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Changes in the forage yield and quality of legume–grass mixtures throughout a vegetation period

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Abstract: The aim of the present study was to determine the changes in the forage yield and quality of binary and ternary mixtures of alfalfa (*Medicago sativa* L.), red clover (*Trifolium pratense* L.), smooth bromegrass (*Bromus inermis* Leys.), orchardgrass (*Dactylis glomerata* L.), and meadow fescue (*Festuca pratensis* Huds.) throughout a vegetation period. Plots were established in 2008 in Isparta, Turkey, in a randomized complete block design with 3 replicates. Four cuttings were done during the 2009 and 2010 vegetative periods. The levels of crude protein (CP), neutral detergent fiber (NDF), acid detergent fiber (ADF), and relative feed value (RFV) were determined for each monoculture and mixture. The highest total dry matter yields were obtained from the alfalfa–smooth bromegrass mixture at 16.65 t ha^{-1} in 2009 and 16.00 t ha^{-1} in 2010. Red clover exhibited the lowest NDF (368 g kg^{-1}) and ADF (256 g kg^{-1}) concentrations compared with the other forage plants, whereas alfalfa displayed the highest CP content (181 g kg^{-1}). The RFV of the mixtures ranged from 107 to 145, and the decrease in yield was larger for the grasses than the legumes throughout the vegetation period. The results indicated that alfalfa–smooth bromegrass, alfalfa–orchardgrass, and alfalfa–meadow fescue mixtures could make valuable legume–grass mixtures.

Key words: Alfalfa, red clover, smooth bromegrass, mixture, seasonal variation

1. Introduction

Quality forage for livestock is produced from natural pastures and forage crops grown under field agriculture conditions worldwide. Legume–grass mixtures are easily established in degenerated pasture or field conditions. Legumes are rich in terms of protein concentration, whereas grasses have higher carbohydrate contents and can benefit from the nitrogen fixed by legumes when they are grown together. Thus, legume–grass mixtures may be more productive than monoculture grasses. Alfalfa (*Medicago sativa* L.) is grown under both irrigated and dry conditions and it may be more productive in mixtures with grasses. Several research studies reported that alfalfa–grass mixtures resulted in higher yields and higher nutritional quality as compared with grasses alone (Serin et al. 1998; Albayrak and Ekiz 2005; Albayrak et al. 2011; Baba et al. 2011; Sanderson et al. 2012). Red clover (*Trifolium pratense* L.) is an important forage legume grown in temperate regions throughout the world; it is most often grown in association with cool season grasses but can be grown alone or with some warm season perennial grasses (Açıkgöz 2001). Red clover is probably best grown in association with grasses, as the mixture increases the dry matter yields and reduces sward weed problems (Keane 1982).

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Our objective in this study was to evaluate the changes in the forage yield and quality of binary and ternary mixtures of alfalfa (*Medicago sativa* L.), red clover (*Trifolium pratense* L.), smooth bromegrass (*Bromus inermis* Leys.), orchardgrass (*Dactylis glomerata* L.), and meadow fescue (*Festuca pratensis* Huds.) throughout a vegetation period.

2. Materials and methods

2.1. Plot establishment

The research was conducted during the 2008–2010 growing seasons in Isparta Province (37°45′N, 30°33′E; elevation 1035 m), located in the Mediterranean region of Turkey. The total precipitation and average temperature data for the experimental area are given in Figures 1 and 2. The major soil characteristics of the research area, determined based on the method described by Rowell (1996), were as follows. The soil texture was clay loam, the organic matter was 1.3% as determined using the Walkley–Black method, the lime was 7.3% as determined using a Scheibler calcimeter, the total salt was 0.34%, the exchangeable K was 117 mg kg^{-1} by 1 N NH_4OAc, the extractable P was 3.6 mg kg^{-1} by 0.5 N $NaHCO_3$ extraction,

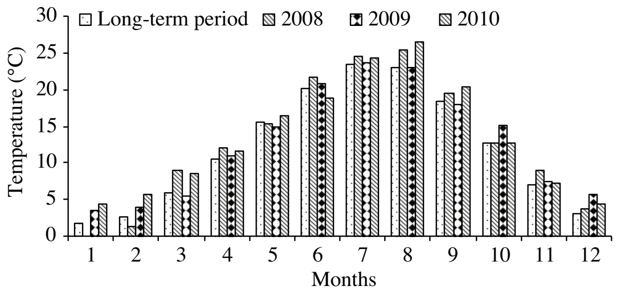

Figure 1. Temperature values for individual experimental years and over the long term.

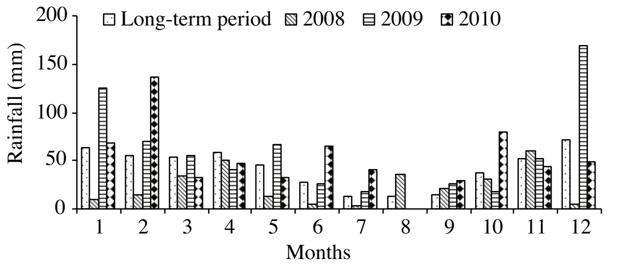

Figure 2. Rainfall values for individual experimental years and over the long term.

and the pH of a soil-saturated extract was 7.9. The soil type was calcareous fluvisol (Akgül and Başayiğit 2005).

Alfalfa (*Medicago sativa* L. cv. Bilensoy), red clover (*Trifolium pratense* L. cv. Raja), smooth bromegrass (*Bromus inermis* Leys. population), orchardgrass (*Dactylis glomerata* L. cv. Amba), and meadow fescue (*Festuca pratensis* Huds. cv. Senu) were used as the experimental material.

Each plot consisted of 6 rows, each 4 m in length. The row spacing was 30 cm. The seeding rates were 20 kg ha^{-1} for each species. The seed mixtures consisted of 1/3 legume and 2/3 grasses. The seeds of the legume and grass species were sown in alternating rows. The plots were not fertilized in the year of establishment. However, all of the grass monoculture plots were fertilized in early April of 2009 and 2010 using N (26% ammonium nitrate) at 80 kg ha^{-1}. No P or K fertilizer was applied, because the soil test results indicated that sufficient amounts were present in the soil. The binary and ternary mixtures were not fertilized. The plots were irrigated once after each harvest.

2.2. Forage yield and quality

The plots were harvested on 28 May, 7 July, 5 August, and 28 September of 2009 and on 4 June, 9 July, 10 August, and 2 October of 2010. The harvest time was based on the 10% flowering stage of alfalfa when the red clover was still in the late vegetative stage. The plots were harvested to a 5-cm stubble height using a plot harvest machine. The botanical compositions were determined for 2 randomly selected 1-m^2 quadrats in each plot (Figures 3 and 4).

After the harvest, samples were collected, hand-separated, dried at 70 °C for 48 h, and weighed. The dried samples were reassembled and ground to pass through a 1-mm screen. The crude protein (CP) content was calculated by multiplying the Kjeldahl nitrogen concentration by 6.25 (Kacar and İnal 2008). The acid detergent fiber (ADF) and neutral detergent fiber (NDF) concentrations were measured according to methods from Ankom Technology. The relative feed value (RFV) was estimated according to the following equation adapted from Aydın et al. (2010):

$$RFV = [120 / NDF] \times [88.9 - (0.779 \times ADF)] \times [0.775].$$

2.3. Experimental design and statistical analysis

The experiment was conducted in a randomized complete block design with 3 replications. A split-split plot design was used for combined analysis of the 2 years (Table 1). The statistical analysis of the yield and quality data was performed using the SAS general linear model procedure (SAS Institute 1998). The years and mixtures were analyzed separately for botanical composition (Figures 3 and 4). The means were compared using Duncan's test at the 0.05 probability level.

3. Results

The results of the variance analysis showed that the effects of the treatments, cuttings, treatment × cutting interactions, and year × cutting interactions on the dry matter (DM) yield were significant (Table 1). The yields from the first cutting were the largest of the 4 (Table 2), and all of the ternary mixtures had higher DM yields than the monocultures and binary mixtures at the first cutting for both years except the alfalfa–smooth bromegrass mixture (Table 2). The binary mixtures demonstrated the greatest DM yields at the last 3 cuttings compared with the ternary mixtures. The DM yield decreased after the first cutting (except for harvest 4) in 2009. Generally, when averaged over all of the cuttings, the mixtures and monoculture legumes showed a 3-fold or 4-fold higher DM yield than the smooth bromegrass, orchardgrass, and meadow fescue monocultures. The average of the 2 years indicated a 57%–78% decline in the yield for the mixtures. The alfalfa grown in monoculture (44%) had the least yield decrease over the course of a season, followed by the red clover, the alfalfa–orchardgrass mixture, and the red clover–orchardgrass mixture with 49%, 57%, and 57%, respectively. The largest yield decrease was found for the orchardgrass monoculture at 84%. The highest DM yield over both years was obtained from the alfalfa–smooth bromegrass, alfalfa–orchardgrass, and alfalfa–meadow fescue binary mixtures (32.21, 31.44, and 30.34 t ha^{-1}, respectively) (Table 2).

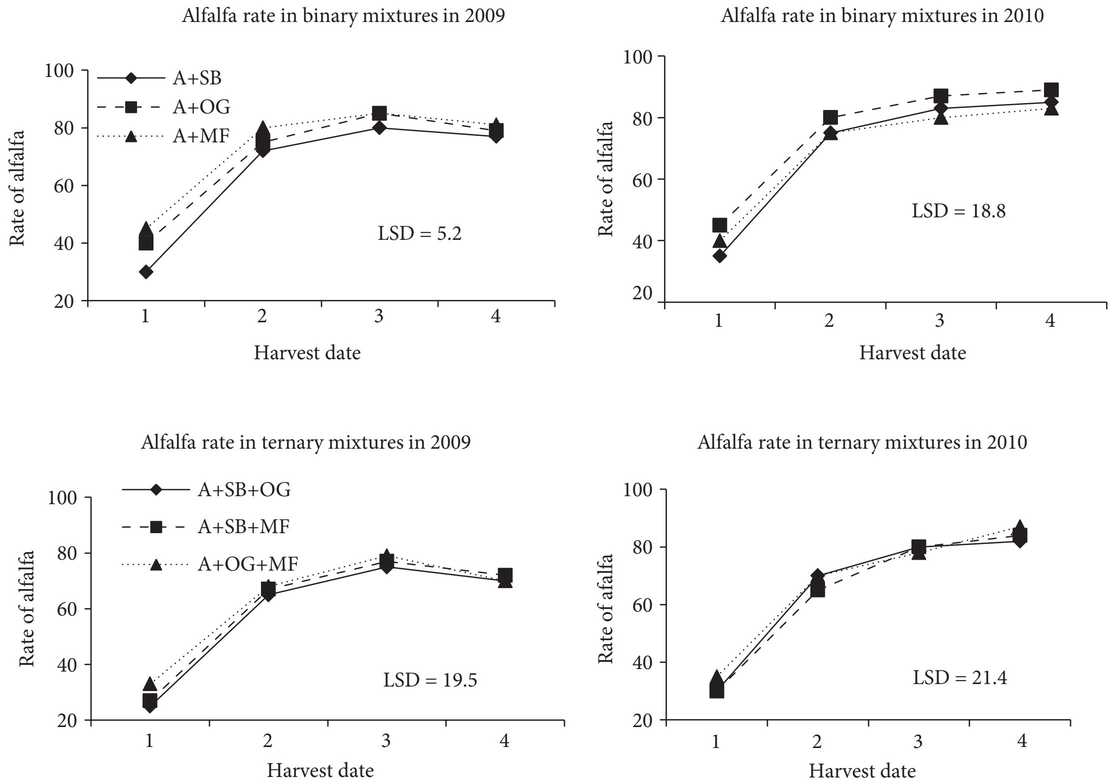

Figure 3. Seasonal variation of alfalfa composition in binary and ternary mixtures. LSD: least significant difference.

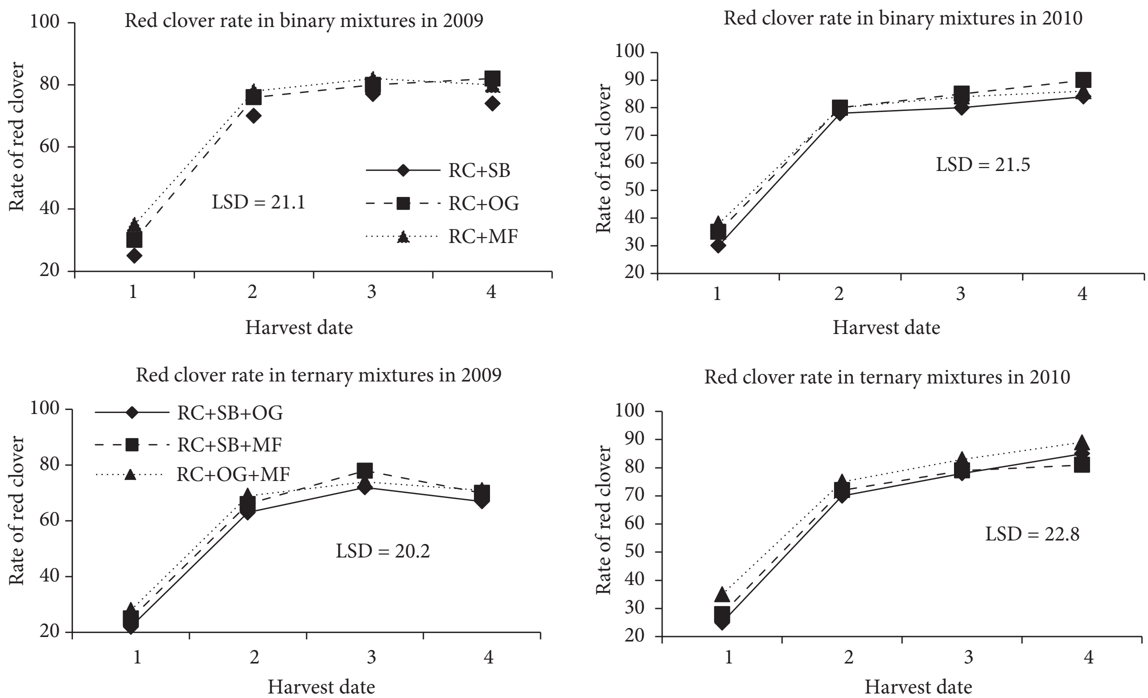

Figure 4. Seasonal variation of red clover composition in binary and ternary mixtures. LSD: least significant difference.

Table 1. Results of analysis of variance and mean squares of the traits determined.

	df	DMY	CP	NDF	ADF	RFV
Block (B)	2	71.051 ns	19.6 ns	51.8 ns	42.37 ns	65.59 ns
Treatment (T)	16	218.845**	845.3**	6646.4**	4531**	10,987**
Error 1	32	2.413	15.1	57.9	40.84	63.85
Year (Y)	1	5.36 ns	19.0 ns	2180**	1545**	4212**
T × Y	16	2.252 ns	2.50 ns	67.6 ns	106.0 ns	144.5**
Error 2	34	3.288	15.2	46.9	73.9	40.15
Cutting (C)	3	3907.72**	1134**	5287**	2133**	6020**
T × C	48	27.899**	14.2 ns	58.6 ns	23.2 ns	25.17 ns
Y × C	3	77.318**	204.5**	1061**	223.0**	1168**
Y × C × T	48	0.986	4.50 ns	33.9 ns	24.19 ns	35.29 ns
Error 3	204	2.090	13.0	45.4	30.05	38.49
CV (%)		14.21	8.03	4.51	5.02	4.97

df = degrees of freedom, CV = coefficient of variation, ns = not significant. *P < 0.05 and **P < 0.01.

Table 2. Dry matter (DM) yields of smooth bromegrass (SB), orchardgrass (OG), meadow fescue (MF), alfalfa (A), and red clover (RC) grown in monoculture and in mixtures (t ha^{-1}).

	2009 cuttings					2010 cuttings				
	1	2	3	4	Total	1	2	3	4	Total
A	5.10f	4.20a	3.10a	3.70a	16.10ac	5.70fg	4.10a	2.80a	2.20a	14.80ac
RC	4.75f	3.50bc	2.70ac	3.10ab	14.05df	5.20g	3.60ad	2.30ab	1.90ab	13.00cd
SB	3.30g	0.90g	0.75g	0.80d	5.75g	3.90h	1.10f	0.70de	0.65cd	6.35e
OG	2.80gh	0.70g	0.50g	0.55d	4.55gh	3.00h	0.80f	0.60e	0.40d	4.80e
MF	2.30h	0.80g	0.40g	0.50d	4.00g	3.40h	1.00f	0.80de	0.50cd	5.70e
A+SB	6.90bd	3.55bc	2.90ab	3.30ab	16.65a	7.40ad	3.70ab	2.60a	2.30a	16.00a
A+OG	6.40ce	3.58bc	2.95ab	3.28ab	16.21ac	6.80ce	3.63ac	2.55a	2.20a	15.18ab
A+MF	6.20e	3.80ab	2.92ab	3.34ab	16.26ab	7.10be	3.52ad	2.80a	2.28a	15.70a
RC+SB	6.30de	3.10ce	2.50bc	2.74ac	14.64bf	6.70cf	3.30ae	2.20ab	2.00a	14.20ad
RC+OG	5.90e	3.21cd	2.48bc	2.58bc	14.17df	6.20eg	3.15be	2.30ab	2.03a	13.68bd
RC+MF	5.00f	3.30bc	2.45bc	2.66bc	13.41f	6.40df	3.21be	2.35a	2.12a	14.08ad
A+SB+OG	7.70a	2.61ef	2.49bc	2.56bc	15.36ad	8.10ab	2.90be	2.05ac	1.98a	15.03ab
A+SB+MF	7.50ab	2.69df	2.28ce	2.64bc	15.11ae	8.40a	2.77de	2.01ac	2.00a	15.19ab
A+OG+MF	7.30ab	2.68df	2.30cd	2.47bc	14.75bf	8.00ab	2.81ce	2.04ac	2.03a	14.88ac
RC+SB+OG	7.40ab	2.35f	1.72ef	2.12c	13.59ef	7.50ac	2.60e	1.50bd	1.10cd	12.70d
RC+SB+MF	7.00bc	2.47f	1.81df	2.08c	13.36f	7.60ac	2.50e	1.28ce	1.15bd	12.53d
RC+OG+MF	7.00bc	2.53ef	1.70f	2.05c	13.28f	7.40ad	2.55e	1.35ce	1.18bc	12.48d
Mean	5.81a	2.70bc	2.11c	2.38c	13.01A	6.40a	2.78b	1.89c	1.65c	12.73A
CV %	6.30	13.02	16.08	24.43	7.38	10.02	18.34	25.75	28.7	9.28

Means in the same column followed by the same letter are not significantly different at the P = 0.05 level.

The years and mixtures were analyzed separately to determine botanical composition (Figures 3 and 4). Differences between the alfalfa and red clover compositions in mixtures were determined. Alfalfa and red clover rates in the mixtures increased throughout the vegetation period, and the alfalfa and red clover proportions in the binary mixtures were higher than in the ternary mixtures.

Treatments, cuttings, and year × cutting were significant for the CP content (Table 1). The grass monocultures exhibited lower CP values than the legume monocultures and the legume–grass mixtures (Table 3). The alfalfa and red clover binary mixtures had higher CP contents than the ternary mixtures.

Differences in NDF and ADF concentrations occurred among the treatments, years, and cuttings (Table 1). The year × cutting interaction also was observed. The legumes in monoculture or in binary and ternary mixtures with grasses had lower NDF and ADF values than the grasses grown in monoculture (Tables 4 and 5). The red clover and alfalfa monocultures demonstrated the lowest NDF and ADF concentrations, followed by the red clover binary and ternary mixtures and the alfalfa binary mixtures. On average, the last 3 cuttings of all species exhibited lower NDF and ADF concentrations than the first cutting, and the NDF and ADF concentrations in 2009 were lower than those in 2010.

RFV was affected by treatment, year, cutting, year × treatment interactions, and year × cutting interactions. The binary legume–grass mixtures had higher RFV than the ternary legume–grass mixtures and the grass monocultures (Table 6). All of the legume–grass mixtures and monocultures displayed higher RFV at cutting 3 in 2009 and cutting 4 in 2010, which may have been due to the decrease in the NDF and ADF concentrations in the mixtures (Tables 4 and 5).

Table 3. Mean crude protein content (CP) of smooth bromegrass (SB), orchardgrass (OG), meadow fescue (MF), alfalfa (A), and red clover (RC) grown in monoculture and in mixtures (g kg^{-1}).

	2009 cuttings					2010 cuttings				
	1	2	3	4	Mean	1	2	3	4	Mean
A	175a	181a	165a	197a	180a	169a	176a	188a	195a	182a
RC	164ab	173ab	158ab	186ab	170a	158a	165ab	173ab	188ab	171b
SB	87g	116g	124fg	118f	111g	85d	104f	118e	123d	108g
OG	95g	127eg	121fg	122f	116g	92d	117ef	121e	126d	114g
MF	89g	122fg	117g	120f	112g	81d	116ef	123de	125d	111g
A+SB	142ce	151cd	144bd	167bd	151bd	131bc	148bd	151c	165c	149cd
A+OG	146cd	156bc	142be	164ce	152bc	139b	151bd	153bc	171bc	154c
A+MF	151bc	159bc	147bc	169bc	157b	137bc	153bc	155bc	169bc	154c
RC+SB	143ce	149cd	142be	158ce	148be	128bc	146bd	144cd	161c	145cf
RC+OG	148cd	154cd	141ce	159ce	151bd	132bc	143bd	149c	167bc	148ce
RC+MF	147cd	152cd	144bd	156ce	150bd	131bc	141cd	147c	168bc	147ce
A+SB+OG	139cf	144cd	135cf	151ce	142cf	127bc	137ce	138ce	159c	140df
A+SB+MF	127ef	138df	132cg	147de	136f	125bc	132ce	137ce	155c	137ef
A+OG+MF	138cf	148cd	134cf	146de	142df	129bc	135ce	139ce	156c	140df
RC+SB+OG	134df	146cd	129dg	145e	139ef	119c	131ce	135ce	153c	135f
RC+SB+MF	126f	142ce	127eg	144e	135f	123bc	128de	137ce	154c	136f
RC+OG+MF	134df	149cd	123fg	148de	139ef	124bc	129de	138ce	157c	137ef
Mean	134b	147ab	137b	153a	143A	125c	138b	144ab	158a	141A
CV %	7.19	7.11	7.28	8.01	4.20	8.73	9.77	9.06	8.29	4.56

Means in the same column followed by the same letter are not significantly different at the P = 0.05 level.

Table 4. Mean neutral detergent fiber (NDF) of smooth bromegrass (SB), orchardgrass (OG), meadow fescue (MF), alfalfa (A), and red clover (RC) grown in monoculture and in mixtures (g kg^{-1}).

	2009 cuttings					2010 cuttings				
	1	2	3	4	Mean	1	2	3	4	Mean
A	415h	391h	368hi	399g	393i	428ij	411jk	395gh	391ij	406j
RC	377i	354i	335i	357h	356j	394j	384k	376h	371j	381k
SB	613a	557a	524a	535a	557a	611a	572a	515a	504ac	551a
OG	565b	511bc	498a	517ac	523bc	578ab	556ab	504ab	508ab	537ab
MF	592a	536ab	484ac	508ad	530b	582ab	544ac	521a	524a	543a
A+SB	484e	442fg	435df	449ef	453g	494fg	462gi	455df	441eh	463fg
A+OG	456fg	421gh	426dg	438ef	435g	482gh	471fh	464ce	446eh	466f
A+MF	479ef	416gh	407eh	447ef	437g	491eg	487eg	451df	438fh	467f
RC+SB	448g	408gh	387gh	417fg	415h	465gi	446hj	434eg	431gi	444gh
RC+OG	423h	413gh	395fh	424fg	414h	453hi	451gi	425eg	422hi	438hi
RC+MF	436gh	401h	384h	415fg	409hi	434i	425ij	418fg	412ad	422ij
A+SB+OG	545bc	509bd	488ac	511ad	513bd	558bd	524be	507ab	488be	519bc
A+SB+MF	528cd	498ce	491ab	524ac	510cd	561bc	521be	498ac	476be	514cd
A+OG+MF	539c	476cf	476bc	527ab	505de	546bd	534bd	511ab	467cf	515cd
RC+SB+OG	536c	482ce	455bd	488cd	492ef	523df	506df	487ad	466df	496de
RC+SB+MF	509d	471ef	461bd	491bd	483f	534ce	514ce	497ac	462df	502ce
RC+OG+MF	525cd	475df	447ce	474de	480f	529cf	508ce	473bd	455dg	491e
Mean	498a	457b	439c	466ab	465B	510a	489b	466c	453c	479A
CV %	2.86	4.77	5.61	4.94	2.28	4.51	4.57	5.05	4.89	2.61

Means in the same column followed by the same letter are not significantly different at the P = 0.05 level.

Table 5. Mean acid detergent fiber (ADF) of smooth bromegrass (SB), orchardgrass (OG), meadow fescue (MF), alfalfa (A), and red clover (RC) grown in monoculture and in mixtures (g kg^{-1}).

	2009 cuttings					2010 cuttings				
	1	2	3	4	Mean	1	2	3	4	Mean
A	308h	274gh	252h	267h	275i	312j	287gh	295hi	285gh	295g
RC	264i	246h	221h	239h	243j	276k	259h	276i	271h	271h
SB	446a	408a	389a	395ab	410a	464a	417a	415a	404a	425a
OG	425a	399a	374ab	387ab	396a	437b	388ab	404ab	408a	409a
MF	415ab	392ab	371ab	406a	396a	448ab	376b	418a	422a	416a
A+SB	361cf	337ce	324df	339dg	340de	391de	364bc	352df	347bd	364c
A+OG	356cg	326cf	314eg	327eg	331eg	377eg	355bd	351df	349bd	358c
A+MF	345eg	331cf	326df	329eg	333eg	383df	357bd	354ce	342ce	359c
RC+SB	327fh	298fg	285g	306g	304h	337ij	302eg	318gh	308fg	316ef
RC+OG	324gh	316df	297fg	329eg	317fh	326ij	297fg	295hi	311fg	307fg
RC+MF	338eh	302eg	289g	314fg	311gh	329ij	309eg	302gi	304fg	311fg
A+SB+OG	386bc	362bc	358ac	374ac	370b	424bc	382b	371cd	369bc	387b
A+SB+MF	374ce	355c	347bd	365bd	360bd	406cd	375b	370cd	373b	381b
A+OG+MF	383bd	351cd	348bd	386ab	367bc	401ce	389ab	383bc	368bc	385b
RC+SB+OG	355cg	346cd	335ce	351ce	347ce	364fh	336ce	324fh	318ef	336d
RC+SB+MF	348dg	329cf	324df	338dg	335ef	351gi	331ce	327eg	323df	333de
RC+OG+MF	343eh	337ce	331ce	341cf	338ef	348hi	327df	321gh	319ef	329de
Mean	359a	336c	323d	341b	339B	375a	344b	346b	342b	352A
CV %	6.21	6.51	5.89	5.90	3.97	4.22	5.96	5.17	4.84	2.99

Means in the same column followed by the same letter are not significantly different at the P = 0.05 level.

Table 6. Mean relative feed value (RFV) of smooth bromegrass (SB), orchardgrass (OG), meadow fescue (MF), alfalfa (A), and red clover (RC) grown in monoculture and in mixtures (%).

	2009 cuttings					2010 cuttings				
	1	2	3	4	Mean	1	2	3	4	Mean
A	146b	161b	175b	159b	160b	141b	150b	155ab	158b	151b
RC	169a	183a	199a	183a	183a	160a	167a	167a	170a	166a
SB	82m	95l	104k	101h	96j	80i	92g	102i	106hi	95g
OG	92kl	105jl	112jk	106h	104hi	88hi	98fg	106i	105hi	99g
MF	89lm	101kl	116jk	105h	103i	86hi	102f	101i	100i	97g
A+SB	117eg	132ef	136eg	130df	129d	110e	122d	126e	131e	122e
A+OG	125de	140de	141ef	135cd	135d	115e	121d	124ef	129ef	122e
A+MF	121ef	141ce	146de	132de	135d	110e	117d	127de	132de	121e
RC+SB	132d	150cd	160cd	145c	147c	126d	137c	138cd	140cd	135d
RC+OG	140bc	145cd	155cd	139cd	145c	130cd	136c	144bc	143c	138cd
RC+MF	134cd	152bc	161bc	145c	148c	136bc	142bc	146bc	148c	143c
A+SB+OG	100jk	111ik	117ik	109gh	109gh	93gh	105f	110gi	115gh	106f
A+SB+MF	105hj	114hj	118ik	108gh	111fg	95gh	107ef	112fi	117g	108f
A+OG+MF	102ij	120gi	121hj	104h	112fg	98fg	102f	108hi	120fg	107f
RC+SB+OG	106hj	120gi	126gj	118fg	117ef	108ef	115de	122eg	128ef	118e
RC+SB+MF	113fh	125fg	129fi	119fg	122e	107ef	114de	119eh	128ef	117e
RC+OG+MF	110gi	123fh	132eh	122ef	122e	109e	116d	126e	131de	120e
Mean	117c	131b	138a	129b	128A	111d	120c	125b	130a	122B
CV %	4.41	4.88	6.19	5.72	3.03	5.26	4.40	5.70	4.65	2.72

Means in the same column followed by the same letter are not significantly different at the P = 0.05 level.

4. Discussion

The DM yields of both the binary and ternary legume–grass mixtures were greater than the yield of any grass under monoculture. The DM yield decreased after the first cutting in both years and may have been caused by differences in the growth of the legume composition at different times throughout the vegetation period (Figures 3 and 4). The percentage of alfalfa and red clover increased in all of the mixtures after the first cutting. The legume composition in a few of the plots decreased in the fourth cutting of 2009. In the first year, the temperatures during August and September were 3.3 °C and 2.3 °C lower, respectively, than during those months of the second year (Figure 1); thus, the grass rates in the mixtures may be slightly increased because of the lower temperature during the fourth cutting in 2009. Out of the 4 cuttings, the first was dominated by grasses, whereas legumes were dominant in the subsequent 3 cuttings, which might have resulted from the slow regrowth of the grasses. Spandl and Hersterman (1997) indicated that alfalfa and alfalfa–grass mixtures had higher DM yields than the red clover monocultures or the red clover binary and ternary mixtures, perhaps because the deep root systems of the alfalfa plants were able to utilize deeper soil water (Table 2). Several researchers reported that grass and legume mixtures had higher DM yields than monocultures (Gokkus et al. 1999; Sleugh et al. 2000; Berdahl et al. 2001; Albayrak et al. 2011), which is consistent with our results.

The grass monocultures demonstrated lower CP contents than the legume monocultures and the legume–grass mixtures (Table 3), and the alfalfa and red clover binary mixtures had higher CP contents than the ternary mixtures. In general, CP content increased after the first cutting (Table 3) for the legume binary and ternary mixtures, with the exception of the third cutting in 2009; this result may have been due to the increase in the legume rate in the mixtures (Figures 3 and 4). There was a significant increase in the CP content of the grasses after the first cutting (Table 3). The CP contents of the grasses at the last 3 cuttings were higher than those at the first cutting because all of the grasses were still in the early vegetative stage at the time of cutting. In the present study, the timing of the cutting was based on the 10% flowering stage of alfalfa. Increasing the alfalfa and red clover proportion resulted in increased CP concentrations for the mixtures, suggesting that the grasses benefited when grown in mixtures with legumes. Ta and Faris (1987) reported that the nitrogen released from legumes was used by the grasses in mixtures. Thus, the mixtures had higher CP contents than the monoculture grasses. Several researchers indicated that legume–grass mixtures had higher CP contents than grasses alone (Kunelius et al. 2006; Springer et al. 2007; Sanderson 2010; Kim and Albrecht 2011), which is similar to our results.

The NDF and ADF concentrations of forage are also important quality parameters (Caballero et al. 1995). The legume monocultures and binary and ternary mixtures had lower NDF and ADF concentrations than the monoculture grasses. This situation can be explained by the fact that the amounts of cell wall constituents (NDF and ADF) in legumes are not as large as those of grasses. The proportion of cell wall constituents in grasses is larger than in legumes and they have quicker lignin accumulation (Buxton et al. 1991). Van Soest (1996) indicated that under similar growth conditions, legumes have low NDF values, whereas grasses have high values, which is in agreement with the present study. In our study, NDF and ADF concentrations decreased throughout the vegetation period, which can be explained by the increased legume proportion in the mixtures and the fact that all of the grasses were in the early vegetative stage after the first cutting (Sulc et al. 1997).

Uzun (2010) stated that forages with an RFV of over 151, 150–125, 124–103, 102–87, 86–75, and less than 75 are categorized as prime, premium, good, fair, poor, and rejected, respectively. Van Soest (1996) reported that the RFV is not a direct measure of the nutritional content of forage, but that it is important for estimating the value of the forage. Based on the average of the 2 years, the binary mixtures and ternary mixtures had relative feed values ranging from 121–145 to 107–121 and, thus, may be categorized as premium and good quality.

According to our study, the forage yields and quality of the legume–grass mixtures were higher than those of the monoculture grasses and equal to or higher than those of the legume monocultures. The alfalfa and red clover binary mixtures (46%–56% and 66%–70%, respectively) and the alfalfa and red clover ternary mixtures (64%–71% and 74%–85%, respectively) decreased in yield over the season compared to their first cutting yields; this yield decrease was larger for the ternary mixtures than the binary mixtures. The alfalfa and red clover under monoculture showed the smallest decrease in yield throughout the vegetation period. Binary mixtures may be preferred to ternary mixtures because of their higher forage yield, higher quality, and smaller decline in yield. The results indicated that alfalfa–smooth bromegrass, alfalfa–orchardgrass, and alfalfa–meadow fescue mixtures could make valuable legume–grass mixtures.

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