	124	211	404	546	760	-150	290	426	636	1202
MB-N0	355	111	110	103	249	341	346	232	-106	230	236	130	490
MB-N50	394	152	154	145	318	379	445	316	-76	227	291	171	613
MB-N100	416	186	190	184	350	411	503	468	-66	224	313	283	754

†MB = meadow bromegrass; Alf = alfalfa; SF = sainfoin; BFT = birdsfoot trefoil, N0 = 0 pound N per acre; N50 = 50 pounds N acre; N100 = 100 pounds N per acre.
‡Annual total gross margin from three harvests.
§ Adjesiwor et al. (2017).

Discussion [Conclusions/Implications]

The study showed that mixtures that include alfalfa and birdsfoot trefoil have potential for higher production and similar market value as good quality pure alfalfa hay (Adjesiwor et al. 2017). Grass-legume mixtures can recoup the investments and still earn profits (Dhakal 2005). In four years, mixtures with alfalfa dominated the most productive and profitable crops overriding changes in weather conditions and management (Dhakal 2005; Adjesiwor et al. 2017). The most promising forage production enterprises were 50-50% mixture of meadow bromegrass with alfalfa, 50-25-25% mixture of meadow bromegrass, alfalfa, and birdsfoot trefoil, and 70-30% mixture of meadow bromegrass with alfalfa. Although mixtures purely comprised of meadow bromegrass and sainfoin had relatively lower gross margins, this crop may have more value considering that sainfoin enhances forage palatability and prevents bloat.

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References

Adjesiwor, A.T., Islam, M.A., Zheljazkov, V.D., Ritten,,J.P. and Garcia y Garcia, A. 2017. Grass-legume seed mass ratios and nitrogen rates affect forage accumulation, nutritive value, and profitability. *Crop Sci*., 57: 2852-2864.

Cosgrove, D.R. and Collins, M. 2003. Forage establishment. In R.F. Barnes et al. (eds.). *Forages: An introduction to grassland agriculture*. Blackwell Publishing, Iowa, pp. 239 -256.

Dhakal, D. 2015. Forage grass-legume mixtures for improved forage yield, forage quality, stand persistence, soil properties, and economics. Ph.D. Dissertation, University of Wyoming, Laramie.

Holzworth, L., Mosley, J., Cash, D., Koch, D. and Crane, K. 2003. *Dryland pastures in Montana and Wyoming: Species and cultivars seeding techniques and grazing management*. Montana State University, Montana, pp. 10-24.

Karellas, S., Boukis, I. and Kontopoulos, G. 2010. Development of an investment decision toll for biogas production from agricultural waste. *Ren. Sust. Ener. Rev.*, 14: 1273-1282.

Patterson, P.E. 2015. Alfalfa hay production. University of Idaho, https://www.uidaho.edu/-/media/UIdaho-Responsive/Files/cals/programs/idaho-agbiz/crop-budgets/Southeastern-irrigated/Alfalfa-hay-2015.ashx?la=en&hash=007C6986954CF66A957B2F4C04543D71DE856BD0 (accessed 29 Jan. 2021).

USDA National Agricultural Statistics Service. 2017. Farm production expenditures 2016 summary. http://usda.mannlib.cornell.edu/usda/current/FarmProdEx/FarmProdEx-08-03-2017.pdf (accessed 29 Jan. 2021)

USDA National Agricultural Statistics Service. 2018. 2016 State agriculture overview, Wyoming. https://www.nass.usda.gov/Quick_Stats/Ag_Overview/stateOverview.php?state=WYOMING (accessed 29 Jan. 2021).