Volume 45 | Number 3 Article 6

1-1-2021

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HAKAN KIR

Turkish Journal of Veterinary and Animal Sciences
http://journals.tubitak.gov.tr/veterinary/
Research Article
Turk J Vet Anim Sci
(2021) 45: 419-426
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doi:10.3906/vet-2005-45

Forage yield and quality of Hungarian vetch mixture with oat varieties under rainfed conditions

Hakan KIR*
Department of Field Crops, Faculty of Agriculture, Kırşehir Ahi Evran University, Kırşehir, Turkey

Received: 12.05.2020 • **Accepted/Published Online:** 21.02.2021 • **Final Version:** 29.06.2021

Abstract: This study was conducted to determine the appropriate mixture rates of Hungarian vetch and oat varieties in Kırşehir province of Turkey for two years 2017–2019. In this study, the yield and quality characteristics of single and mixed cultivations of three oat (*Avena sativa* L.) varieties and Hungarian vetch (*Vicia pannoica* Crantz) were determined. Yield characteristics such as green forage and dry matter, crude protein and digestible dry matter yields and quality characteristics such as crude protein ratio, neutral detergent fiber, acid detergent fiber, digestible dry matter, total digestible nutrient, dry matter intake and relative feed value were examined in the single and mixed cultivations. The result of the two-year research indicated that the highest green forage, dry matter, crude protein and digestible dry matter yields were obtained from the mixture of 25% HV + 75% O mixture of Saia oat variety (18.3, 5.7, 0.76, 3.6 t ha^{-1}, respectively). The highest crude protein, total digestible nutrients, relative feed value and the lowest ADF, NDF ratio were obtained from the single cultivation of Hungarian vetch (18.1%, 65.6%, 163.1 and 27.7%, 38.4%, respectively). In conclusion, with respect to the investigated quality parameters with forage yield, 50% HV + 50% O mixtures can be suggested.

Key words: Crude protein, dry matter yield, acid detergent fiber, relative feed value

1. Introduction

Different cultivation systems have been adopted in forage crops cultivation to benefit from the environmental conditions of the region. Intercropping, which is introduced as the sustainable agricultural technique, is the cultivation of two or more species in the same area at similar or different times [1,2]. Farmers in the arid and semiarid climatic regions minimize losses from external impact by adopting the intercropping system. The resistance against environmental problems also increases with the cultivation of species together [3]. The cultivation of different species in the same field enables the use of limited environmental resources more effectively. The utilization of resources such as soil, water, light and plant nutrients by different species and varieties will be better in mixed cultivation; thus, the yield per unit area will increase in mixed intercropping system [4–6]. In addition, Banik et al. [7] also indicated that cultivation of a mixture of two or more crops provides a better vegetation coverage on soil surface and reduces the density of weeds, water runoff, and sediment and nutrient losses. Cereal-legume mixed intercropping system is one of the most common intercropping systems adopted in arid and semiarid regions. In addition to high carbohydrate content, the rapid growth and high yield of the cereals, and high protein content of legumes ensure the production of high yield and forage quality in the cereal and legume mixtures [8]. Annual cereal + legume mixtures, which are cultivated for winter in the production of quality forage, are important in the regions where the precipitation changes depending on the season and generally occurs in autumn and early spring. Oat, which is a cool season cereal plant, is cultivated in marginal areas with cool, rainy climates and low fertile soils. In addition, the fact that oats are soft-stemmed and abundant with leaves, and their richness in organic and mineral substances increase their importance in animal nutrition [9]. Hungarian vetch is an annual legume forage crop that can grow without harming frost at high altitudes in regions where the winter is harsh and needs moderate water [10]. Appropriate cereal + legume combination rates should be determined in addition to the suitable species and varieties for a region to obtain the maximum yield from the cereal and legume mixtures in mixed intercropping system [11]. Yolcu et al. [12] who conducted a study using single barley, wheat, rye, oat, Hungarian vetch and their mixtures with Hungarian vetch, obtained the highest forage and hay yields from the single rye and mixtures of rye with Hungarian vetch. The highest crude

* Correspondence: hakankir@ahievran.edu.tr

protein ratio and the lowest NDF and ADF ratios were recorded in the single Hungarian vetch cultivation. Dhima et al. [13] stated that the hay and protein yields in mixtures were higher than single cultivated beans, while similar to or higher than the single planted oat varieties. Researchers have suggested the 25% faba bean + 75% oat mixture as an alternative feed source for adequate hay and protein yields. The highest hay and crude protein yields in the ecological conditions of Kırşehir province was obtained from 60% pea + 40% oat or 50% pea + 50% oat mixtures can be harvested at the beginning of flowering period, and the quality also increased with the increase of legume rate in the mixtures [14]. The aim of this study was to evaluate the yield and quality of forage and hay obtained in the single and cereal + legume mixtures under rainfed conditions in central Anatolia of Turkey. For this purpose, the oat varieties with high yield and quality and the appropriate mixture rate of oat varieties with Hungarian vetch in Kırşehir ecological conditions were determined.

2. Materials and methods

The field studies were carried out under rainfed conditions in Kırşehir province (1090 m asl., 39º08'N and 34º06'E), Turkey during 2017–2018 and 2018–2019 vegetation periods (Figure). The soils in experimental field was slightly alkaline (pH, 7.96), highly calcareous (calcium carbonate content, 35.29%), and electrical conductivity indicated that salinity (electrical conductivity, 738.6 µS cm^{-1}) does not constrain plant growth. The soils had clayey loam texture, low in organic matter content (1.09%) and plant available phosphorus concentration (99.6 kg ha^{-1}), and rich in potassium concentration (2400.0 kg ha^{-1})[15]. Three oat (*Avena sativa*) varieties (Seydişehir, Saia and Çekota) and a Hungary vetch (*Vicia pannonnica* Crantz) variety (Altınova-2002) were used in the study. The treatments of the study were single cultivation of Hungary vetch (HV) and oat (O) varieties, and three mixture rates of HV and O varieties (75% HV + 25% O, 50% HV + 50% O, 25% HV + 75% O).The experimental design randomized 4 monocrops (HV and three Oat varieties) and three mixture ratio (three oat varieties with HV) of was a complete block with 13 treatments replicated three times. All the treatments were repeated three times in the experiment. The number of seeds used in single cultivation of Hungary vetch was 220 seeds m^{-2}[16] and in oat was 500 seeds m^{-2} [14] and the mixing ratios were calculated accordingly. Before seed sowing, fertilizer at a rate of 40 kg ha^{-1} nitrogen and 70 kg ha^{-1} phosphorus (P_2O_5) were applied to soil. The plots in the experiment had 8 rows, the length of each row was 5 m, and the interrow spacing was 20 cm [14]. The seeds of both species were sown manually in rows opened with a marker. In the first vegetation period, seeds were sown on October 23, 2017 and harvested on May 18, 2018. In the second vegetation period, seeds were sown on October 22, 2018, and harvested on May 25, 2019. Since the cereals mature more quickly, the harvest date was determined according to the maturation of cereals. The oat varieties were harvested in the flowering period, and the Hungarian vetch was harvested in the full flowering period [14]. One row from each plot edge and 50 cm from the ends of each plot were considered as edge effects and the remaining area was harvested with a scythe. Harvested plants were weighed and green forage yield was calculated for per hectare. Five hundred gram of fresh samples were dried in an oven at 60 º until a constant weight attained (approximately 48 h) and dry matter yield was calculated for each plot [17]. The dried samples were then ground and sieved through a 1 mm sieve for nutrient analysis. Acid detergent fiber (ADF) and

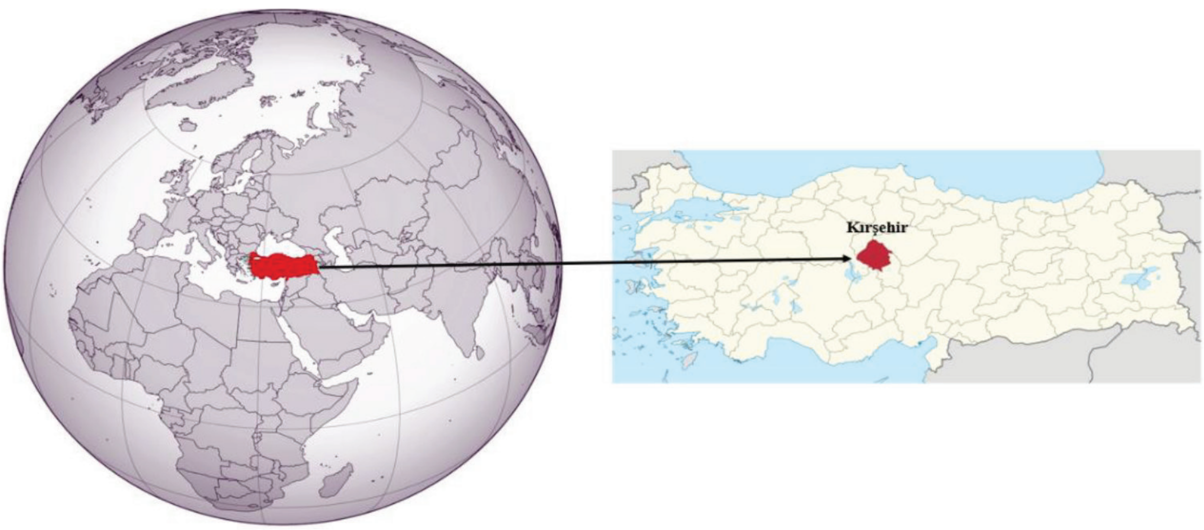

Figure. Geographical location of the research.

neutral detergent fiber (NDF) contents were determined by ANKOM 200 Fiber analyzer (ANKOM Technology, Macedon, NY, USA) according to the methods reported by Van Soest et al. [18]. The nitrogen contents of the species and mixtures were determined by the Kjeldahl method, and the nitrogen contents were multiplied by the coefficient of 6.25 to obtain crude protein ratios [19]. All the analyses were repeated twice. The total digestible nutrient (TDN) ratio was calculated using the equation of TDN (%)= (–1.291 × ADF) + 101.35 introduced by Horrocks and Valentine [20], and digestible dry matter (DDM) was dtermined by the equation of DDM = 88.9 – (0.779 × ADF) explained by Sheaffer et al. [21]. Digestible dry matter yield (DDMY) was calculated by multiplying the DDM by the hay yield. Relative feed value (RFV) was calculated by the equation of RFV = dry matter intake (DMI) × digestible dry matter (DDM)/1.29 [22]. Dry matter intake was determined by the equation of DMI (BW%) = 120/NDF [23]. The results of the quality analysis were compared according to Lacefield [24] quality standards (Table 1).

2.1. Statistical analysis

The data were subjected to variance analysis using MSTAT-C statistical software. Analysis of variance (ANOVA) was carried out to assess the effects of single and mixture cultivation of varieties on yield and quality traits. When the effect considered significant at $p < 0.05$ level, then the means were compared using Duncan's homogeneity test or least significant difference (LSD) test [25].

3. Results

3.1. Weather conditions

The average temperature in the first year (9.1 °C) of the experiment was higher than the second year (8.1 °C) and the long-term (6.9 °C) averages (Table 2). The temperatures in March, April and May, where plants rapidly grow, were different between years. The temperatures were higher in March and April of the first year, whereas the temperature in May of the second year was lower (Table 2). Similar to the temperature averages, the total precipitation in the first year (365.1 mm) was higher than the long-term average (315.8 mm), while it was lower than the long-term average (315.8 mm) in the second year (301.5 mm). Total precipitation in March, April and May, where the plants grow rapidly, in the first year remained above the total precipitation in the second year and the long-term (Table 2).

3.2. Forage production

The results of two years data indicated that the species, varieties and their mixture rates had significant effects ($p < 0.01$) on green forage yield, dry matter yield, crude protein yield and digestible dry matter yield, while the effects of year, species and variety × year interactions were not significant interactions were not significant ($p > 0.01$). Significant differences were not observed about green forage, dry matter, crude protein and digestible dry matter yields between the oat varietiesof Çekota, Saia and Seydişehir. High yielding group (green forage, dry matter, crude protein and digestible dry matter yields) included the mixtures of 25% HV + 75% O Çekota, Saia and Seydişehir varieties and 50% HV + 50% O Çekota and Seydişehir varieties. The 25% HV + 75% O mixture of Saia variety is only in the high group in terms of protein and digestible dry matter yield (Table 3). The highest green forage (18.3 t ha^{-1}), dry matter yield (5.7 t ha^{-1}) and digestible dry matter yields (3.6 t ha^{-1}) were obtained with the 25% HV + 75% O mixture of Saia oat variety, and the lowest yields (10.9 t ha^{-1}, 2.9 t ha^{-1}, 1.9 t ha^{-1}, respectively) were obtained from the single cultivation of Hungarian vetch. The highest crude protein yield was obtained from 25% HV + 75% O

Table 1. Legumes, grass and legume-grass mixture quality standards.

Quality standards	Laboratory analyses			Calculated values		
	Protein % of dry matter	ADF % of dry matter	NDF % of dry matter	DDM %	DMI % of BW	RFV
Prime (Prime)	>19	<31	<40	>65	>3.0	>151
1 (Premium)	17–19	31–40	40–46	62–65	3.0–2.6	151–125
2 (Good)	14–16	36–40	47–53	58–61	2.5–2.3	124–103
3 (Fair)	11–13	41–42	54–60	56–57	2.2–2.0	102–87
4 (Poor)	8–10	43–45	61–65	53–55	1.9–1.8	86–75
5 (Reject)	<8	>45	>65	<53	<1.8	<75

Source: Hay Market Task Force, American Forage and Grassland Council.
ADF: Acid detergent fiber, NDF: Neutral detergent fiber, DDM: Digestible dry matter, DMI: Dry matter intake (% of Body Weight), RFV: Relative feed value.

Table 2. Monthly rainfall and mean air temperature during the two growing seasons of the experimentation*.

Months	Temperature (°C)			Rainfall (mm)		
	2017–2018	2018–2019	Long years	2017–2018	2018–2019	Long years
October	12.4	14.2	12.8	20.6	45.4	35.1
November	6.3	8.1	6.4	56.0	21.1	37.2
December	4.4	3.3	2.1	35.6	101.1	43.8
January	2.1	0.9	0.4	74.3	42.2	42.7
February	6.5	3.9	1.5	17.0	36.3	32.2
March	9.7	6.5	5.6	87.7	10.2	35.7
April	14.0	9.7	10.8	4.4	28.7	48.8
May	17.3	18.1	15.9	69.5	16.5	40.3
Av./ Tot.	9.1	8.1	6.9	365.1	301.5	315.8

* Turkish State Meteorological Service.

Table 3. Some yield characteristics for Hungarian vetch mixture with oat varieties.

Treatments		Green forage yield (t ha^{-1})		Dry matter yield (t ha^{-1})		Crude protein yield (t ha^{-1})		Digestible dry matter yield (t ha^{-1})	
Hungarian vetch		10.9	f	2.9	d	0.51	d	1.9	f
Oat (Çekota)		15.5	cde	5.1	ab	0.53	d	3.2	cd
25% HV + 75% O		18.0	ab	5.6	a	0.70	ab	3.6	ab
50% HV + 50% O		16.9	abc	5.2	ab	0.74	a	3.4	abc
75% HV + 25% O		11.8	f	3.3	d	0.53	d	2.2	f
Oat (Saia)		14.5	de	4.7	bc	0.56	d	3.0	de
25% HV + 75% O		18.3	a	5.7	a	0.76	a	3.6	a
50% HV + 50% O		16.1	bcd	4.8	bc	0.71	ab	3.1	cde
75% HV + 25% O		11.3	f	3.1	d	0.52	c	2.1	f
Oat (Seydişehir)		16.1	bcd	5.3	ab	0.58	cd	3.3	bcd
25% HV + 75% O		18.2	a	5.1	ab	0.64	bc	3.2	cd
50% HV + 50% O		17.3	abc	5.1	ab	0.73	a	3.3	cd
75% HV + 25% O		13.9	e	4.3	c	0.70	ab	2.9	e
Average		15.3		4.6		0.63		3.0	
Years	2017–2018	15.2		4.6		0.64		3.0	
	2018–2019	15.4		4.7		0.63		3.0	
SEM		0.317		0.113		0.509		0.070	
p-value	Treatments (T)	**		**		**		**	
	Years (Y)	NS		NS		NS		NS	
	T × Y	NS		NS		NS		NS	

**: $p < 0.01$, there is no difference between the same letters in each column. NS: Not significant, HV: Hungarian vetch, O: Oat.

of the Saia oat variety (0.76 t ha^{-1}), while the lowest crude protein yield was obtained from the single cultivation of Hungarian vetch (0.51 t ha^{-1}). Single cultivation of Çekota. Seydişehir and Saia oat varieties are in the group that gives low crude protein yield (Table 3).

3.3. Forage nutritive value

The results of two-year data showed statistically significant differences in ADF, NDF, DDM, TDN, DMI ratios and RFV between species, varieties, mixture rates and years ($p < 0.01$). However, the difference in crude protein ratio was recorded only between the species, variety and mixture rates ($p < 0.01$). The differences in quality criteria (ADF, NDF, DDM, TDN, DMI ratios and RFV) between oat varieties were not statistically significant ($p > 0.01$) (Table 4). Çekota, Saia and Seydişehir oat varieties were placed in the high ADF and NDF ratio group, while the Hungarian vetch was in the low statistical group. The oat varieties were placed in the low crude protein, DDM, TDN, DDI and RFV group, while single Hungarian vetch was in the high statistical group. Single Hungarian vetch cultivation yield the lowest ADF and NDF ratios (27.7% and 38.4%, respectively), while the CP, DDM, TDN, DDI ratios and RFV (18.1%, 67.4%, 65.6%, 3.1% and 163.1, respectively) were at the highest level in Hungary vetch cultivation (Table 4). The single cultivations of Çekota, Saia and Seydişehir oat varieties were placed in the highest ADF and NDF ratio group, while the oat varieties were included in the lowest forage quality group with other forage quality indicators. The DDM (66.0%), TDN (63.4%), RFV (133.4) and DDI (2.6%) in the first year were higher than the second year, in contrast the ADF (32.0%) and NDF (48.7%) ratios were higher in second year (Table 4). The effects of species, varieties and mixture ratio x year interactions on nutritive quality of forages were not found significant (Table 4).

4. Discussion

4.1. Forage production

Determining the suitable species and varieties and their mixing rates for a region is needed to increase the forage production. The yields of all the mixtures were higher than the single cultivated Hungarian vetch and oat varieties, and the yield increased as the rate of Hungarian vetch decreased

Table 4. Some quality characteristics for Hungarian vetch mixture with oat varieties.

Treatments		Crude protein (%)		Acid detergent fiber (%)		Neutral detergent fiber (%)		Digestible dry matter (%)		Total digestible nutrients (%)		Dry matter intake (%)		Relative feed value	
Hungarian vetch		18.1	a	27.7	h	38.4	f	67.4	a	65.6	a	3.1	a	163.1	a
Oat (Çekota)		10.5	h	33.0	a	55.2	a	63.2	gh	58.7	h	2.2	f	106.7	g
25% HV + 75% O		12.4	fg	31.7	bc	51.0	c	64.2	def	60.4	fg	2.4	de	117.3	e
50% HV + 50% O		14.3	de	30.4	de	46.8	d	65.3	c	62.2	de	2.6	c	129.8	c
75% HV + 25% O		16.2	bc	29.0	fg	42.6	e	66.3	b	63.9	bc	2.8	b	144.8	b
Oat (Saia)		11.8	gh	32.6	ab	54.8	ab	63.5	fgh	59.2	gh	2.2	f	108.2	fg
25% HV + 75% O		13.4	ef	31.4	cd	50.7	c	64.5	cde	60.8	ef	2.4	de	118.6	de
50% HV + 50% O		15.0	cd	30.2	ef	46.6	d	65.4	bc	62.4	cd	2.6	c	130.8	c
75% HV + 25% O		16.5	b	28.9	g	42.5	e	66.4	b	64.0	b	2.8	b	145.4	b
Oat (Seydişehir)		11.0	h	33.2	a	53.1	b	63.1	h	58.5	h	2.3	ef	110.7	f
25% HV + 75% O		12.8	fg	31.8	bc	49.4	c	64.1	efg	60.3	fg	2.4	d	120.8	d
50% HV + 50% O		14.6	de	30.4	de	45.8	d	65.2	cd	62.1	de	2.6	c	132.6	c
75% HV + 25% O		16.3	bc	29.1	fg	42.1	e	66.3	b	63.9	bc	2.9	b	146.5	b
Average		14.1		30.7		47.6		65.0		61.7		2.6		128.9	
Years	2017–2018	14.3		29.4 B		46.6 B		66.0 A		63.4 A		2.6 A		133.4 A	
	2018–2019	13.9		32.0 A		48.7 A		63.0 B		60.0 B		2.5 B		124.4 B	
SEM		0.2735		0.2672		0.6105		0.2081		0.3450		0.0331		2.010	
p-value	Treatments (T)	**		**		**		**		**		**		**	
	Years (Y)	NS		**		**		**		**		**		**	
	T × Y	NS		NS		NS		NS		NS		NS		NS	

**: $p < 0.01$, there is no difference between the same letters in each column, NS: Not significant, HV: Hungarian vetch, O: Oat.

in the mixtures. Since plants in intercropping utilize the available environmental resources at the highest level, they are more productive in the mixed cropping compared to the single cultivation [26] sander. Leguminous and cereals in the mixtures use different environmental sources, and these different families also have complementary effects [1,27]. The mixtures use light, soil moisture and nutrients more efficiently than single plantings [2,28]. The beneficial effects of legumes and cereals on each other caused to obtain higher yields compared to the single cultivations. In addition, suitable growth environment in spring season, when the oats grow rapidly had a favorable impact on the yield of the oat varieties, which are better adapted to cool and rainy climates [29]. The results indicated that the green forage and dry matter yields increased with the increased ratio of cereals in the mixtures compared to the single cultivations due to the tillering characteristics of the cereals [30]. Dhima et al. [13] and Lithourgidis et al. [26] also stated that mixed intercropping yielded higher hay and crude protein yields than single cultivation.

4.2. Forage nutritive value

The quality values of forage were significantly different in single Hungarian vetch and oat varieties and the mixture cultivations. Higher CP and lower ADF and NDF ratios were recorded in the single cultivation of Hungarian vetch and the mixtures with high Hungarian vetch rates. The crude protein content increased with the increase of the legume rate. The higher cell wall concentrations of cereals compared to legumes also provided advantages in DDM, TDN, DDI and RFV in both the single Hungarian vetch cultivation and also in the mixtures with the high rate of Hungarian vetch whereas the opposite is expected due to the cell wall component of plants increase, intake and digestibility are decreased. Increasing the rate of legumes in the mixtures increases the digestibility in addition to the increase in the protein content; thus the quality of forage obtained from the mixtures increases [3,31]. The aforementioned differences between legumes and cereals have been reported by many researchers [11,13,32]. The ADF and NDF ratios of mixtures have been affected by the rates of legumes in mixtures due to the lower thin cell wall tissues of legumes compared to the cereals [31]. Therefore, lower ADF and NDF ratios were obtained due to the increase in Hungarian vetch rate in the mixed intercropping. The quality class, in terms of ADF, of forage obtained in the single cultivated Hungarian vetch are classified as prime, oat varieties and oat mixtures with Hungarian vetch was prime and premium class (Table 1). The quality class, in terms of NDF, of the single cultivated Hungarian vetch and the mixtures with high rates of Hungarian vetch was prime and premium quality (Table 1) [24]. The ADF ratio and DDM yield have negative correlations and the DDM ratio is calculated based on the ADF ratios. Therefore, the DDM ratio of Hungarian vetch and mixtures were higher due to the lower ADF ratios in the single Hungarian vetch and the mixtures of oat varieties with Hungarian vetch. Aşcı and Eğritaş [31] reported a low DDM ratio in single cultivated oat varieties, which had a high ADF ratio. The quality class of forage, in terms of DDM ratio, obtained in single Hungarian vetch cultivation was the prime grade, and the quality decreased as the rate of oats in mixtures increased (Table 1). The DDMY in mixtures with equal rates of oat and Hungarian vetch or higher oat rates was high depending on the dry matter yields. The TDN, an estimate of the energy value of forages, represents the digestible cellulose in forage [33]. The highest TDN, considered expressing the animal performance [34], was obtained in Hungarian vetch, while the TDN values obtained in all oat varieties were low. The legumes with higher TDN values are considered to be more intense forages than cereals [35]. Carr et al. [36] stated that the single legumes and mixtures with high legume rates had higher TDN values compared to single cereal and mixtures with high cereal rates. The NDF values are used to determine the dry matter intake. Negative correlation was reported between NDF and dry matter intake (DMI) ratios [20]. The DMI of a forage is high when the NDF ratio is low. Hungarian vetch with low NDF ratios had high and the oat varieties had low DMI ratios. The classification of forage quality according to Linn and Martin [37] was as follows; single Hungarian vetch was superior, single Hungarian vetch and equal rates in mixtures with cereals were high, and single oat varieties and mixtures with high oat varieties were good (Table 1). Van Soest et al. [18] stated that RFV is not a direct measure of the nutrient content of the forages, but it is important to estimate the quality. The RFV had a negative correlation with ADF and NDF ratios [37,38]. The forages with low RFV were obtained in the single oat varieties and the mixtures with high rate of oat varieties; in contrast, the forages with high RFV were obtained in single Hungarian vetch and the mixtures with high rates of Hungarian vetch. The classification of forages based on the relative feed value proposed by Lacefield [24] were as follows; single Hungarian vetch was the prime grade, single oat varieties were the second grade, mixtures with high legume rates were the first grade and mixtures with low legume rates were the second grade (Table 1). The DDM, TDN, DMI ratios and RFV in the first year of the experiment were higher compared to the second year, while the ADF and NDF ratios in the second year were higher than the first year (Table 3). Andrzejewska et al. [29] stated that the feeding value of winter oats was higher, and the cool and rainy autumn affected the oat yield. Regular precipitation in the March, April and May, when the growth of the cool season cereals was rapid, of the second year increased the oat ratio and caused an increase in ADF and NDF ratios

(Table 1).The warmer temperatures in the first year of the study increased the leaf/stem ratio of plants and caused an in the DDM, TDN, DMI ratios and RFV. Pinkerton and Cross [39] reported that the leaf/stem ratio is an important quality criterion for forage crops, and the increase in this ratio decreases the lignocellulosic structure in the feed and increases the feeding value.

5. Conclusion

The cultivation of legumes is preferred due to the forage quality, while cereals have yield advantages; therefore, legume + cereal mixtures in the mixed intercropping system is very important to meet the high-quality forages needed in rainfed condition. The results revealed that, the increase in the rate of oat, which is a cereal, in the mixtures increased the yield, while the increase in the rate of Hungarian vetch, which is a legume, in the mixture increased the quality of forages. Considering the yield and quality values in the mixtures. Among three current oat varieties Çekota, Saia and Seydişehir were not different from each other in terms of yield and quality properties in mixtures. In the mixtures, high yield was obtained with the mixture of 25% HV + 75% O and high quality was obtained with the mixture of 75% HV + 25% O.

The result concluded that 50% HV + 50% O mixture better utilizes the environmental resources; thus, this rate can be recommended to the growers due to the higher dry matter yield, crude protein yield, digestible dry matter yields and lower neutral detergent fiber, acid detergent fiber in the Kırşehir or in the similar ecological conditions.

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