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Forage Yield and the Quality of Perennial Legume-Grass Mixtures under Rainfed Conditions

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Abstract

This study was performed to determine suitable perennial forage species and their mixtures for the establishment of short-term artificial pastures under rainfed conditions in Turkey. The study was conducted from 2008 through 2010. Alfalfa (*Medicago sativa* L.), sainfoin (*Onobrychis sativa* Lam.), brome grass (*Bromus inermis* Leys.), intermediate wheatgrass (*Agropyron intermedium* (Host). Beauv.), crested wheatgrass (*Agropyron cristatum* L. Gaertn.) and their binary and ternary mixtures were used as experimental material. The study found significant differences in yield and quality among the forage mixtures investigated. Sainfoin + bromegrass + crested wheatgrass and sainfoin + crested wheatgrass mixtures gave the highest dry matter yield (8.36 and 7.75 t/ha, respectively). Binary and ternary mixtures of alfalfa + grasses had higher crude protein levels and lower values of ADF and NDF content than mixtures of sainfoin + grasses. Pure alfalfa (56.64%) and binary mixtures of alfalfa + grasses (53.53 to 54.28%) had the highest TDN values. The relative feed values of the mixtures ranged from 95.64 to 112.58. The results of the study indicated that alfalfa and sainfoin binary mixtures with grasses may both be used to establish artificial pastures in similar ecologies owing to their high forage yield and quality.

Keywords: alfalfa, sainfoin, bromegrass, mixture, relative feed value

Introduction

Grass-legume mixtures are preferred over pure-grass forage stands throughout the world because they often increase the total yields of herbage and protein and offer balanced nutrition (Albayrak and Ekiz, 2005). Mixtures offer several potential advantages over pure grasses or pure legumes. These advantages include the control of erosion, weed control and prolonged stand longevity (Casler, 1988). Alfalfa is one of the most commonly used legumes for both hay and pasture in Turkey because of its high yield, high nutritional quality, ability to fix nitrogen, and vigorous fall regrowth (Açıkgöz, 2001). It is generally grown with a mixture of grasses that usually includes bromegrass. Bromegrass is grown with alfalfa to reduce invasion by weeds, reduce the danger of bloat, improve trafficability, reduce the curing time of alfalfa in the swath, and provide insurance against yield reductions due to winterkill or disease of the alfalfa (Bitman *et al.*, 1991). Sainfoin is a non-bloat forage legume. It provides a harmonious mixture with crested wheatgrass that has resistance to cold and dry conditions (Karnezos *et al.*, 1994). Intermediate wheatgrass offers wide adaptation and high productivity, but is not used as widely as bromegrass or crested wheatgrass. The reason that it is not used widely may be that it does not persist for more than 4 to 5 years, especially under intense management (Sleugh *et al.*, 2000). This grass tolerates alkaline and saline soils and does well with alfalfa under dryland or limited irrigation conditions (Asay, 1995).

Grass-legume mixtures tend to provide a superior nutrient balance and produce higher forage yields. However, grass-legume mixtures are more difficult to manage than monoculture pastures because of competition for light, water, and nutrients (Charles and Lehmann, 1989; Serin *et al.*, 1998; Berdahl *et al.*, 2001; Albayrak and Ekiz, 2005).

Accordingly, the objective of this study was to determine the best legume-grass composition using alfalfa, sainfoin, brome grass, intermediate wheatgrass and crested wheatgrass and to compare the performance of the selected pure and mixed forage compositions in an artificial pasture establishment under rainfed conditions in Turkey.

Materials and methods

The research was carried out 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 Tab. 1.

The major soil characteristics of the study area, based on the method described by Rowell (1996) were found to be as follows. The soil texture was clay, organic matter was 1.2% by the Walkley-Black method, total salt was 0.35%, lime was 7.1% by Schiebler calcimeter, extractable P was 3.4 mg kg^{-1} by 0.5N $NaHCO_3$ extraction, exchangeable Kwas 113 mg kg^{-1} by 1N NH_4OAc and pH in a soil saturation extract was 7.8. the soil type was calcareous fulvisol (Akgül and Başayiğit, 2005).

Tab. 1. Monthly precipitation and mean temperature in the experimental area

Months	Precipitation (mm)				Temperature (°C)			
	(Long years)	2008	2009	2010	(Long years)	2008	2009	2010
Jan.	64.2	10.0	124.7	68.0	1.8	-0.1	3.4	4.3
Feb.	54.9	15.0	70.3	136.8	2.6	1.4	4.0	5.6
Mar.	52.9	34.2	55.2	33.2	5.9	8.9	5.5	8.6
Apr.	58.8	51.1	40.4	47.0	10.6	12.1	11.0	11.5
May	46.0	13.3	66.6	32.4	15.5	15.4	15.0	16.5
Jun.	27.8	4.4	26.8	64.5	20.1	21.7	20.9	18.9
Jul.	12.8	2.6	18.0	40.1	23.5	24.5	23.6	24.4
Aug.	12.9	35.7	0.2	0.2	22.9	25.3	23.1	26.4
Sep.	15.4	20.4	26.2	29.7	18.3	19.4	18.0	20.3
Oct.	38.0	31.2	18.1	79.1	12.8	12.8	15.1	12.6
Nov.	51.5	60.7	51.6	43.7	7.0	9.0	7.5	7.2
Dec	70.9	5.0	168.6	48.5	3.1	3.7	5.7	4.4
Total	506.1	293.6	666.7	623.2	-	-	-	-
Mean	-	-	-	-	12.01	12.84	12.73	13.39

Alfalfa (*Medicago sativa* L.), sainfoin (*Onobrychis sativa* Lam.), brome grass (*Bromus inermis* Leys.), intermediate wheatgrass (*Agropyron intermedium* Host. Beauv.) and crested wheatgrass (*Agropyron cristatum* L.) (Gaertn.) were used as experimental material. The experiment was conducted in a completely randomized block design with 3 replications. Each plot consisted of 6 rows each 4 m in length. The between-row spacing was 35 cm. The seeding rates were 100 kg ha for sainfoin and 20 kg ha for the other species. Seed mixtures consisted of 1/3 legume and 2/3 grasses. The seeds of legume and grass species were sown in the same rows. Herbage was not harvested during the 2008 growing season, when the plots were originally established. In 2009 and 2010, the plots were harvested exactly once each year. Samples were collected following the harvest. A samples were 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 content was calculated by multiplying the Kjeldahl nitrogen concentration by 6.25 (Bozkurt and Kaya, 2010).

ADF (acid detergent fiber) and NDF (neutral detergent fiber) concentrations were measured according to standard laboratory procedures for forage quality analysis Ankom Technology, (Anonymous, 2010). Total digestible nutrients (TDN), dry matter intake (DMI), digestible dry matter (DDM) and relative feed value (RFV) were estimated according to the following equations adapted from Aydın *et al*. (2010),

TDN = (-1.291 x ADF) + 101.35

DMI = 120% NDF % dry matter basis

DDM = 88.9-(0.779 x ADF % dry matter basis)

RFV = DDM% x DMI% x 0.775

Data were analyzed with analysis of variance (SAS, 1998) at the $P<0.05$ and 0.01 levels of significance, and means were compared using the least significant difference test at $P<0.05$.

Results and discussion

The dry matter yields of the pure-sown plots and mixtures were significantly different ($P <0.05$) in both years (Tab. 2). The yield of both binary and ternary legume + grass mixtures was greater than or equal to the yield of any grass in monoculture. In the first year, the sainfoin + grasses binary mixtures (8.33 to 8.37 t ha) and the sainfoin + grasses ternary mixtures (8.52 to 8.96 t ha) produced the highest yields, whereas the pure grasses gave the lowest (3.10 to 3.50 t ha). In the second year, the alfalfa binary mixtures except alfalfa + crested wheatgrass and the alfalfa ternary mixtures except alfalfa + bromegrass + intermediate wheatgrass had higher dry matter yields than the other mixtures or the pure-sown grass. Sainfoin mixtures, except for sainfoin + bromegrass+ crested wheatgrass, gave lower dry matter yield compared with the first harvest year.

Based on the average of the 2 years, sainfoin + bromegrass + crested wheatgrass and sainfoin + crested wheatgrass gave the highest dry matter yields (8.36 and 7.75 t ha, respectively).

The mixtures were superior to the single grass or legume stands (Sıma *et al*., 2010; Albayrak and Ekiz, 2005; Berdahl *et al*., 2001; Sleugh *et al*., 2000; Gokkus *et al*., 1999) owing to utilization of symbiotically fixed nitrogen (Whitehead, 1995), more enhanced interception of light (Hay and Walker, 1989) and allelopathic (Pudnam and Duke, 1978) and some other effects. These factors created a micro-environment that favored higher yields than those obtained from sole legume or grass stands (Sengul, 2003).

Grass monocultures had lower crude protein content than legume monocultures and legume + grass mixtures (Tab. 2). Of the legumes in monoculture, alfalfa had the highest CP content. Binary and ternary mixtures of alfalfa + grasses had a higher crude protein content than sainfoin + grasses mixtures. The crude protein contents of all

Tab. 2. Dry matter yield (DM) and crude protein content (CP) of legume-grass mixtures

Treatments	DMY (t ha)			CP (%)		
	2009	2010	Mean	2009	2010	Mean
A	4.90 e	5.76 ef	5.33 g	19.60 a	18.25 a	18.93 a
S	5.80 de	5.28 f	5.54 g	17.45 ab	16.30 ab	16.88 b
B	3.10 f	3.21 g	3.16 h	11.13 fg	10.45 gh	10.79 j
C	3.44 f	3.74 g	3.59 h	9.50 g	8.90 h	9.20 k
I	3.50 f	2.97 g	3.24 h	10.42 g	9.90 h	10.16 jk
A+B	5.34 de	7.86 ab	6.60 de	16.50 bc	15.70 bd	16.10 bc
A+C	5.88 d	5.91 ef	5.90 fg	16.20 bc	15.90 bc	16.05 bd
A+I	6.84 bc	7.77 ab	7.31 bc	16.15 bc	15.42 bd	15.79 be
S+B	8.81 a	6.59 ce	7.70 b	14.70 ce	14.50 be	14.60 dg
S+C	8.37 a	7.13 bd	7.75 ab	14.90 ce	13.80 df	14.35 eg
S+I	8.33 a	7.01 bd	7.67 b	13.90 de	13.10 ef	13.50 fi
A+B+C	6.24 cd	7.21 ac	6.72 ce	14.85ce	14.50 bf	14.68 cg
A+B+I	5.94 cd	6.51 ce	6.22 ef	15.30 bd	14.40 bf	14.85 cf
A+C+I	7.31 b	8.05 a	7.68 b	14.40 ce	14.10 cf	14.25 fh
S+B+C	8.93 a	7.79 ab	8.36 a	12.90 ef	12.80 ef	12.85 hı
S+B+I	8.52 a	5.84 ef	7.18 bd	13.15 df	12.40 gh	12.78 ı
S+C+I	8.96 a	6.24 de	7.60 b	13.70 de	12.75 ef	13.23 gı
LSD (%5)	0.94	0.89	0.21	2.17	2.06	1.47

Means within a column followed by the same lowercase letter are not significantly different ($p<0.05$);A: alfalfa, S: sainfoin, B: bromegrass, C: crested wheatgrass, I: intermediate wheatgrass

species decreased in 2010. Schmidt (1993) has reported that the quality of forages could be altered owing to differences in temperature and precipitation. Previous studies have shown that alfalfa contains significantly more crude protein than grasses and that grass + legume mixtures contain more crude protein than do the pure sowing grasses (Barnett and Posler, 1983; Höflich *et al*., 1990; Spandl and Hesterman, 1997; Albayrak and Ekiz, 2005).

Other important quality parameters for forages are the concentrations of ADF and NDF (Caballero *et al*., 1995; Assefa and Ledin, 2001). Legumes in monoculture or binary and ternary mixtures with grasses had lower ADF and

Tab. 3. Acid detergent fiber (ADF) and neutral detergent fiber (NDF) of legume-grass mixtures

Treatments	ADF (%)			NDF (%)		
	2009	2010	Mean	2009	2010	Mean
A	33.85 f	35.42 g	34.64 h	44.88 j	47.85 h	46.37 ı
S	36.12 ef	39.44 cg	37.78 fg	46.85 ıj	48.53 gh	47.69 hı
B	41.75 ab	43.50 ac	42.64 ac	57.85 ab	59.78 ab	58.82 ab
C	42.67 a	45.75 a	44.21 a	59.64 a	61.81 a	60.73 a
I	41.88 ab	44.28 ab	43.08 ab	56.57 ac	58.86 ab	57.72 bc
A+B	35.88 ef	38.21 dg	37.05 gh	49.25 gı	51.13 eh	50.19 eh
A+C	36.21 df	37.85 eg	37.03 gh	48.88 hı	51.45 eh	50.17 fh
A+I	35.75 ef	37.17 eg	36.46 gh	49.87 gı	50.18 fh	50.03 gh
S+B	37.42 cf	38.83 dg	38.13 eg	51.63 dh	51.96 dh	51.80 eg
S+C	36.54 cf	39.16 cg	37.85 fg	50.88 fh	52.81 cg	51.85 eg
S+I	36.48 cf	39.25 cg	37.87 fg	50.45 fh	52.46 ch	51.46 eg
A+B+C	38.65 be	40.13 bf	39.39 df	51.84 dh	53.89 cf	52.87 df
A+B+I	39.45 ae	40.56 bf	40.01 cf	52.50 df	53.45 cf	52.98 de
A+C+I	38.79 be	41.54 af	40.17 bf	51.45 eh	52.64 ch	52.05 eg
S+B+C	39.9 ad	42.85 ad	41.38 ad	53.56 cf	56.86 bc	55.21 cd
S+B+I	40.12 ac	41.56 af	40.84 be	54.74 be	53.35 be	55.05 cd
S+C+I	40.16 ac	41.89 ae	41.03 be	54.87 bd	56.41 bd	55.64 cd
LSD (%5)	3.73	4.69	2..94	3.35	4.62	2.80

Means within a column followed by the same lowercase letter are not significantly different ($p<0.05$); A: alfalfa, S: sainfoin, B: bromegrass, C: crested wheatgrass, I: intermediate wheatgrass

Tab. 4. Total digestible nutrients (TDN) and relative feed value (RFV) of legume-grass mixtures

Treatments	TDN (%)			RFV (%)		
	2009	2010	Mean	2009	2010	Mean
A	57.65 a	55.62 a	56.64 a	129.82 a	119.28 a	124.55 a
S	54.72 ab	50.43 ae	52.58 bc	120.67 b	111.56 ab	116.12 b
B	47.45 ef	45.16 eg	46.30 fh	90.64 ıj	85.57 gh	88.11 g
C	46.26 f	42.29 g	44.28 h	86.90 j	80.16 h	83.53 g
I	47.28 ef	44.18 fg	45.73 gh	92.51 hj	86.00 fh	89.26 g
A+B	55.03 ab	52.02 ad	53.53 ab	115.21 bc	107.70 bc	111.46 bc
A+C	54.60 ac	52.49 ac	53.55 ab	115.59 bc	107.42 bc	111.51 bc
A+I	55.20 ab	53.36 ab	54.28 ab	114.03 bd	111.12 ab	112.58 bc
S+B	53.04 ad	51.22 ad	52.13 bd	107.65 cf	105.05 bc	106.35 cd
S+C	54.18 ad	50.79 ae	52.49 bc	110.76 ce	103.13 bd	106.95 cd
S+I	54.25 ad	50.68 ae	52.47 bc	111.64 ce	103.65 bd	107.65 cd
A+B+C	51.45 be	49.54 bf	50.50 be	105.47 dg	99.49 ce	102.48 de
A+B+I	50.42 bf	48.99 bf	49.71 cf	103.20 eg	99.82 ce	101.51 df
A+C+I	51.27 be	47.72 bg	49.50 cg	106.18 dg	99.99 ce	103.09 d
S+B+C	49.84 cf	46.03 dg	47.94 ch	100.43 fh	90.86 eg	95.64 f
S+B+I	49.55 df	47.70 cg	48.63 dg	98.06 gı	95.21 df	96.64 ef
S+C+I	49.50 df	47.27 cg	48.39 dg	97.78 gı	93.57 eg	95.68 f
LSD (%5)	4.81	6.05	3.79	8.82	9.45	6.34

Means within a column followed by the same lowercase letter are not significantly different ($p<0.05$); A: Alfalfa, S: sainfoin, B: bromegrass, C: crested wheatgrass, I: intermediate wheatgrass

NDF than the grasses grown in monoculture (Tab. 3). The alfalfa monoculture had the lowest ADF and NDF. Binary and ternary mixtures of alfalfa + grasses had lower ADF and NDF contents than sainfoin + grasses mixtures. The ADF and NDF concentrations in 2009 were lower than those in 2010. The ADF concentration refers to the cell wall portions of the forage. These portions consist of cellulose and lignin. The ADF values are important because they describe the ability of an animal to digest the forage. As the ADF increases, the digestibility of the forage usually decreases. The NDF value refers to the total cell wall, composed of the ADF fraction plus hemicellulose. Neutral detergent fiber values are important in ration formulation because they reflect the amount of forage that the animal can consume. As the NDF percentages increase, the dry matter intake will generally decrease (Joachim and Jung, 1997). Reich and Casler (1985) have found that ADF and NDF were 10 to 15% higher in an alfalfa-bromegrass mixture than in pure alfalfa at most stages of spring growth. Cell wall concentration is higher in grass than alfalfa at equal maturity. Indigestible cell wall concentration is greater in alfalfa, owing to the greater lignin concentration. Thus, digestion may occur at a faster rate for alfalfa, but the digestion of grasses may be more complete (Spandl and Hesterman, 1997).

The TDN refers to the nutrients that are available for livestock. This variable is related to the ADF concentration of the forage. As ADF increases, TDN declines. As a result, animals are unable to utilize the nutrients that are present in the forage (Aydın *et al.*, 2010). In the present study, pure alfalfa (56.64%) and binary mixtures of alfalfa + grasses had the highest TDN values (53.53 to 54.28%) whereas pure grasses had the lowest values (44.28 to 46.30%) (average of two years) (Tab. 4).

The RFV is an index that is used to predict the intake and energy value of forages. This index is derived from the DDM and dry matter intake (DMI). Forages with an RFV value over 151, between 150-125, 124-103, 102-87, 86-75, and less than 75 are categorized as prime, premium, good, fair, poor and rejected, respectively (Uzun, 2010). The relative is not a direct measure of the nutritional content of forage, but it is important for estimating the value of forage (Van Soest, 1982). Based on the average of the 2 years, pure alfalfa, pure sainfoin, alfalfa + grass and sainfoin + grass binary mixtures and alfalfa + crested wheatgrass + intermediate wheat grass ternary mixture had relative feed value ranging from 103.09 to 124.55. These values correspond to, grades of 3 or above (Rohweder *et al.*, 1978). All other mixtures studied and all pure grasses except crested wheatgrass were in grade 4 (Tab. 4).

Conclusions

The results of this study demonstrated that alfalfa and sainfoin binary mixtures with brome grass, crested wheatgrass and intermediate wheat grass may be used to establish artificial pastures in rainfed conditions in Turkey because of their high forage qualities.

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