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INTERCROPPING OF HUNGARIAN VETCH (*VICIA PANNONICA* CRANTZ.) AND BARLEY (*HORDEUM VULGARE* L.) UNDER DIFFERENT PLANT VARIETIES AND MIXTURE RATES

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ABSTRACT

This study was conducted to determine the effects of different varieties and mixture ratios on the forage yield and quality of a Hungarian vetch and barley intercropping system at the Middle Kizilirmak Basin of Turkey (40°202 N, 33°582 E, elevation 550 m), during the 2011–2012 and 2012–2013 growing seasons. As per the results averaged over 2 years, the different varieties and mixture ratios had significant effect on the forage yield and quality, and also the interactions for the characters studied were statistically significant. The highest Hungarian vetch rate (37.3%), green herbage (36.3 t ha^{-1}) and crude protein (CP) yields (1510 kg ha^{-1}) were obtained from the mixture of 80% Hungarian vetch (Tarm Beyazi-98) and 20% barley, the highest hay yield (10.5 t ha^{-1}) was obtained from the mixture of 20% Hungarian vetch (Anadolu Pembesi-2002) and 80%barley. In terms of the forage quality parameters, such as crude protein rate (CPR), neutral detergent fiber, acid detergent fiber, and relative feed value, except for the CPR (16%, in 80% Hungarian vetch (Tarm Beyazi-98)+ 20% barley combination), the most desirable results were assessed (54.6%, 31.3%, and 110%, respectively) from the mixture of 80% Hungarian vetch (Ege Beyazi-79) and 20% barley. The cultivar Tarm Beyazi-98 showed the highest forage yield among the tested cultivars of Hungarian vetch, while cultivar Ege Beyazi-79 had the highest forage quality. Moreover, despite the forage yield having been increased with the increasing barley seed ratio in the mixture, the forage quality significantly decreased concurrently. From the results of the study, it was concluded that the optimal values, both in yield and quality, were obtained from the 80% Hungarian vetch+ 20% barley intercropping system.

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

INTRODUCTION

Wheat, oats, barley, and triticosecale crops are usually grown as green fodder for winter feeding of livestock (Anwar *et al.* 2010). These types of cereal-based forages have the potential to supply a large amount of energy for animals (Eskandari *et al.* 2009), but are deficient in protein to fulfill the body and productivity requirements of the animals (Anwar *et al.*, 2010). Intercropping of cereals with legumes has been a common cropping system in rain-fed areas (Lithourgidis *et al.* 2006; Dhima *et al.* 2007) and it has been suggested as a practical management practice to improve the quality of forage produce in resource-limited conditions, specifically in arid and semiarid environments (Karadag 2004; Sadeghpour *et al.* 2013). Forage legumes are commonly grown with cereals in a mixture because of their ability to increase the herbage yield and produce forage with more balanced nutrition for livestock feeding (Giambalvo and Ruisi, 2011; Koc *et al.* 2013). Legumes are a good source of protein and their incorporation in an intercropping system significantly increases the crude protein (CP) (Eskandari *et al.* 2009). Hungarian vetch, for example, in mixtures, improves the quality of forage by increasing the protein concentration (Vasilakoglou *et al.* 2008).

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When the components of a mixture are complementary to each other, a higher yield occurs as a result of the effective use of environmental resources such as light, water, and nutrients (Dhima *et al.* 2007; Lithourgidis *et al.* 2011a; Koc *et al.* 2013). Beyond that, this system contributes to a greater uptake of water and nutrients, and increased soil conservation (Vasilakoglou *et al.* 2008), and reduced incidence of pests, weeds, and diseases (Mohsenabadi *et al.* 2008) compared to monocrop systems. Thus, this system has recently risen in popularity worldwide (Lithourgidis *et al.* 2011a). Vetch and cereal mixtures are commonly used for hay production (Koc *et al.* 2013). Cereals can provide support for climbing vetches, improve light interception, and thus facilitate mechanical harvesting (Nadeem *et al.* 2010). Most of the researches on this have been performed on Hungarian vetches to prevent the stalks from falling (Lithourgidis *et al.* 2006; Dhima *et al.* 2007). Nevertheless, some factors affect the growth of species used in intercropping, including species, cultivar, seeding ratios, mixture ratios, row spacing and competition between mixture components (Dhima *et al.* 2007; Giambalvo and Ruisi, 2011), and extra work in preparing and planting seed; and crop management practices (Lithourgidis *et al.* 2011a).

In the vetch mixtures with cereals, it is required to know the ratios of the vetch and cereal 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; Mohsenabadi *et al.* 2008; Lauk and Lauk, 2009). For example, an increased proportion of cereal in a mixture with vetch significantly decreases the stand lodging and has a positive influence on the forage yield, but the haylage quality is poorer (Karagic *et al.* 2011). In addition to the mixture ratios, selecting the optimal variety is another important factor for desirable forage. If the best variety is not used in the mixture, the forage yield and quality will be unsatisfactory.

The objectives of this study were to evaluate the forage production capacities and qualities of different Hungarian vetch varieties and to assess their performance on an intercropping system with barley at different mixture ratios as well as to determine the most convenient variety and mixture combination in this intercropping system under semiarid climate conditions.

MATERIALS AND METHODS

Research site history: This study was carried out at the Research and Implementation Area of the Kizilirmak Vocational High School of Cankiri Karatekin University (40°202 N, 33°582 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 longterm annual rainfall of 407.8 mm (Turkish State Meteorological Service, 2013), and while the average temperature of the first growing season (4.6 ℃) was lower than the longterm value (8.3 ℃), it was closer to this value in the second growing season (8.5 ℃). 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 half of the cultivated area in the region depending the restricted precipitation (Turkish Statistical Foundation, 2013). Major soil characteristics are given in Table 2 for experimental

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

Months	Mean temperature (℃)			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	-	-	-

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

area. The soil at the experimental site has a clay or clay-loam texture and moderate lime content.

Plant materials, experiment design, and statistical analyses: The Hungarian vetch cultivars 'Budak', 'Tarm Beyazi-98', 'Anadolu Pembesi-2002', 'Oguz-2002', and 'Ege Beyazi-79' and barley cultivar 'Tarm-92', which is a 2-row feed barley and is widely grown as forage for livestock, were used as the plant material. In the study, Hungarian vetch cultivars were planted both as sole crops and in mixtures with barley at different ratios. A formulation of 4 different mixtures of Hungarian vetch (*Vicia pannonica* Crantz.) and barley (*Hordeum vulgare* L.) (80% Hungarian vetch + 20% barley, 60% Hungarian vetch + 40% barley, 40% Hungarian vetch + 60%barley, and 20% Hungarian vetch+ 80%barley), were studied. The experiments were established according to a randomized complete-block design with a split-plot arrangement. Cultivars of Hungarian vetch were the main plots and the mixture ratios were the subplots. Three replications were made for each treatment.

Before seeding, 150 kg ha^{-1} diammonium phosphate (18-46-0) (27 kg ha^{-1} N and 69 kg ha^{-1} phosphorus) was applied as a starter fertilizer. Seeds were planted in October of both the first and second years, at a rate of 120 kg ha^{-1} for the Hungarian vetch (Balabanli and Turk, 2006; Balabanli 2009) and 250 kg ha^{-1} for the barley (Balabanli and Turk, 2006). Each plot was 12 m^2 (2.4 × 5 m). The harvest time was concluded by taking the physiological stage of the Hungarian vetch into consideration. Hence, at the fruit development stage of the Hungarian vetch (Balabanli 2009) and at milk ripening stage of the barley (at the end of the May), the plots were ready to be harvested for forage yield. At which time, contribution ratio of the rate of Hungarian vetch to the mixture yield was determined. Analysis of variance of the experimental results was performed using MSTAT-C statistical software (Freed 1991) and means were compared using LSD multiple range test at a significance of $P < 0.05$.

Chemical analyses: A total of 500 g of fresh plant sample was taken from each plot and dried at 70 °C for 48 h. Next, the dry matter rates and hay yields were determined. Afterwards, the hay samples were ground in a hand-mill with a 1-mm sieve. The Kjeldahl method was used to determine the N contents of the dry samples (AOAC 1990). CP rates (CPR) were calculated using the equation of N × 6.25 and the CP yields (CPY) 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: $RFV = DDM\% \times DMI\% \times 1.29$. The RFVs were evaluated using the values provided in the standards for dry hays 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 AND DISCUSSION

All of the properties evaluated in this study were influenced by the effects of varieties of Hungarian vetch, mixture ratios, and variety × mixture ratio interactions.

As shown in Tables 4 and 5, among the varieties of Hungarian vetch, the highest, Hungarian vetch rate (24.4%), green herbage yield (31.3 t ha^{-1}), CPR (14.9%), and CPY (1227 kg ha^{-1}) were obtained from the cultivar Tarm Beyazi-98. The cultivars Oguz-2002, Tarm Beyazi-98, and Anadolu Pembesi-2002, which were statistically on par, gave higher hay yields than the other cultivars. The highest NDF (59.2%) and crude ash (11.1%) were obtained from the cultivar Budak, while the cultivars Tarm Beyazi 98, Anadolu Pembesi-2002 and Budak, which were on par, showed higher ADF rates (36.4%, 36.4%, and

TABLE 4: Hungarian vetch ratio, green herbage yield, hay yield and crude protein ratio of Hungarian vetch and barley mixtures at different by varieties and mixture ratios. Data are the means of the 2 years.

			Hungarian vetch ratio (%)			
			Mixture ratio (MR)			
Variety (V)	MR1	MR2	MR3	MR4	MR5	Mean
Budak	-	28.3 b	26.7 c	18.3 e	14.6 gh	22.0 b
Tarm Beyazi-98	-	37.3 a	27.0 c	18.7 e	14.5 gh	24.4 a
An. Pembesi-2002	-	28.3 b	22.4 d	15.3 fg	13.7 hý	19.9 c
Oguz-2002	-	26.1 c	22.5 d	16.3 f	11.9 j	19.2 c
Ege Beyazi-79	-	26.9 c	26.0 c	19.0 e	13.3 ý	21.3 bc
Mean		29.4 a	24.9 b	17.5 c	13.6 d	
LSD (%)	V: 0.50** MR: 0.48** V× MR: 1.06**					
			Green herbage yield (t ha^{-1})			
			Mixture ratio (MR)			
Variety (V)	MR1	MR2	MR3	MR4	MR5	Mean
Budak	20.8 o	23.3 n	25.7 l	26.6 jk	29.4 g	25.1 d
Tarm Beyazi-98	27.0 j	36.3 a	33.5 c	31.2 e	28.3 1	31.3 a
An. Pembesi-2002	26.0 kl	30.2 f	31.3 e	29.2 gh	34.1 c	30.2 b
Oguz-2002	26.9 j	29.4 g	34.2 b	32.4 d	28.8 g-1	30.3 b
Ege Beyazi-79	26.6 jk	28.6 h1	29.0 gh	28.2 1	24.6 m	27.4 c
Mean	25.5 d	29.6 b	30.7 a	29.5 b	29.0 c	
LSD (%)	V: 0.28** MR: 0.29** V× MR: 0.64**					
			Hay yield (t ha^{-1})			
			Mixture ratio (MR)			
Variety (V)	MR1	MR2	MR3	MR4	MR5	Mean
Budak	4.7 n	6.2 kl	7.4 j	7.6 1j	8.0 h1	6.8 c
Tarm Beyazi-98	5.5 m	9.5 c	9.5 c	8.8 de	8.9 de	8.4 ab
An. Pembesi-2002	5.6 m	8.6 d-f	8.8 de	8.6 d-f	10.5 a	8.4 ab
Oguz-2002	6.0 l	8.3 f-h	9.4 c	10.0 b	8.9 d	8.5 a
Ege Beyazi-79	6.6 k	8.1 gh	8.4 e-g	9.3 c	7.6 ýj	8.0 b
Mean	5.7 c	8.1 b	8.7 ab	8.9 a	8.8 a	
LSD (%)	V: 0.17** MR: 0.18** V× MR: 0.41**					
			Crude protein ratio (%)			
			Mixture ratio (MR)			
Variety (V)	MR1	MR2	MR3	MR4	MR5	Mean
Budak	18.0 b	14.2 g	14.1 g	11.9 k	11.5 l	13.9 c
Tarm Beyazi-98	18.9 a	16.0 d	14.4 g	13.3 h1	12.0 k	14.9 a
An. Pembesi-2002	18.4 b	15.0 f	14.5 g	13.1 1j	11.7 kl	14.5 b
Oguz-2002	18.9 a	15.5 e	14.2 g	12.7 j	12.0 k	14.7 ab
Ege Beyazi-79	17.2 c	13.3 h1	13.6 h	11.4 l	10.2 m	13.1 d
Mean	18.3 a	14.8 b	14.2 c	12.5 d	11.5 e	
LSD (%)	V: 0.15** MR: 0.18** V× MR: 0.40**					

Numbers followed by the same letters are not significantly different at the 5% level of significance. NS= Not significant, *P < 0.05, **P < 0.01,

HV= Hungarian vetch B= Barley

MR1= Sole Hungarian vetch, MR2= 80%HV+ 20%B, MR3= 60%HV+ 40%B, MR4= 40%HV+ 60%B, MR5= 20%HV+ 80%B.

36.2%, respectively) than the other cultivars. The highest RFV value (107) was calculated for the cultivar Ege Beyazi-79. In different mixture ratios, the highest Hungarian vetch rate (29.4%) were obtained in the mixture of 80%Hungarian vetch+ 20%barley. The highest green herbage (30.7 t ha^{-1}) and CPY (1233 kg ha^{-1}) were obtained from the mixture of 60% Hungarian vetch + 40% barley. The maximum NDF (59.8%), ADF (36.8%) were determined in the hay of the mixture 20% Hungarian vetch + 80%barley. The mixtures of 40% Hungarian vetch + 60%barley, 20%Hungarian vetch+ 80%barley and 60% Hungarian vetch+ 40%barley gave higher hay yields (8.9 t ha^{-1}, 8.8 t ha^{-1}, and 8.7 t ha^{-1}, respectively) than the other mixtures studied. The highest CPR (18.3%) and RFV values (120) were

TABLE 5: Crude protein yield, neutral detergent fiber, acid detergent fiber, and relative food value of Hungarian vetch and barley mixtures at different by varieties and mixture ratios. Data are the means of the 2 years.

	Crude protein yield (kg ha^{-1})					
	Mixture ratio (MR)					
Variety (V)	MR1	MR2	MR3	MR4	MR5	Mean
Budak	857 j	879 j	1052 1	907 j	905 j	920 d
Tarm Beyazi-98	1029 1	1510 a	1358 c	1181 ef	1057 1	1227 a
An. Pembesi-2002	1018 1	1295 cd	1269 d	1133 f-h	1240 de	1191 b
Oguz-2002	1140 fg	1281 d	1335 b	1261 d	1069 g-1	1217 ab
Ege Beyazi-79	1141 fg	1069 h-1	1150 f	1078 g-1	778 k	1043 c
Mean	1037 c	1207 ab	1233 a	1112 b	1009 c	
LSD (%)	V: 33.5** MR: 28.4** V× MR: 63.4**					
	Neutral detergent fiber (%)					
	Mixture ratio (MR)					
Variety (V)	MR1	MR2	MR3	MR4	MR5	Mean
Budak	49.8 m	60.6 bc	60.9 b	61.5 b	63.4 a	59.2 a
Tarm Beyazi-98	51.5 l	56.4 j	57.9 g-1	57.0 h-j	59.2 d-f	56.4 b
An. Pembesi-2002	48.8 m	57.8 g-1	56.8 1j	58.4 e-g	59.7 cd	56.3 b
Oguz-2002	49.0 m	57.0 hj	57.9 g-1	58.1 f-1	57.6 g-j	55.9 c
Ege Beyazi-79	46.9 n	54.6 l	58.3 e-h	57.7 g-j	59.4 de	55.4 c
Mean	49.2 d	57.3 c	58.3 b	58.5 b	59.8 a	
LSD (%)	V: 0.44** MR: 0.51** V× MR: 1.13**					
	Acid detergent fiber (%)					
	Mixture ratio (MR)					
Variety (V)	MR1	MR2	MR3	MR4	MR5	Mean
Budak	33.2 j	36.2 fg	36.7 d-f	36.6 e-g	38.1 a	36.2 a
Tarm Beyazi-98	33.3 j	36.3 fg	37.1 c-e	37.4 b-d	38.0 ab	36.4 a
An. Pembesi-2002	33.2 j	37.1 c-e	37.4 b-d	37.8 a-c	36.8 d-f	36.4 a
Oguz-2002	32.6 j	35.2 h	36.0 g	36.3 fg	36.3 fg	35.3 b
Ege Beyazi-79	31.5 k	31.3 k	34.1 1	33.1 j	35.0 h	33.0 c
Mean	32.8 d	35.2 c	36.2 b	36.2 b	36.8 a	
LSD (%)	V: 0.36** MR: 0.28** V× MR: 0.63**					
	Relative feed value					
	Mixture ratio (MR)					
Variety (V)	MR1	MR2	MR3	MR4	MR5	Mean
Budak	118 c	93 k-m	92 lm	91 m	87 n	96 d
Tarm Beyazi-98	114 d	100 fg	96 h-j	98 gh	93 k-m	100 c
An. Pembesi-2002	120 b	97 hý	98 gh	95 ý-k	94 j-l	101 c
Oguz-2002	121 b	100 fg	98 gh	97 h1	98 gh	103 b
Ege Beyazi-79	128 a	110 e	100 fg	102 f	97 h-j	107 a
Mean	120 a	100 b	97 c	97 c	94 d	
LSD (%)	V: 1.01** MR: 1.03** V× MR: 2.30**					

Numbers followed by the same letters are not significantly different at the 5% level of significance. NS= Not significant, * P < 0.05, ** P < 0.01,

HV= Hungarian vetch B= Barley

MR1= Sole Hungarian vetch, MR2= 80%HV+ 20%B, MR3= 60%HV+ 40%B, MR4= 40%HV+ 60%B, MR5= 20%HV+ 80%B

obtained in sole Hungarian vetch. When different variety × mixture ratio combinations were considered. The highest Hungarian vetch rate (37.3%), green herbage yield (36.3 t ha^{-1}), and CPR (16.0%) were obtained from the mixture of 80% Hungarian vetch (Tarm Beyazi-98) + 20% barley interaction. Highest hay yield (10.5 t ha^{-1}) was obtained from the mixture of 20% Hungarian vetch (Anadolu Pembesi-2002) + 80%barley combination. The highest CPY (1335 kg ha^{-1}), NDF (63.4%), ADF (38.1%), were obtained from the mixture of 60%Hungarian vetch (Oguz 2002) + 40%barley, and from the mixture of 20% Hungarian vetch (Budak) + 80% barley combinations, respectively. The highest RFV (110) was calculated for the mixture of 80% Hungarian vetch (Ege Beyazi-79) + 20%barley interaction. As the mean of 2 years, green herbage of 29.5 t ha^{-1}, hay yield of 10.8 t ha^{-1}, CPY of 937 kg ha^{-1}, CPR of 8.7%, NDF of 57.9%, ADF of 36.4% and RFV value of 97 were obtained from sole crop of barley.

Different percentages of Hungarian vetch determined in previous mixture studies showed that the percentage of vetch in a mixture affects the quality of the harvested herbage and its ratio in it differs greatly. Bedir (2010) and Ozel 2010 found vetch rates of 13.6% and 26.3%, respectively, which was the highest rate, in the mixture of 80% Hungarian vetch+ 20% barley; Karadag (2004), Gunes 2009, and Yolcu *et al.* (2009) obtained vetch rates of 7.0%, 14.8%, and 29.8%, respectively, from the mixture of 66% Hungarian vetch + 34%barley mixture; Gunduz (2010), and Orak and Nizam (2012) found vetch rates of 16% and 42%, respectively, from the combination of 50% Hungarian vetch + 50% cereal mixture; and Albayrak *et al.* (2004) found a vetch rate of 66% in a different mixture ratio of Hungarian vetch + triticale. Similarly, Lithourgidis *et al.* (2006) stated that there were differences in the legume rate among various intercropping interactions. Moreover, these researchers indicated that a high rate is obtained if the plants subject to harvest contain a high percentage of Hungarian vetches in the mixtures. Similar results were observed in this study. These differences might be the result of ecological and environmental factors, and the cultivars and mixture ratios in the experiments. On the other hand, Lithourgidis *et al.* (2011b) reported that cereals like wheat, intercropped with legumes, for example vetch, showed greater competitive ability to exploit environmental resources.

The average across the different varieties and mixture ratio interactions for the Hungarian vetch rate ranged between 11.9% and 37.3% in the present study. The vetch rate decreased as a result of the increased percentage of barley and the lowest average values were seen in the mixture of 20% Hungarian vetch + 80% barley (13.6%) for all varieties. Based on the barley ratios in the mixture, much lower Hungarian vetch rates than original designed mixtures were obtained in harvest. This is because cereals suppress legumes in the spring, owing to their high tillering and growth characteristics (Karadag 2004). Accordingly, it might be concluded in this study that the superior growing performance of the Hungarian vetch in the 80% mixture was effective on increasing the Hungarian vetch rate in the mixture. The competitive ability of the plants shows differences among the species (Mariotti *et al.* 2009); hence, between plant species, there may be aboveground competition for light and space, and belowground competition for water and nutrients (Koc *et al.* 2013). The growth of legumes is very slow in winter as a result of low temperatures, while cereals produce tillers and stems and cover the small legume seedlings (Twidwell *et al.* 1987).

Green herbage and hay yield values derived from the sole sowing of Tarm Beyazi-98 and Ege Beyazi-79 were reported as 6.2–35.2 t ha^{-1} and 1.7–7.9 t ha^{-1}, and 4.7–29.7 t ha^{-1} and 1.2-6.3 t ha^{-1}, respectively, in previous studies. Green herbage and hay yield values obtained our results were higher than the findings of some researchers (Balabanli and Turk, 2006; Pinar 2007; Gunduz 2010; Ozel 2010; Unal *et al.* 2011; Albayrak *et al.* 2011). This might be explained by the difference in varieties and ecological conditions. Green herbage and hay yields were evaluated by earlier researchers for Hungarian vetch and barley mixtures in different varieties and mixture ratios, ranging from 9.1 to 43.8 t ha^{-1} and 3.2 to 12.9 t ha^{-1}, respectively. Several researchers determined the highest green herbage and hay yield

values of Hungarian vetch with barley mixtures, in which the Hungarian vetch had a rate of between 66% and 87.5% (Karadag 2004; Pinar 2007; Yolcu *et al.* 2009; Budak *et al.* 2011), and superior yield results of Hungarian vetch were obtained in mixtures where the Hungarian vetch and cereals had an equivalent mixture ratio (Gunduz 2010; Aksoy and Nursoy, 2010; Nadeem *et al.* 2010). In contrast to the above mentioned studies, Balabanli and Turk (2006), Tuna and Orak (2007), and Bedir (2010) indicated that the highest yield values of Hungarian vetch were observed in a mixture in which cereals had a 75%–80% mixture rate. Despite this, the maximum green herbage yield (36.3 t ha^{-1}) was obtained from the mixture of 80% Hungarian vetch (Tarm Beyazi-98) + 20% barley and the maximum hay yield (10.5 t ha^{-1}) was obtained from the 20% Hungarian vetch (Anadolu Pembesi) + 80% barley combination.

Balabanli (2009) stated that the percentage of Hungarian vetch in a mixture must be at least 60% for high yield. Nevertheless, Bedir (2010) and Gunduz (2010) stated that the yield decreased when the percentage of Hungarian vetch was higher than 50%. When compared to previous studies, the green herbage and hay yield values derived from the present study were quite close to the top values observed in the sole sowing of Hungarian vetch. Seeding ratio mixtures indicated a significant advantage from intercropping, which was attributed to better economics and land use efficiency than with the other mixtures (Dhima *et al.* 2007). Forage yields are commonly higher in mixtures based on the transfer of symbiotically fixed N grasses and more efficient light utilization (Vasilakoglou *et al.* 2008; Lauk and Lauk, 2009). Additionally, the stand will always be more productive than with the 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). Accordingly, cereals with legumes are more productive than pure cereal or legume sowing and they can support greater animal performance (Hauggard-Nielsen *et al.* 2009). Higher yield values were obtained in mixtures compared to the sole sowings of Hungarian vetch in the present study. On the other hand, although the values obtained were at a sufficient level for livestock feeding, from the mixtures, these results were still lower than the acquired values of sole barley. This might be explained by the higher shooting and tillering capability of cereals (Karadag 2004; Lithourgidis *et al.* 2011a). Moreover, this difference might be clarified by the ecological conditions recorded during the vegetative growth cycle and being sown at different ratios in the mixture cultivars in the experiments. The green herbage yields increased depending on the increasing Hungarian vetch ratio in mixture, whereas the hay yield decreased in the same situation.

In previous researches, the CPR and CPY of sole Hungarian vetch were reported as 15.4% – 24.1% and 324 –1242 kg ha^{-1}, respectively (Gunes 2009; Bedir 2010; Aksoy and Nursoy, 2010; Albayrak *et al.* 2011). While Hungarian vetch has 15% – 17% CP (Balabanli 2009), barley also contains lower than this quantity, varying from 6% to 10%. The CPR and CPY values of sole Hungarian vetch calculated in this study were comparable to those in previous studies. These values determined in sole barley were 5.8% – 12.7% and 389 – 1052 kg ha^{-1}, respectively (Balabanli and Turk, 2006; Pinar 2007; Gunes 2009; Ozel 2010; Bedir 2010; Sadeghpour *et al.* 2013). The parallel findings were evaluated in the present study. The highest CPR (16%) and CPY (1510 kg ha^{-1}) were obtained from the mixture of 80% Hungarian vetch (Tarm Beyazi-98) + 20 % barley. The CPR and CPY were assessed by earlier researches for Hungarian vetch and barley mixtures in different varieties, and the mixture ratios ranged from 9.0% to 14.2% and 363 to 1378 kg ha^{-1}, respectively. Both the CPR and CPY were higher than the values reported in previous studies. Furthermore, though the maximum hay yields were obtained based on increasing the barley ratios in the mixtures, both of these values gradually decreased in parallel.

While most of the researchers found the highest CPR and CPY in mixtures where the percentage of Hungarian vetch was 60% and higher (Albayrak *et al.* 2004; Balabanli and Turk, 2006; Yolcu *et al.* 2009; Budak *et al.* 2011), the highest values were obtained from mixtures in which both species had the same ratio (Gunduz 2010; Aksoy and Nursoy, 2010), and mixtures where the percentage of cereal was 60% (Bedir 2010).

Obtaining the optimum forage quality is also a very important requirement in forage crop cultivation for animal nutrition, as well as for obtaining a high forage yield from the unit area. Ecologically, temperature and precipitation, and agronomical conditions such as plant species, varieties, legume ratio in the mixture, and harvest time are the factors directly influencing the CPR. The hay yield affects the CPY. There is no doubt that cereals produce efficient and palatable fodders with a sufficient amount of carbohydrate, but they are deficient in protein, which is necessary for animal health and productivity. Protein is needed by livestock, for growth and milk production and by rumen bacteria, which digest much of the feed for ruminant animals (Ghanbari-Bonjar 2000). Some researchers reported that the insufficient intake of organic matter and CP limited animal performance (Vasilakoglou *et al*. 2008; Anwar *et al.* 2010). It is expected that the CPR of mixtures that contain high levels of Hungarian vetch is high. Additionally, Hungarian vetch naturally includes a higher CPR compared to barley.

Previous authors reported different results for forage quality parameters, such as RFV, NDF, ADF, and crude ash. Albayrak *et al.* (2011) determined the RFV, NDF and ADF rates in Hungarian vetch as 142, 41.8%, and 33.0%, respectively. In addition, different NDF and ADF rates were determined by previous researchers. Yolcu et al. (2009), for example, found the NDF and ADF in different mixtures of the crops with cereals as 53.9% and 33.0%, respectively; Aksoy and Nursoy (2010), in a Hungarian vetch and wheat mixture, found these values as between 37.5% and 57.6%, and from 25.9% to 38.2%, respectively, at different harvest times.

Among the most important characters that have an effect on the quality of herbage are the CP, NDF, ADF, and RFV. The TDN refers 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 TDN, 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 that is 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 results of this study, which are given in Table 5, the outstanding NDF (54.6%), ADF (31.3%) and RFV (110) values were determined in the mixture of 80% Hungarian vetch (Ege Beyazi-79) + 20%barley intercropping system. However, it was observed in these combinations, that the hay and CPY, except for Budak, and CPR were lower than the other interactions of different varieties. In the meantime, superior values were obtained in the 80%Hungarian vetch + 20%barley intercropping systems, and the rising percentage of barley in the mixture negatively affected the quality parameters all of the varieties. In this mixture ratio, while the ADF was of high quality (level 1), the CP was good (level 2), and the NDF and RFV, which are the important digestibility indicators, were of medium quality (level 3).

CONCLUSIONS

The interaction in which the percentage of Hungarian vetch was 80% can be used in terms of forage yield and quality in the event where Hungarian vetch and barley are grown in a mixture. Additionally, while the best values for the CPR, forage, and protein yield parameters were obtained from the 80%Hungarian vetch (Tarm Beyazi-98) + 20%barley intercropping system, in terms of the forage quality parameters, such as NDF, ADF, and RFV, the optimum findings were assessed in the same ratio of the Ege Beyazi-79 variety.

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