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EFFECTS OF MIXTURE RATIO AND ROW SPACING IN HUNGARIAN VETCH (*Vicia pannonica* Crantz.) AND ANNUAL RYEGRASS (*Lolium multiflorum* Lam.) INTERCROPPING SYSTEM ON YIELD AND QUALITY UNDER SEMIARID CLIMATE CONDITIONS

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ABSTRACT

This study was conducted at the Middle Kizilirmak basin of Turkey (40°20′N, 33°58′E, elevation 550 m), during the 2011–2012 and 2012–2013 growing seasons, to determine the effects of different mixture ratios (sole Hungarian vetch (HV), annual ryegrass (AR); 80%HV+20%AR, 60%HV+40%AR, 40%HV+60%AR, and 20%HV+80%AR) and row spacings (20, 30, and 40 cm) on the forage yield and quality of the HV and AR intercropping system. The experiment was planned in a randomized complete block design, where a split-plot arrangement of mixture ratios was considered as the main plot with the row spacings considered as subplots. According to the mean of 2 years, the different mixture ratios and row spacings had a statistically significant effect on all of the properties. At the end of the research, among the different mixture ratios and row spacing interactions, the highest green herbage yield (33.4 t ha^{-1}), hay yield (7.5 t ha^{-1}), lowest neutral detergent fiber (52.2%), and crude ash (7.8%) rates were obtained from the 60%HV+40%AR mixture and 30-cm row spacing interaction. The highest crude protein (CP) rate (17%), CP yield (1156 kg ha^{-1}) and ADF (39.5%) ratios were obtained from the 80%HV+20%AR mixture and 30-cm row spacing interaction. The highest RFV value (107) was obtained from the 80%HV+20%AR mixture and 20-cm row spacing interaction. These results show that increasing the HV ratio in the mixture has positive effects on the yield and quality, whereas raising the row spacing has adverse effects on the forage values. Therefore, 80%HV+20%AR or 60%HV+40%AR with a 30-cm row spacing interaction can be suggested for forage production in an HV and AR intercropping system.

Key words: Acid detergent fiber, Animal feeding, Crude protein, Forages, Neutral detergent fiber, Relative feed value

INTRODUCTION

Intercropping had been neglected in research on plant production systems in Europe, possibly due to the complexity of these systems (Hauggard-Nielsen et al. 2009), but afterwards, in forage crop production, many intercropping systems were used for different purposes (Acar et al. 2006). This system allows lower inputs through reduced fertilizer and pesticide requirements, and it contributes to a greater uptake of water and nutrients, increased soil conservation, and high productivity and profitability (Lithourgidis et al. 2011; Akman et al. 2013) compared to monocrop systems.

Forage grasses or cereals are commonly grown with legumes in a mixture because of their ability to increase the herbage yield and to produce forage with more balanced nutrition for livestock feeding (Koc et al. 2013). Legumes are a particularly good source of protein (Eskandari et al. 2009) and incorporating them into an intercropping system could be of paramount importance for the nutritive value of forage (Nadeem et al. 2010). Another advantage of grass-legume intercropping is that nitrogen (N) can be transferred from the legume into the soil; hence, grasses can use it during their growth (Lauk and Lauk 2009; Mariotti et al. 2009). Accordingly, this system has risen in popularity lately worldwide and it has been a common cropping method in rain-fed areas, particularly in Mediterranean countries such as Turkey (Lithourgidis et al. 2006; Dhima et al. 2007). It is most important that mixtures must contain at least 1 grass and legumes (Acar et al. 2006).

Although there is a large diversity of *Vicia* species, in the Mediterranean Basin, including Turkey, vetches, particularly common vetch (*Vicia sativa* L.) and Hungarian vetch (HV) (*Vicia pannonica* Crantz.) are the most common annual forage crops cultivated (Acikgoz 2001; Uzun et al. 2004). HV is a winter-hardy and drought-resistant legume species, which is widely used in regions with cool winter growing conditions (Uzun et al. 2004; Albayrak et al. 2011). It has satisfactory forage yields with tiny plentiful and palatable leaves, and good quality hay with high crude protein (CP) (Tuna and Orak 2007; Unal et al. 2011). Moreover, that is generally recommended in dry regions (Uzun et al. 2004).

HV has a semierect growth habitus with a leaning tendency in pure stands, especially during rainy years. Intensive early spring rains lead to the decay of plant parts close to the ground to, as a consequence of high humidity. This results in a decrease in the rate of forage yield and quality (Iptas 2002). Cereals can provide support for climbing vetches, improve light interception, and thus facilitate mechanical harvesting (Nadeem et al. 2010). For instance, HV can be grown with forage grasses or cereals under Mediterranean conditions, during which the fallow+cereal system is performed.

One of the most important forage crops is annual ryegrass (AR) (*Lolium multiflorum* Lam.), which is a cool-season grass that is suitable for quality herbage production on account of its rich protein, minerals, and water-soluble carbohydrate content (Kusvuran and Tansi 2005). It is generally a highly nutritious grass that may be presented as forage for beef cattle through grazing, dried out and fed as hay, or ensiled and fed as silage (Acikgoz 2001; Kusvuran and Tansi 2011; Durst et al. 2013), and desirably eaten by livestock, especially in milk production (Kusvuran 2011). In recent years, one of the cultivars of AR, 'Caramba', has quite well adapted to Turkey's climate and soil conditions (Ozkul 2012), which has been recognized as potential roughage for ruminant animals (Van Niekerk et al. 2008; Catanese et al. 2009). Furthermore, (Ozkul et al. 2012) reported that it will rise crucially in the use and importance of AR in future and it will be preferred by livestock as a sole crop when compared to cereals such as barley and triticosecale (Van Niekerk et al. 2008; Catanese et al. 2009). Accordingly, HV+AR herbage can be used for feeding directly to livestock as fresh material or used as hay or silage.

Some factors affect the growth of the species used in intercropping, including cultivar selection, seeding ratios, mixture ratios, row spacing and competition between the mixture components (Dhima et al. 2007; Akman et al. 2013), extra work in preparing and planting seed, and crop management practices (Lithourgidis et al. 2011).

In vetch mixtures with cereals or grasses, it is necessary to know the ratios of the vetch and cereal/grass species (Albayrak et al 2004; Balabanli and Turk 2006), because it affects the growth rate of the individual species in the mixtures as well as the forage yield and quality (Lithourgidis et al. 2006; Lauk and Lauk 2009). In the mixtures, for example, an increased proportion of the cereal in its mixture with vetch significantly decreases the stand lodging, and has a positive influence on the forage yield, but the forage nutrient is of a poorer quality (Karagic et al 2012), because a high cereal ratio in the botanic composition of legume+cereal mixtures causes low protein. Mariotti et al. (2009) reported that cereals had a higher belowground competitive ability than legumes and legumes had a higher aboveground competitive ability than cereals in their mixtures, and that the competitive ability of the plants showed differences among the species. Between plant species, there may be aboveground competition for light and space, and belowground competition for water and nutrients (Mariotte et al. 2012). Thus, these competition conditions have important influences on the mixtures and these factors must be considered in this system.

The effects of different mixture ratios in the intercropping system have been evaluated in many studies. In these studies (Albayrak et al. 2004; Lithourgidis et al. 2006; Pinar 2007; Ozel 2010), increasing the ratio of those vetches whose forage quality was higher in the mixtures, increased the both forage yield and nutrient content, while some researchers reported the opposite findings; that increasing rate of the cereal/grass whose dry matter content was higher, resulted in a higher forage yield, but lower forage quality (Orak and Uygun 1996; Balabanli and Turk 2006; Tuna and Orak 2007; Dhima et al. 2007; Gunduz 2010; Bedir 2010). Moreover, the optimal forage yield and CP contents were obtained when the legume and cereal ratio was equal in the mixture (Basbag et al. 1999).

In addition to the mixture ratios, row spacing is another important factor for higher yield realization through light penetration in the crop canopy. An advantage of narrow row spacing is more equidistant plant spacing, which leads to increased canopy leaf area development and greater light interception earlier in the season (Shibles and Weber 1966). These changes in the canopy formation increase the crop growth rate and dry matter accumulation (De Bruin and Pedersen 2008; Albayrak et al. 2011).

HV and AR have been grown at different row spacings for forage in several studies. Generally, these species were grown at a 20-cm row spacing (Geren et al. 2003; Pinar 2007; Darvishi et al. 2009; Gunduz 2010; Bedir 2010). Moreover, while some researchers planted at a 25-cm row spacing (Gultekin 2008; Unal et al. 2011; Yolcu et al. 2012), both species were grown at a 30-cm row spacing by Kilavuz (2006), Balabanli and Turk (2006), and Nadeem et al. (2010) in different researches.

Some researchers reported the most suitable row spacing in AR as 30 cm (Orak and Uygun 1996; Kusvuran and Tansi 2011; Kara 2013) and they reported that increasing the row spacing had a negative impact on the forage yield and quality. The highest forage yields and nutrient values were obtained at 17-, 20-, and 25-cm row spacings in HV by Uca et al. (2007), Nizam et al. (2007), and Bagci (2010), respectively. These researchers reported that while the herbage quality increased gradually depending on the rising row spacing, a significant decreasing was determined from the forage yield at narrower row spacings. Contrary the these researches, Orak and Tuna (1994) and Akkopru et al. (2007) reported that optimal values were obtained at 35- and 40-cm row spacings, and they stated that increasing the row spacing had a positive effect on the forage yield and quality. On the other hand, Albayrak et al. (2011) reported that there was no difference in the forage quality with row spacings of between 17 and 35 cm.

To date, many new researches have been conducted where HV was grown with different cereals in an intercropping system, whereas few associated with AR have been carried in recent years.

The objectives of this study were: a) to evaluate the forage production capacities of HV+AR mixtures, b) to assess the effects of different mixture ratios and row spacings on the yield and quality of the mixtures, and c) to determine the most convenient mixture ratio and row spacing interaction in this intercropping mixture system.

MATERIALS AND METHODS

Research Site

The study was carried out at the Research and Implementation Area of the Kizilirmak Vocational High School of Cankiri Karatekin University (40°20′N, 33°58′E, elevation 550 m), which is located on the Middle Kizilirmak Basin of Turkey, during the 2011–2012 and 2012–2013 growing seasons.

The region is under semiarid and central Anatolian climate conditions. It has a longterm annual rainfall of 407.8 mm (TSMS, 2013), and while the average temperature of the first growing season (4.6 °C) was lower than the longterm average value (8.3 °C), it was closer to this value in second growing season (8.5 °C). The total precipitation was 329.1 mm and 309.5 mm during the 2011–2012 and 2012–2013 growing seasons, respectively (Table 1.). Hence, the fallow-cereal system was applied to half of this cultivated area based on the restricted precipitation (TSI 2013).

The major soil characteristics are given in Table 2 for the experimental area. The soil at the experimental site had a clay or clay-loam texture and moderate lime content.

Table 2. Initial chemical and physical properties of the soil.

Property	Depth (0-30 cm)	Depth (30-60 cm)
Sand (%)	13.5	21.3
Silt (%)	31.1	42.1
Clay (%)	55.4	36.6
Soil Texture	Clay	Clay-Loam
pH (1:2.5)	8.03	7.86
Salt (mmhos cm $^{-1}$)	0.50	1.19
Lime (%)	16.0	17.9
P_2O_5 (kg ha^{-1})	6.5	65.4

Table 1. Climate data of the location in 2011-2012-2013 years and long term average (1960-2012) at Cankiri, Turkey.

Months	Mean Temperature (°C)			Total precipitation (mm)		
	2011-2012	2012-2013	Long-term	2011-2012	2012-2013	Long-term
October	9.6	15.5	11.9	45.5	23.2	27.7
November	1.3	7.5	5.6	2.5	28.3	26.8
December	0.8	2.7	1.6	31.9	63.9	47.9
January	-2.1	1.2	-0.6	100.4	40.4	42.3
February	-5.0	4.4	0.9	52.5	22.5	34.5
March	2.2	6.8	5.6	21.0	39.8	36.8
April	13.4	12.1	11.0	6.5	61.6	46.4
May	16.2	18.1	15.7	68.8	29.8	54.4
Total	-	-	-	329.1	309.5	316.8
Average	4.6	8.5	8.3	-	-	-

Plant materials and treatments

The HV ‘Tarm Beyazi-98’ cultivar and AR ‘Caramba’ cultivar were used as the plant material of the study, and both species were planted as sole crops and mixtures. A formulation of 4 different HV (*Vicia pannonica* Crantz.) and AR (*Lolium multiflorum* Lam.) mixtures (80%HV+20%AR, 60%HV+40%AR, 40%HV+60%AR, 20%HV+80%AR), as the sole of these species, and 3 different row spacings (20, 30, and 40 cm) were used in this study.

After seeding, 27 kg ha$^{–1}$ of N and 69 kg ha$^{–1}$ of phosphorus were applied as a starter fertilizer using diammonium phosphate. Seeds were planted in October of both the first and second year, at a rate of 120 kg ha$^{–1}$ for the HV (Acikgoz 2001; Balabanli and Turk 2006; Balabanli 2009) and 45 kg ha$^{–1}$ for the AR (Kusvuran 2011; Kusvuran and Tansi 2011) in each plot. The HV and AR seeds were sown in the same rows. The size of each plot was 12 m^2 (2.4 × 5 m). During both the first and second year, the experiments were carried out without supplementary irrigation.

The harvest time was determined by taking the physiological periods of the HV into consideration. Hence, plots were harvested at the full pod set stage for the HV (Balabanli 2009) and at the beginning of flowering for the ryegrasses (at the end of May) (Kusvuran and Tansi 2005) at the same time for the forage yield.

Following the harvest, the HV ratios in the mixtures were determined in the fresh material.

Experiment design and statistical analyses

The experiments were conducted in a randomized complete block design with a split-plot arrangement (the mixtures were placed in the main plots and the row spacings were placed in subplots) with 18 treatments in 3 replications. Analysis of variance of the experimental results was performed using MSTAT-C statistical software (Freed 1991) and $P < 0.05$ and 0.01 were considered as statistically significant, and means were compared using Duncan's multiple range test at a significance of $P < 0.05$.

Chemical analyses

A total of 500 g of fresh sample was taken from the harvested plants and dried at 70 °C for 48 h. Next, dry matter ratios and hay yields were determined. Afterwards, hay samples were ground in a hand mill with a 1-mm sieve. The crude ash contents of the samples were determined by burning the samples at 550 °C for 8 h. The Kjeldahl method was used to determine the N contents of the dry samples (Kacar and Inal, 2008). CP ratios (CPRs) were calculated using the equation of N × 6.25 and CP yields (CPYs) were determined using the equation of CPR × hay yield. The neutral detergent fiber (NDF) (Van Soest and Wine, 1967) and acid detergent fiber (ADF) (Van Soest 1963) contents were analyzed with an ANKOM 200 fiber analyzer (ANKOM Technology Corp. Fairport, NY, USA). The dry matter digestibility (DMD), dry matter intake (DMI), and relative feed value (RFV) were calculated using the following equations (Rohweder et al. 1978):

To calculate the RFV, initially, the DMD was calculated from the ADF value by:

$DM\% = 88.9 – (0.779 \times ADF\%)$.

The DMI, based on animal live-weight, was calculated from the NDF value by:

$DMI\ \%\ of\ BW = 120 / NDF\%$.

Next, the RFV was calculated from the DMD and DMI by:

$RFV = DDM\% \times DMI\% \times 1.29$.

RFVs were evaluated using the values provided in the standards for dry hays given in Table 3.

Table 3. Relative feed value standards[a]

Quality Standards	CP	ADF, % (DM)	NDF, % (DM)	RFV
The best quality	>19	<31	<40	>151
1	17-19	31-40	40-46	151-125
2	14-16	36-40	47-53	124-103
3	11-13	41-42	54-60	102-87
4	8-10	43-45	61-65	86-75
5	8,00	>45	>65	<75

[a] Relative feed value is assumed to be 100 when the ADF is 41% and NDF is 53% (Rohweder et al 1978).

RESULTS

All of the parameters were significantly influenced by the different mixture ratios, row spacings, and mixture ratio × row spacing interactions (Table 4).

With regard to the different row spacings, the highest plant height (90.4 cm), green herbage (30.0 t ha^{-1}), hay (6.7 t ha^{-1}) and CPY (996 kg ha^{-1}), and CP (15.2%) and ADF (38.2%) rates were obtained from 30-cm row spacing; the highest HV rate (78.0%) and RFV value (104) were observed at 20-cm row spacing; and the highest NDF (58.1%) and crude ash (8.5%) rates were obtained from 40-cm row spacing.

Among the different mixture ratios, the highest plant height (88.5 cm), HV (86.2%), CP rate (15.8%), CPY (1042 kg ha^{-1}), and RFV value (103) were observed from the 80%HV+20%AR mixture; the highest green herbage (30.9 t ha^{-1}) and hay (6.9 t ha^{-1}) yields were obtained from the 60%HV+40%AR mixture; the highest NDF (55.9%) and ADF (38.5%) rates were observed from the 20%HV+80%AR mixture; and the highest crude ash rate (8.2%) was obtained from the 40%HV+60%AR mixture.

For the different mixture ratio × row spacing interactions, the highest plant height (92.3 cm), CP (17.0%) and ADF (39.5%) rates, and CPY (1156 kg ha^{-1}) were obtained from the 80%HV+20%AR × 30-cm interaction; the highest HV rate (90.4%) and RFV (108) values were observed from the 80%HV+20%AR × 20-cm interaction; the highest green herbage (33.4 and 32.9 t ha^{-1}) and hay (7.5 and 7.3 t ha^{-1}) yields were obtained from the 60%HV+40%AR × 30-cm and 40%HV+60%AR × 30-cm interactions, which were not statistically significant, as they were in the same group; the highest NDF rate (59.2%) was observed from the 20%HV+80%AR × 40-cm interaction; and the highest crude ash rate (8.5%) was obtained from the 40%HV+60%AR × 40-cm interaction.

Table 4. Summary of ANOVA and mean squares of the traits determined based on the combined analysis over two-years.

Source of Variation	DF	PH	HVR	GHY	HY	CPR
Replication (R)	2	6.708ns	1.392ns	1,030ns	0,334ns	0,019ns
Year (Y)	1	8214.938**	28.727ns	225,333**	6,700*	50,841**
Error 1	2	4.293	5.952	0,853	0,340	0,069
Mixture ratios (MR)	5	1389.700	13501,332**	92,062**	5,343**	122,893**
YXMR	5	166.235**	41,714**	12,895**	2,304**	13,253**
Row Spacing (RS)	2	88.915**	308,154**	167,031**	5,814**	9,551**
YXRS	2	8.781ns	76,683**	18,986**	0,651**	0,812**
MRXRS	10	36.831**	56,658**	17,611**	1,178**	8,737**
YXMRXRS	10	67.801	16,365**	7,581**	0,191**	3,431**
Error 2	68	4.789	2,918	0,400	0,049	0,052
CV (%)		2.47	2,28	2,29	3,54	1,60
Source of Variation	**DF**	**CPY**	**NDF**	**ADF**	**CAR**	**RFV**
Replication (R)	2	6967,148ns	0.017ns	0.154ns	0.148ns	0.857ns
Year (Y)	1	753838.231**	1.100*	18.008**	38.401**	6.356*
Error 1	2	5298.370	0.034	0.019	0.010	0.181
Mixture ratios (MR)	5	348853.320**	139.577**	32.186**	6.178**	732.790**
YXMR	5	18419.231**	16.173**	1.193**	0.177**	46.733**
Row Spacing (RS)	2	233712.954**	179.941**	16.066**	0.935**	661.211**
YXRS	2	11289.343**	5.343**	14.300**	1.039**	97.255**
MRXRS	10	36068.954**	8.817**	16.335**	0.267**	49.220**
YXMRXRS	10	10368.143**	10.797**	2.624**	0.148**	54.660**
Error 2	68	1100.651	0.068	0.038	0.010	0.350
CV (%)		3.77	0.47	0.52	1.18	0.59

Degrees of freedom, CV: Coefficient of variation, NS: Not significant, *P < 0.05, **P < 0.01, PH: Plant height, HVR: Hungarian vetch ratio GHY: Green herbage yield, HY: Hay yield, CPR: Crude protein ratio CPY: Crude protein yield NDF: Neutral detergent fiber ADF: Acid detergent fiber CAR: Crude ash ratio RFV: Relative feed value

DISCUSSION

While sole HV grows semierect and can reach up to 90 cm in height (Acikgoz 2001; Balabanli 2009), AR grows erect and can rise to a height of 130 cm (Baytekin et al. 2009). Some researchers obtained plant heights of between 34 and 103 cm in sole HV (Balabanli and Turk 2006; Gunduz 2010; Nadeem et al. 2010; Unal et al. 2011), while others obtained heights of between 60 and 133 cm in AR (Kusvuran and Tansi 2005, 2011; Gultekin 2008; Kesiktas 2010; Kusvuran 2011). In this study, the highest plant height (92.3 cm) was observed from the 80%HV+20%AR mixture and 30-cm interaction, and its values diminished with more than 30-cm row spacing.

Aside from genetic factors, the plant species, sowing ratio, soil, climate, and environmental conditions also influence plant heights. The average plant heights obtained from sole sowings of the species in the present study were similar to those reported in previous studies. In the mixtures, higher average plant heights were achieved due to higher HV plant heights in relation to the existence of AR in the mixture. Generally, when the ryegrass rate increased in the mixtures, the plants heights also increased. The higher height of the plants in the mixtures compared to sole HV sowing could be caused by the competition between the HV and AR, and this position might have affected the height of the plant positively. Additionally, as is known, intercropping of forage grasses with legumes provides structural support for climbing vetches and improves light interception (Nadeem et al. 2010). Thus, the obtained higher plant heights from the mixtures can arise from these situations when compared to sole HV sowing.

Separately, while Orak and Uygun (1996), Akkopru et al. (2007), and Bagci (2010) reported that plant heights decreased depending on the increasing row spacing, Kusvuran and Tansi (2011) found that there was no difference with different row spacings. These researchers reported that the high plant height probably resulted from light competition between the legume and grass species in the mixtures.

The vetch ratio in the mixture affects the quality of the harvested herbage. Different vetch ratios in mixtures were observed in previous intercropping systems, ranging from 14% to 91.3%. In these studies, the highest vetch ratio was obtained using vetch at a rate of 70% or higher in the harvested herbage (Albayrak et al. 2004; Kilavuz 2006; Pinar 2007; Nizam et al. 2007; Ozel 2010; Tas 2010). In addition to these studies, while Yolcu et al. (2009) found the average vetch rate as 34% in different HV-cereal mixtures; Gunduz (2010), and Orak and Nizam (2012) found rates of 16% and 42%, respectively, in a 50%HV+50%cereal mixture; Geren et al. (2003) found a vetch rate of 85% in a 50%vetch+50%AR mixture; Albayrak et al. (2004) found a rate of 66% in a different mixture ratio of HV+triticosecale; and Bedir (2010) observed a rate of 14% in different HV+barley mixtures. Similarly, Lithourgidis et al. (2006) reported different legume ratios in various intercropping systems.

Table 5. Forage yield and yield components of Hungarian vetch and annual ryegrass mixtures at different by mixture ratio and row spacing. Data are the means of the 2 years.

	Plant height (cm)				**Hungarian vetch ratio (%)**			
Mixture ratios (MR)	Row spacing (RS) (cm)				Row spacing (RS) (cm)			
	20	30	40	Mean	20	30	40	Mean
Hungarian Vetch (HV)	79.6 g	78.3 g	75.5 h	77.8 d	-	-	-	-
Annual Ryegrass (AR)	99.8 b	107.6 a	106.9 a	104.8 a	-	-	-	-
80%HV+20%AR	87.8 d	92.3 c	85.1 ef	88.5 b	90.4 a	82.0 c	86.2 b	86.2 a
60%HV+40%AR	87.6 de	88.3 d	84.6 f	86.8 c	84.3 b	69.8 e	74.1 d	76.1 b
40%HV+60%AR	86.2 df	87.6 de	87.4 de	87.1 bc	60.2 f	56.9 g	55.5 g	57.5 c
20%HV+80%AR	88.2 d	88.0 d	84.2 f	86.8 c	33.2 h	24.6 j	30.7 ı	29.5 d
Mean	88.3 b	90.4 a	87.3 b		78.0 a	72.2 c	74.4 b	
LSD (5%)	MR:1.46 RS:1.03 MRxRS:2.52				MR:1.14 RS:0.80 MRxRS:1.97			

	Green herbage yield (t ha^{-1})				**Hay yield (t ha^{-1})**			
Mixture ratios (MR)	Row spacing (RS) (cm)				Row spacing (RS) (cm)			
	20	30	40	Mean	20	30	40	Mean
Hungarian Vetch (HV)	25.9 f	25.0 gh	22.7 j	24.5 e	5.7 gh	5.2 ı	5.1 ı	5.3 d
Annual Ryegrass (AR)	27.0 e	28.1 d	25.6 fg	26.9 cd	6.0 fg	6.3 de	6.1 ef	6.2 c
80%HV+20%AR	29.5 c	30.9 b	28.4 d	29.6 b	6.8 bc	6.8 b	6.4 de	6.7 b
60%HV+40%AR	30.5 b	33.4 a	28.6 d	30.9 a	7.0 b	7.5 a	6.5 cd	7.0 a
40%HV+60%AR	24.7 h	32.9 a	23.9 ı	27.2 c	5.7 h	7.3 a	5.6 h	6.2 c
20%HV+80%AR	25.3 fh	29.6 c	25.2 fh	26.7 d	5.8 gh	7.0 b	5.6 h	6.1 c
Mean	27.2 b	30.0 a	25.7 c		6.1 b	6.7 a	5.8 c	
LSD (5%)	MR:0.42 RS:0.30 MRxRS:0.73				MR:0.15 RS:0.10 MRxRS:0.26			

	Crude protein ratio (%)				**Crude protein yield (kg ha^{-1})**			
Mixture ratios (MR)	Row spacing (RS) (cm)				Row spacing (RS) (cm)			
	20	30	40	Mean	20	30	40	Mean
Hungarian Vetch (HV)	18.4 b	20.6 a	17.6 c	18.6 a	1043 bc	1075 ab	898 e	994 b
Annual Ryegrass (AR)	11.1 l	13.0 ı	10.0 m	11.4 f	660 j	815 f	617 k	697 f
80%HV+20%AR	14.9 e	17.0 d	14.8 e	15.8 b	1010 c	1156 a	947 c	1042 a
60%HV+40%AR	13.8 g	14.4 f	13.4 h	13.9 c	957 d	1055 b	883 e	965 c
40%HV+60%AR	13.4 h	13.6 gh	12.6 j	13.2 d	757 g	1002 c	705 hı	821 d
20%HV+80%AR	11.9 k	12.6 j	13.1 ı	12.6 e	684 ıj	871 e	732 gh	762 e
Mean	13.9 b	15.2 a	13.6 c		852 b	996 a	797 c	
LSD (5%)	MR:0.15 RS:0.11 MRxRS:0.27				MR:22.1 RS:15.6 MRxRS:38.2			

	NDF (%)				**ADF (%)**			
Mixture ratios (MR)	Row spacing (RS) (cm)				Row spacing (RS) (cm)			
	20	30	40	Mean	20	30	40	Mean
Hungarian Vetch (HV)	49.9 k	53.2 ı	54.6 g	52.5 f	34.1 k	36.0 ı	37.3 f	35.8 e
Annual Ryegrass (AR)	59.2 b	58.7 c	64.0 a	60.6 a	39.1 c	37.4 f	42.4 a	39.7 a
80%HV+20%AR	52.2 j	52.4 j	56.5 e	53.7 e	36.7 h	39.5 b	36.9 g	37.7 c
60%HV+40%AR	55.5 f	52.2 j	57.1 d	54.9 d	35.2 j	38.0 e	36.9 gh	36.7 d
40%HV+60%AR	54.7 g	54.0 h	57.0 d	55.2 c	37.4 f	38.8 d	36.9 gh	37.7 c
20%HV+80%AR	54.6 g	53.8 h	59.2 b	55.9 b	39.0 cd	39.4 b	37.0 g	38.5 b
Mean	54.4 b	54.1 c	58.1 a		36.9 c	38.2 a	37.9 b	
LSD (5%)	MR:0.17 RS:0.12 MRxRS:0.30				MR:0.13 RS:0.09 MRxRS:0.22			

	Crude ash ratio (%)				**RFV**			
Mixture ratios (MR)	Row spacing (RS) (cm)				Row spacing (RS) (cm)			
	20	30	40	Mean	20	30	40	Mean
Hungarian Vetch (HV)	8.1 f	7.9 g	7.9 g	7.9 e	116 a	108 b	102 e	109 a
Annual Ryegrass (AR)	9.2 c	9.4 b	9.9 a	9.5 a	93 j	94 ı	81 k	89 f
80%HV+20%AR	8.1 f	8.1 f	8.2 f	8.1 cd	107 b	103 d	99 g	103 b
60%HV+40%AR	8.3 e	7.8 g	8.3 e	8.1 c	103 d	106 c	98 h	102 c
40%HV+60%AR	8.3 e	7.8 g	8.5 d	8.2 b	103 d	100 g	98 h	100 d
20%HV+80%AR	8.1 f	7.9 g	8.2 f	8.0 d	100 g	101 f	95 ı	98 e
Mean	8.3 b	8.2 c	8.5 a		104 a	102 b	96 c	
LSD (5%)	MR:0.07 RS:0.05 MRxRS:0.12				MR:0.39 RS:0.28 MRxRS:0.68			

Numbers followed by the same letters are not significantly different at the 5% level of significance.
HV: Hungarian vetch AR: Annual ryegrass

In fresh material, the average across the different mixture ratios and row spacing interactions showed that the HV rate ranged between 25% and 90% in the present study. Our findings were similar to those in previous studies. As expected, the HV rate decreased depending on the increased AR ratio in the mixtures. All of the abovementioned researchers stated the same findings in previous studies. The lowest average values determined in 30-cm row spacing averaged across the different row spacings. Researchers commonly use either 20- or 25-cm row spacing for forage production for AR (Geren et al. 2003; Gultekin 2008; Darvishi et al. 2009; Kesiktas 2010). However, 30-cm row spacing was recommended by Orak and Uygun (1996), and Kusvuran and Tansi (2005, 2011). Accordingly, it may be concluded in the present study that the superior growing performance of AR at 30-cm row spacing was effective on decreasing the HV rate in the mixture.

The plant species in mixtures, environmental conditions, competition index, sowing ratios, and harvest times of the species influence the post-harvest ratios of species in mixtures. The competitive ability of the plants show differences among the species (Mariotti et al. 2009), and there may be an aboveground competition for light and space and below grow competition for water and nutrients among the plants species (Mariotte et al. 2012; Koc et al. 2013). The growth of legumes is very slow in winter due to low temperatures, while cereals produce tillers and stems, and cover the small legume seedlings (Twidwell et al. 1987). Therefore, Iptas (2002) and Ozel (2010) reported that the percentage of cereal seeds in the mixtures should not be higher than 40% for successful production.

Green herbage and hay yield values derived from the sole sowing of HV were reported as 6.2–17.0 t ha^{-1} and 1.7–4.0 t ha^{-1}, respectively, in the previous studies (Karadag and Buyukburc 2004; Balabanli and Turk 2006; Unal et al. 2011; Albayrak et al. 2011; Orak and Nizam 2012). In AR, green herbage and hay yield values ranged between 6.2–80.7 t ha^{-1} and 0.7–14.9 t ha^{-1}, respectively, in previous studies (Parlak et al. 2007; Simic et al. 2009; Darvishi et al. 2009; Kesiktas 2010; Kusvuran 2011; Rivera et al. 2013). Green herbage and hay yields of HV and cereal mixtures by earlier researchers in different mixture ratios ranged between 9.8–47.2 t ha^{-1} and 3.4–13.0 t ha^{-}1, respectively.

When compared to previous studies, the green herbage and hay yield values of the present study were quite close to the upper limit values observed in the sole sowing of HV. However, while satisfactory yield values were obtained from the sole sowing of AR and its mixtures with HV, the values were not close to the upper limits specified in some earlier researches. AR can be cut more than once during the vegetation period. The reason the highest yield levels were not reached, was because of single cut of the present study.

While several researchers reported the highest green herbage and hay yields of HV mixtures as 66%–87.5% (Albayrak et al. 2004; Yolcu et al. 2009; Budak et al. 2011; Koc et al. 2013), others reported the highest values for equivalent rate mixtures (50%–50%) (Karadag and Buyukburc 2004; Gunduz 2010; Aksoy and Nursoy 2010; Nadeem et al. 2010). Contrary to other researches, Balabanli and Turk (2006), Tuna and Orak (2007), and Bedir (2010) reported the highest yield values for cereals mixture rates of 75%–80%.

In the present study, while the highest green herbage (33.4 t ha^{-1}) and hay (7.5 t ha^{-1}) yields were observed from the 60%HV+40%AR and 30-cm row spacing interaction, the yields were then decreased based on the decreasing HV ratio. Some researchers (Albayrak et al. 2004; Lithourgidis et al. 2006; Balabanli 2009; Ozel et al. 2010) stated that the HV ratio in the mixtures should not be less than 60% for high yield. They also indicated that increasing the proportion of legumes in mixed forages increases the yields of green herbage and hay per unit area. In contrast to these researchers, Orak and Uygun (1996), Balabanli and Turk (2006), Dhima et al. (2007), Bedir (2010), and Gunduz (2010) reported that the increase of the rate of cereal and its occurrence of above 50% in the mixture produces higher yields, mainly due to its being taller and growing more strongly than vetch species.

In addition to the mixture rate, the highest yields in the present study were determined at 30-cm row spacing, and the yields then decreased based on the increasing row spacing. According to Nizam et al. (2007), Uca et al. (2007), Bagci (2010), and Albayrak et al. (2011), narrow row spacing; for example, 17- and 20-cm row spacing, increased the forage yield compared to wider row spacing. Contrary to these researchers, Orak and Tuna (1994), Orak and Uygun (1996), Akkopru et al. (2007), and Kusvuran and Tansi (2011) obtained top yields in wider row spacings, such as 30, 35, and 40 cm. These differences were probably because of the plant species and various soil and climate conditions at the experiment sites.

Mixed intercropping systems have a significant advantage over sole sowing because of better economics and land use efficiency (Dhima et al. 2007). When the components of a mixture are complementary to each other, a higher yield occurs based on the transfer of symbiotically fixed N grasses (Lauk and Lauk 2009; Akman et al. 2013). Simic et al. (2009) and Kusvuran (2011) reported that increasing the N dose has a positive effect on the yield and quality in AR. Moreover, intercrops can use available environmental resources, such as light, water, and nutrients, more efficiently (Corre-Hellou et al. 2006; Lithourgidis et al. 2011). On the other hand, if the mixture ratio and row spacing are below optimum, then the nutrients, water, and light will not be utilized to their fullest, thus resulting in poor yield (Lone at al. 2010; Albayrak et al. 2011).

Accordingly, grass mixtures with legumes are usually more productive than pure grass or legume sowings and they can support greater animal performance (Hauggard-Nielsen et al. 2009). Additionally, the stand will always be more productive than sole cropping of the component if a mixture establishes a suitable complementary species with the proper sowing design (Mariotti et al. 2009; Koc et al. 2013). The high yielding capacity of a mixture over sole cropping of a component was reported by Nizam et al. (2007), Mariotti et al. (2009), and Albayrak et al. (2004, 2011). However, Pinar (2007) reported that the sole sowing of a species has a higher yield when compared with mixtures.

Parallel with previous researches, this study shows that growing AR with HV in a mixture produced more herbage yield than sole sowing of the species. On the other hand, although the values were considered to be sufficient for livestock feeding, the green herbage and hay yields were lower than the values of HV+cereal mixtures. This might be explained by the higher shooting and tillering capability of cereals compared to AR. Moreover, cereals produce more vegetative components than AR.

In previous researches, the CPR and CPY of sole HV sowings were between 15.4%–24.1% and 561–1461 kg ha^{-1}, respectively (Karadag and Buyukburc 2004; Bedir 2010; Albayrak et al. 2011; Yolcu et al. 2012). While HV has 15%–17% of CP (Balabanli 2009), AR also has CP contents of around the same values (Ozkul et al. 2012). These CPRs and yields of sole AR sowings were reported as between 7.3%–25.4% and 101–5197 kg ha^{-1}, respectively (Parlak et al. 2007; Gultekin 2008; Catanese et al. 2009; Simic et al. 2009; Kusvuran 2011; Durst et al. 2013; Rivera et al. 2013).

The CPR and yields observed in the sole HV sowing of the present study were quite similar to those in previous studies, but the values of sole ryegrass were relatively lower than those in previous studies. When the cutting period is delayed in AR, the CPR and digestibility decrease based on the increased lignification and cellulose concentration. The sole sowing system in AR enables multiple cuts in a growing season and the cuts are carried out during the early stages of the plant. An early cut has a positive influence on the CPR and multiple cuts increase the forage yield. However, in the present study, only 1 cutting was carried out because of the mixture sowings, and the obtained lower CPR can result from this position.

The CPR and yield of the HV-cereal and grass mixtures were between 10.3%–15.3% and 376–1609 kg ha^{-1}, respectively. The highest values were observed at 30-cm row spacing (15.2 and 996 kg ha^{-1}), and as the row spacing was increased to 40 cm, the CP rates and yields decreased gradually. The works of Parlak et al. (2007), Bagci (2010), and Kusvuran and Tansi (2011) supported the results obtained with this study. On the other hand, Akkopru et al. (2007) and Uca et al. (2007) reported increasing CPRs with increasing row spacing, and they found that the best values were at 40-cm row spacing.

Obtaining optimum forage quality is also a very important requirement in forage crop cultivation for animal nutrition, as well as obtaining a high forage yield from the unit area. Plant species, legume ratio in the mixture, and row spacing are the factors directly influencing how the CPR and hay yield affects the CPY. HV, for example, in mixtures, improves the quality of forage by increasing the protein concentration (Vasilakoglou et al. 2008). The mixtures had comparable or better quality values than the grass monocultures. In most cases, the mixtures had higher CP contents than the grass monocultures in all of the mixtures owing to the utilization of symbiotically fixed N and more enhanced interception of light, except for sole HV (Zemenchik et al. 2002; Albayrak et al. 2011). The difference in CP between the grass monocultures and the mixtures can partially be explained by the low fertilizer N rate. The CP content of grasses is known to increase with higher N rates (Buxton 1996; Zemenchik et al. 2002).

The rate of the species in the mixtures ranks first among the factors affecting the quality of the mixture. The highest CPR and yield were determined from the 80%HV+20%AR mixture and 30-cm row spacing interaction in the present study, and previous results are in agreement our findings. In the mixtures, decreased CPYs were observed with decreasing HV ratios. While most researchers found the highest CPRs and yields with 60% or higher HV in the mixture (Albayrak et al. 2004; Karadag and Buyukburc 2004; Balabanli and Turk 2006; Lithourgidis et al. 2006; Bingol et al. 2007; Yolcu et al. 2009; Budak et al. 2011), some others observed the highest yields in equal mixtures (50%–50%) (Basbag et al. 1999; Gunduz 2010; Aksoy and Nursoy 2010) and 60% cereal mixtures (Bedir 2010). HV contains remarkably more CP than grasses and its mixtures with grasses contain more CP than the sole sowing of AR.

A high CPR is expected in mixtures that contain a high level of HV. Additionally, HV naturally includes higher a CPR than grasses. However, its CPY ranks lower in comparison to the 80%HV+20%AR mixture in this study, due to its low biomass productivity among all of the treatments. Similarly, despite the highest hay yield being achieved from the 60%HV+40%AR mixture, a lower CPY was obtained in this mixture because of the decreased CPR, related to the increased AR ratio.

Previous authors reported different results for forage quality parameters such as RFV, NDF, ADF, and crude ash. Albayrak et al. (2011) determined RFV, NDF, and ADF rates for HV, respectively, as 142%, 42%, and 33%. Yolcu et al. (2009) found the NDF and ADF of different mixtures as 57% and 33%, respectively; Aksoy and Nursoy (2010) reported these values of HV-wheat mixture as 43% and 34%, respectively, and Bingol et al. (2007) reported the values in HV-barley mixtures as 57% and 30%, respectively.

Crop species differences in the forage quality between grasses and legumes can be very large. The protein content of legumes is typically much higher than that of grasses, and legume fiber tends to digest faster than grass fiber, allowing the ruminant to eat more of the legume (Eskandari et al. 2009). Along with an increase in the hay production in the mixtures, there is also a change in the chemical composition of the produced. A lower rate of vetch in the mixture, below a definite point, is not desired when the nutrient quality of the mixture is considered (Tas et al. 2007). Grasses have higher cell wall concentrations and a more rapid accumulation of lignin and cellulose than legumes. Thus, this composition leads to a further decline in the digestibility of the mixtures (Buyukburc and Karadag 2002; Tas 2010).

In previous studies, the rates of ADF, NDF, and crude ash in AR were determined. Catenase et al. (2009) reported a NDF rate of 50% and Rivera et al. (2013) reported an ADF rate of 27%. While Durst et al. (2013) found these values as 56% and 31%, Gultekin (2008) reported them as 58% and 37%. Bingol et al. (2007) reported a crude ash rate of 8.9%, while Geren et al. (2003) found this value as 12.9% in the mixture.

CP, NDF, ADF, and RFV are among the most important quality parameters. The total digestible nutrients (TDNs) refer to the nutrients that are available for livestock and are related to the ADF concentration of the forage. As the ADF increases, there is a decline in the TDNs, which means that animals are not able to utilize the nutrients that are present in the forage (Aydin et al. 2010). The RFV is an index used to predict the intake and energy value of the forages and it is derived from the DDM and DMI (Rohweder et al. 1978; Albayrak et al. 2011).

According to the results provided in Table 3, the best NDF (52.2%), ADF (39.5%), and crude ash (7.8%) values were determined with 60% or 80% HV and 30-cm row spacing, and the highest RFV (107) was obtained from the same mixtures, and was sown at 20-cm row spacing. In this study, depending on the increasing HV ratio in mixture, these values were affected positively. Some researchers (Parlak et al. 2007; Simic et al. 2009; Kusvuran 2011) reported that the forage N content increased based on the increasing N fertilization; hence, a higher ADF quality was obtained in the hay (Zhang et al. 1995). In this study, a higher HV ratio in the mixture probably caused this result.

The hay and CPs of this interaction were at satisfactory levels, the CPRs were at high levels, and the crude ash values were at low levels. NDF, ADF, and RFV are significant digestibility indicators. Accordingly, the values observed in the present study were at medium levels.

Considering all of the investigated parameters in the present study, 60% or 80% HV and a 30-cm row spacing interaction can be recommended for high yield and quality forage production.

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