

## Effect of Different Hungarian Vetch (*Vicia pannonica* Crantz) - Cereal Mixtures on Forage Yield and Nutritional Quality

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### ABSTRACT

This study was conducted under the ecological conditions of the Southeastern Anatolia Region of Turkey during the 2022-2023 and 2023-2024 growing seasons to assess the yield and nutritional quality of winter forage combinations. Hungarian vetch (*Vicia pannonica*) was grown alone and in combination with barley (*Hordeum vulgare* L.), oat (*Avena sativa* L.), and triticale ( $\times$ *Triticosecale* Wittmack) at three mixture ratios: 25% HV + 75% cereal, 50% HV + 50% cereal, and 75% HV + 25% cereal. Pure sowings of Aegean white (Hungarian vetch), Kendal (barley), Kazan (oat), and Esin (triticale) were also included. The forage was evaluated for fresh and dry yield, crude protein content and yield, acid detergent fiber (ADF), neutral detergent fiber (NDF), digestible dry matter (DDM), dry matter intake (DMI), relative feed value (RFV), and macroelement contents (Ca, P, K, Mg). Results indicated that pure oat and oat-rich mixtures produced the highest fresh and dry forage yields, along with the greatest crude protein yields. Mixtures with moderate to high proportions of Hungarian vetch enhanced fiber digestibility and overall forage quality. Overall, Hungarian vetch-oat mixtures provided the best balance between yield and nutritional value, demonstrating their potential as high-quality winter forage for livestock production.

**Keywords:** Hungarian vetch, cereal mixtures, forage yield, crude protein, fiber content, relative feed value.

### INTRODUCTION

Pasturelands constitute the primary and most economical source of roughage for livestock production. However, in many regions of the world, including Türkiye, pasture areas have experienced serious degradation due to overgrazing, uncontrolled grazing practices, and insufficient pasture management. As in other regions of the country, pasturelands in the Southeastern Anatolia Region have undergone a significant decline in both productivity and forage quality. This deterioration has resulted in a considerable reduction in the availability of high-quality roughage, creating a substantial forage deficit for the livestock sector. Ensuring a stable supply of high-quality forage is therefore essential for improving livestock productivity, sustaining animal health, and supporting the economic viability of animal production systems.

One of the most effective strategies to reduce or eliminate the roughage deficit is to expand forage crop cultivation, diversify

forage species, and introduce alternative forage production systems. Among these approaches, intercropping or mixed cultivation of legumes and cereals has gained increasing attention due to its agronomic, nutritional, and ecological advantages. Mixed cropping systems have the potential to improve forage yield and quality while enhancing resource-use efficiency in agricultural production systems.

Legume-cereal mixtures are reported to provide several advantages, including higher total dry matter yield, improved crude protein and carbohydrate balance, reduced dependence on nitrogen fertilizers, and enhanced soil fertility through biological nitrogen fixation. Additionally, mixed cropping systems can reduce the incidence of weeds, diseases, and pests while improving the utilization of environmental resources such as water, light, and nutrients (Ross et al., 2004; Tuna and Orak, 2007; Lithourgidis et al., 2011). In this context, Petcu et al. (2022) further emphasized that cover crop systems based on wheat, triticale, and pea,

both in pure stands and mixtures, provide significant benefits in terms of weed suppression and soil improvement, highlighting the broader agroecological value of mixed cropping systems beyond forage production alone. Such systems also contribute to sustainable agriculture by improving soil structure and increasing organic matter content in the soil.

The forage obtained from legume-cereal mixtures is generally considered to be superior in nutritional value due to the complementary characteristics of the component species. Legumes are typically rich in protein, while cereals contribute higher carbohydrate content and structural biomass, thereby producing a more balanced and nutritionally superior forage. Reynolds et al. (1994) reported that legumes can increase the total biomass of mixtures and consequently improve yield in legume-cereal systems. Similarly, Albayrak and Ekiz (2000) stated that when species forming the mixtures are appropriately selected, mixed cropping systems can produce higher yields than pure stands. Miller (1984) also emphasized that mixtures often provide both higher yield and improved forage quality compared to monoculture cultivation.

Hungarian vetch (*Vicia pannonica* Crantz) is an important winter forage legume widely cultivated in semi-arid and temperate regions due to its good cold tolerance, high forage quality, and adaptability to diverse environmental conditions. However, Hungarian vetch is prone to lodging during later growth stages, which may reduce harvest efficiency and forage quality. For this reason, it is commonly recommended to cultivate Hungarian vetch in mixtures with cereals such as barley, oat, wheat, or triticale, which provide structural support and improve stand stability (Taş, 2002). Cereal components in such mixtures also contribute to higher biomass production and facilitate mechanical harvesting.

Previous studies have demonstrated that mixed cropping systems frequently outperform pure stands in terms of forage

yield and quality. For instance, Rakeih et al. (2010) and Ghanbari-Banjar and Lee (2003) reported that legume-cereal mixtures produced higher yields than pure legume stands. Similarly, Turan et al. (2020) indicated that appropriate mixture ratios can significantly enhance both forage productivity and nutritional value. Despite these advantages, determining the optimal mixture ratio remains a key factor influencing the success of legume-cereal intercropping systems.

Therefore, this study was conducted to determine the most suitable mixture ratios for maximizing forage yield and forage quality by cultivating Hungarian vetch in combination with selected cereal crops (barley, oat, and triticale) at different proportions under the ecological conditions of the Southeastern Anatolia Region.

## MATERIAL AND METHODS

### Location and Duration of the Study

The study was conducted during the 2022-2023 and 2023-2024 growing seasons at the Research and Application Field of the Faculty of Agriculture, Siirt University, Türkiye. The experimental site represents a rainfed production environment typical of the region.

### Climatic Conditions

Climatic data were obtained from the Siirt Meteorology Directorate. The long-term average temperature, precipitation, and relative humidity of the region were 12.63°C, 568.95 mm, and 56.10%, respectively. During the experimental years, mean temperatures were close to the long-term averages, whereas precipitation and relative humidity were slightly higher. The highest rainfall occurred in January, while the lowest temperatures were recorded in January and February. Due to adequate rainfall during the growing seasons, no irrigation was applied. The climate Characteristics of research area are presented in Table 1.

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Table 1. Temperature, precipitation and relative humidity values of the research area \*

Months	Temperature (°C)			Precipitation (mm)			Relative humidity (%)		
	LYA**	2022-23	2023-24	LYA**	2022-23	2023-24	LYA**	2022-23	2023-24
November	11.37	11.8	12.6	63.13	64.0	55.8	62.00	64.4	50.2
December	5.80	8.0	7.2	74.92	60.4	70.6	72.61	71.1	75.0
January	4.04	5.8	5.3	92.98	180.6	186.4	69.84	64.5	72.7
February	6.23	4.9	7.2	70.08	70.6	57.4	64.14	61.1	73.0
March	9.95	12.4	9.1	129.40	61.4	106.0	61.94	58.9	63.1
April	15.64	14.5	19.3	77.23	88.2	36.4	52.41	57.6	60.2
May	20.44	20.0	19.7	56.63	57.2	55.6	46.25	43.9	47.1
June	27.58	27.2	28.8	4.58	0.0	5.2	27.58	29.0	26.6
Total/Average	12.63	13.08	12.78	568.95	582.40	573.40	56.10	56.31	58.49

\*: Meteorology Directorate, Siirt, \*\*: LYA: Long years' average (2013-2024).

### Soil Characteristics

Before establishing the experiment, soil samples were collected from a 0-20 cm depth and analyzed at the Siirt University Science and Technology Application and Research Center Laboratory.

The soil had a pH of 7.95, electrical conductivity (EC) of 107  $\mu\text{S cm}^{-1}$ , 10.5%  $\text{CaCO}_3$ , and 1.35% organic matter. Available

phosphorus and potassium levels were 23  $\text{kg ha}^{-1}$  ( $\text{P}_2\text{O}_5$ ) and 652 ppm ( $\text{K}_2\text{O}$ ), respectively. Soil texture consisted of 14% sand, 58% clay, and 28% silt, indicating a clayey soil structure. Overall, the soil was classified as slightly alkaline, non-saline, moderately calcareous, with low organic matter and phosphorus but high potassium content.

Table 2. Some physical and chemical properties of the soil at the research site (0-20 cm)\*

pH	EC ( $\mu\text{S/cm}$ )	Lime ( $\text{CaCO}_3$ ) (%)	Organic Matter (%)	P ( $\text{P}_2\text{O}_5$ ) ( $\text{kg ha}^{-1}$ )	K ( $\text{K}_2\text{O}$ ) (ppm)	Soil texture (%)		
						Sand	Clay	Silt
7.95	107.0	10.5	1.35	23.0	652	14.0	58.0	28.0

\*The analyses were conducted at the Siirt University, Science and Technology Application and Research Center Laboratory.

### Experimental Treatments and Design

The experiment was arranged according to a Randomized Complete Block Design (RCBD) with three replications. A total of 13 treatments consisting of pure stands and different mixture ratios of Hungarian vetch with cereals were evaluated: i) Barley (B) - 100%, ii) Hungarian vetch (HV) - 100%, iii) Triticale (T) - 100%, iv) Oat (O) - 100%, v) HV 25% + B 75%, vi) HV 25% + T 75%, vii) HV 25% + O 75%, viii) HV 50% + B 50%, ix) HV 50% + T 50%, x) HV 50% + O 50%, xi) HV 75% + B 25%, xii) HV 75% + T 25% and xiii) HV 75% + O 25%. These treatments were designed to evaluate the forage yield and quality performance of

Hungarian vetch when grown alone or in mixtures with cereals at different proportions.

### Collection of plant materials

The plant materials used in the experiment included Aegean White Hungarian vetch (*Vicia pannonica* Crantz) obtained from the Aegean Agricultural Research Institute, Kazan oat (*Avena sativa* L.) from the Bahri Dagdas International Agricultural Research Institute, and Esin triticale ( $\times$ *Triticosecale* Wittmack) and Kendal barley (*Hordeum vulgare* L.) from the GAP International Agricultural Research and Training Center. These cultivars are known for their tolerance to cold and drought conditions and are widely

recommended for several agroecological regions of Türkiye.

### Experimentation

Sowing was performed as winter sowing in both experimental years. Hungarian vetch was sown at a rate of 120 kg ha<sup>-1</sup>, while cereal species were sown at 200 kg ha<sup>-1</sup>. Based on the results of soil analysis, 150 kg ha<sup>-1</sup> diammonium phosphate (DAP) fertilizer was applied at sowing, providing 27 kg ha<sup>-1</sup> nitrogen (N) and 69 kg ha<sup>-1</sup> phosphorus (P). Weeds emerging during the germination and vegetative growth stages were removed manually to avoid competition with the experimental crops.

Harvesting was carried out when a few pods had formed on the lower parts of the Hungarian vetch plants, while the cereal crops had reached the heading stage. To minimize border effects, one row from each side of the plots and 0.5 m from both ends of the plots were discarded. The remaining area was harvested for yield measurements. Harvesting was conducted during the first week of June in both years.

### Data Collection

For the determination of plant height, 10 plants from legumes and cereals were randomly selected from each plot and their heights were measured, and the average values were calculated.

The harvested forage from each plot was weighed to determine fresh forage yield,

which was then converted to fresh forage yield per hectare.

From each plot, a 500 g representative sample was taken according to the mixture composition. These samples were first air-dried and then oven-dried at 78°C for 24 hours (Uzun, 2010). Dry matter yield per hectare was calculated based on the dry weight of the samples.

The dried samples were ground and analyzed using a Near Infrared Reflectance Spectroscopy (NIRS) device with the #IC-0904FE calibration set to determine:

- Crude protein (CP)
- Acid detergent fiber (ADF)
- Neutral detergent fiber (NDF)

Crude protein yield (CPY) was calculated by multiplying crude protein content (%) with dry matter yield. Digestible dry matter (DDM), dry matter intake (DMI), and relative feed value (RFV) were calculated using the following equations (Van Dyke and Anderson, 2000):

Digestible Dry Matter

$$\text{DDM} = 88.9 - (0.779 \times \% \text{ADF})$$

Dry Matter Intake

$$\text{DMI} = 120 / \% \text{NDF}$$

Relative Feed Value

$$\text{RFV} = (\text{DDM} \times \text{DMI}) / 1.29$$

The forage quality parameters obtained in this study were evaluated according to the quality standards proposed by Rohweder et al. (1978), which classify forage based on CP, ADF, NDF, DDM, DMI, and RFV values (Table 3).

Table 3. Quality standards for legumes, cereals and legume-cereal mixtures (Rohweder et al., 1978)

Kalite Stand.	CP	ADF	NDF	DDM %	DMI % of BW	RFV
	% of DM					
Prime	>19	<<31	<<40	>65	>3.0	>151
1	17-19	31-35	40-46	62-65	3.0-2.6	151-25
2	14-16	36-40	47-53	58-61	2.5-2.3	124-03
3	11-13	41-42	54-60	56-57	2.2-2.0	102- 7
4	8-10	43-45	61-65	53-55	1.9-1.8	86-75
5	<<8	>45	>65	<<53	<<1.8	<<75

### Statistical Analysis

All obtained data were subjected to analysis of variance (ANOVA) using the JUMP statistical software at 5% and 1% significance levels (SAS, 1998). When

significant differences among treatments were detected, mean comparisons were performed using the LSD multiple comparison test (Gulumser et al., 2017).

## RESULTS AND DISCUSSION

### Fresh Herbage Yield and Hay Yield

Significant differences at the  $P < 0.01$  level was observed between years and varieties in terms of fresh forage and dry matter yields (Table 4). These differences are likely due to the varieties' responses to ecological conditions, particularly precipitation, which was lower in the first year compared to the second year, affecting the overall performance.

Among the tested varieties, the highest average fresh forage yield ( $37283.30 \text{ kg ha}^{-1}$ ) was obtained from pure oat (Kazan), while

the lowest ( $23008.30 \text{ kg ha}^{-1}$ ) was recorded in the 75% Hungarian vetch + 25% triticale mixture. The two-year average fresh forage yields were  $29268.90 \text{ kg ha}^{-1}$  and  $28538.60 \text{ kg ha}^{-1}$  for 2023 and 2024, respectively, with no statistically significant difference between the years. The slightly higher yield in the first year may be due to lower precipitation and higher temperatures, which increased the dry matter content of the forage. Similar observations regarding rainfall effects on legume forage yield have been reported by Acikgoz and Cakmakci (1986), Karadag and Buyukburc (2004), and Sayar and Han (2014).

Table 4. Average values of fresh and dry forage yields ( $\text{kg ha}^{-1}$ ) of the mixtures and the resulting groups

Genotypes	Fresh herbage yield						Hay yield					
	First year (2023)		Second year (2024)		Mean		First year (2023)		Second year (2024)		Mean	
Barley %100	30288.90	b-d	22333.3	fg	26311.10	d-f	9363.60	ab	7331.20	c-e	8347.40	bc
HV %25 + B %75	33677.80	ab	21500.00	g	27588.90	de	7837.80	cd	5139.50	g	6488.60	e
HV %25 + T %75	21066.70	e	30500.00	c	25783.30	ef	5682.20	f-h	7667.90	c	6675.10	e
HV %25 + O %75	19622.20	e	48000.00	a	33811.10	b	4525.30	h	11120.00	a	7822.60	cd
HV %50 + B %50	28155.60	d	24666.70	e	26411.10	d-f	6275.10	ef	6277.40	f	6276.30	ef
HV %50 + T %50	26766.70	d	21888.90	fg	24327.80	fg	5031.30	gh	5450.30	g	5240.80	gh
HV %50 + O %50	22712.20	e	31500.00	c	27106.10	de	5508.80	f-h	7454.10	cd	6481.50	e
HV %75 + B %25	32183.30	bc	13833.30	h	23008.30	g	6720.90	d-f	3047.00	h	4883.90	h
HV %75 + T %25	36623.30	a	30556.70	c	33590.00	b	8147.20	bc	6936.60	de	7541.90	d
HV %75 + O %25	33166.70	a-c	27833.30	d	30500.00	c	10547.60	a	6867.60	e	8707.60	ab
Hung. vetch %100	32611.10	bc	23777.80	ef	28194.40	d	6100.50	fg	5234.60	g	5667.50	fg
Triticale %100	33888.90	ab	29777.80	cd	31833.30	bc	9608.90	a	8407.50	b	9008.20	ab
Oats %100	29733.30	cd	44833.30	b	37283.30	a	7375.90	c-e	10795.30	a	9085.60	a
Mean	29268.90		28538.60		28903.80		7132.70		7056.10		7094.40	
LSD	381.80**		217.04**		226.98**		121.48**		55.11**		69.76**	
CV	7.76		4.52		6.74		10.13		4.64		8.46	

The difference between the averages indicated by the same letter in the same group is not statistically significant.

\*\* : Significant difference at  $P < 0.01$  level, CV: Variation coefficient, LSD: Least Significant Difference.

In terms of dry matter yield, the highest values in the first year were observed in the 75% Hungarian vetch + 25% oat mixture ( $10547.60 \text{ kg ha}^{-1}$ ), pure triticale ( $9608.90 \text{ kg ha}^{-1}$ ), and pure barley ( $9363.60 \text{ kg ha}^{-1}$ ), which were not statistically different. In the second year, the highest dry matter yields were  $11120.00 \text{ kg ha}^{-1}$  and  $10795.30 \text{ kg ha}^{-1}$  in the 25% Hungarian vetch + 75% oat mixture and pure oat, respectively. Previous

studies support these findings. Lithourgidis et al. (2006) reported the highest fresh forage yield in pure oat and triticale, while Strydhorst et al. (2008) observed the highest yield in pure barley in barley-legume mixtures. Lithourgidis and Dardas (2010) found the highest yield in pure rye. Basbag et al. (1999) recommended a 50:50 legume-cereal mixture, whereas Kokten et al. (2003) suggested 25% vetch + 75% triticale for

optimal yields. Gummadov and Acar (2007) reported the highest fresh forage yield (43730 kg ha<sup>-1</sup>) in Hungarian vetch + barley mixtures, and the lowest (33333.30 kg ha<sup>-1</sup>) in Hungarian vetch + triticale. Yıldırım and Parlak (2016) found an average green forage yield of 19256.00 kg ha<sup>-1</sup> and dry matter yield of 3187.80 kg ha<sup>-1</sup> for triticale, faba bean, pea, and Hungarian vetch grown pure or in mixtures with triticale.

The variations between the yields obtained in this study and those reported in the literature are likely due to differences in ecological conditions, including soil type, climate, sowing time, and genotypic characteristics.

#### Acid detergent fiber (ADF) rates and Neutral detergent fiber (NDF) rates

The study evaluated the ADF and NDF content of different mixture ratios of Hungarian vetch (HV) with barley, triticale, and oats. Analysis of variance revealed

statistically significant differences ( $P < 0.01$ ) in both ADF and NDF values across years and genotypes (Table 5).

The average ADF content was higher in the first year (37.82%) compared to the second year (32.31%), with overall mean ADF across both years being 35.06%. Across genotypes and mixtures, ADF ranged from 31.98% (HV 50% + B 50%) to 39.26% (Triticale 100%). According to the quality standards for legumes, cereals, and their mixtures (Rohweder et al., 1978), genotypes such as pure barley, pure triticale, and HV 25% + B 75% belong to the **second quality class** (36-40%), while the other mixtures fall within the **first quality class** (31-35%).

The differences observed between ADF and NDF values can be attributed to several factors, including the species composition of the mixtures, cutting stages, mixture ratios, and ecological conditions affecting forage growth and fiber accumulation.

Table 5. Average values of my mixtures for ADF and NDF rates and the resulting groups (%)

Genotypes	ADF						NDF					
	First year (2023)		Second year (2024)		Mean		First year (2023)		Second year (2024)		Mean	
Barley % 100	40.01	b	35.30	a	37.65	b	69.29	a	66.35	67.82	a	
HV %25 + B %75	39.22	bc	32.92	bc	36.07	c	65.21	ab	51.12	58.16	cd	
HV %25 + T %75	37.01	d-f	32.56	c	34.79	c-e	64.61	ab	65.56	65.09	ab	
HV %25 + O %75	38.70	b-d	31.34	c-e	35.02	cd	44.74	e	51.80	48.27	f	
HV %50 + B %50	34.43	h	29.53	e	31.98	f	62.78	b	54.90	58.84	b-d	
HV %50 + T %50	36.95	d-g	31.24	c-e	34.09	de	47.83	de	57.95	52.89	d-f	
HV %50 + O %50	38.65	b-d	29.91	de	34.28	de	49.29	c-e	50.53	49.91	ef	
HV %75 + B %25	37.95	c-e	32.85	bc	35.40	cd	66.62	ab	60.10	63.36	a-c	
HV %75 + T %25	36.48	e-g	31.38	c-e	33.93	de	45.93	e	65.06	55.50	de	
HV %75 + O %25	40.13	ab	29.57	e	34.85	c-e	55.38	c	58.68	57.03	cd	
Hung. vetch % 100	34.96	gh	32.00	cd	33.48	e	53.23	cd	52.94	53.09	d-f	
Triticale % 100	42.12	a	36.40	a	39.26	a	69.41	a	67.51	68.46	a	
Oats % 100	35.05	f-h	35.05	ab	35.05	cd	52.98	cd	52.98	52.98	d-f	
Mean	37.82 A		32.31 B		35.06		57.48		58.11		57.80	
LSD	2.02**		2.36**		1.48**		6.46**		-		6.84**	
CV	3.17		4.35		3.65		6.68		12.90		10.26	

The difference between the averages indicated by the same letter in the same group is not statistically significant.

\*\* : Significant difference at  $P < 0.01$  level, CV: Variation coefficient, LSD: Least Significant Difference.

### Digestibility Dry Matter (DDM) rates and Dry Matter Intake (DMI) rates

The two-year average DDM of the pure and mixed forage ratios was 61.58%. The highest average DDM was observed in the HV 50% + Barley 50% mixture (63.99%), while the lowest was recorded in pure triticale (58.32%). According to the quality classification of Rohweder et al. (1978), the DDM values of the pure and mixed forages fall within the 1st and 2nd quality classes (Table 6).

The average dry matter intake (DMI) across all mixtures was 2.11%. The highest

DMI values, statistically grouped together, were obtained in HV 25% + Oat 75%, HV 50% + Triticale 50%, HV 50% + Oat 50%, HV 75% + Triticale 25%, Hungarian vetch 100%, and Oat 100%. According to Rohweder et al. (1978), these DMI values correspond to the 2nd quality class, while the other pure and mixed forages fell into the 4<sup>th</sup> and 5<sup>th</sup> quality classes (3.3). Overall, mixtures containing moderate to high proportions of Hungarian vetch and oat demonstrated superior digestibility and intake, indicating their potential to provide high-quality forage for livestock.

Table 6. Average values of DDM and DMI rates of mixtures and resulting groups (%)

Genotype	DDM						DMI					
	First year (2023)		Second year (2024)		Mean		First year (2023)		Second year (2024)		Mean	
Barley % 100	57.73	g	61.40	e	59.57	e	1.73	f	1.21	1.47	g	
HV %25 + B %75	58.35	fg	63.26	cd	60.80	d	1.84	f	2.35	2.09	b-f	
HV %25 + T %75	60.07	c-e	63.54	c	61.80	b-d	1.88	f	1.83	1.86	ef	
HV %25 + O %75	58.75	e-g	64.49	a-c	61.62	cd	2.69	a	2.33	2.51	a	
HV %50 + B %50	62.08	a	65.90	a	63.99	a	1.91	f	2.20	2.06	c-f	
HV %50 + T %50	60.12	b-e	64.57	a-c	62.34	bc	2.51	a-c	2.21	2.36	a-c	
HV %50 + O %50	58.79	e-g	65.60	ab	62.20	bc	2.44	b-d	2.43	2.43	ab	
HV %75 + B %25	59.34	d-f	63.31	cd	61.32	cd	1.81	f	2.03	1.92	d-f	
HV %75 + T %25	60.48	b-d	64.45	a-c	62.47	bc	2.61	ab	1.84	2.23	a-d	
HV %75 + O %25	57.64	gh	65.86	a	61.75	b-d	2.17	e	2.07	2.12	b-e	
Hung. vetch %100	61.66	ab	63.98	bc	62.82	b	2.26	de	2.3	2.28	a-d	
Triticale %100	56.09	h	60.55	e	58.32	f	1.73	f	1.78	1.75	fg	
Oats %100	61.60	a-c	61.60	de	61.60	cd	2.31	c-e	2.31	2.31	a-c	
Mean	59.44	B	63.73	A	61.58		2.14		2.07	2.11		
LSD	1.57**		1.83**		1.16**		0.24**		-		0.36**	
CV	1.56		1.71		1.61		6.54		10.28		14.69	

The difference between the averages indicated by the same letter in the same group is not statistically significant.

\*\* : Significant difference at P<0.01 level, CV: Variation coefficient, LSD: Least Significant Difference, Ca: Calcium, P: Phosphor, Mg: Magnesium, K: Potassium, CP: Crude protein.

### Crude Protein Yield (CPY) and Relative Feed Value (RFV)

The average CPY of the studied mixtures was 1077.90 kg ha<sup>-1</sup>. The highest CPY was obtained in pure oat (Oat 100%; 1501.70 kg ha<sup>-1</sup>) and the HV 25% + O 75% mixture (1425.50 kg ha<sup>-1</sup>), which were statistically grouped together. In contrast, the lowest CPY was observed in the HV 75% + B 25% mixture (625.30 kg ha<sup>-1</sup>).

Comparisons with previous studies (Acikgoz and Cakmakci, 1986; Aydin and Tosun, 1991; İptas and Yilmaz, 1998, 1999; Kokten et al., 2003; Gulumser et al., 2006; Gummadov and Acar, 2007; Aksoy and Nursoy, 2010; Taş, 2010; Asci et al., 2015; Gumustas and Turan, 2022) indicate that the CPY values obtained in this study are generally consistent, though some variations exist. These differences may be

attributed to the plant species used, harvesting periods, mixture ratios, and ecological conditions.

The average relative feed value (RFV) of the mixtures was 100.72. Examination of the two-year averages revealed that RFV did not differ significantly among most mixtures, except for Barley 100%, HV 25% + B 75%, HV 25% + T 75%, HV 75% + B 25%, and Triticale 100%. According to the quality classification by Rohweder et al. (1978), the

roughages evaluated in this study fall within **quality classes 2 and 5**, reflecting moderate to lower feed value depending on species composition and mixture ratios.

In summary, both CPY and RFV values highlight the positive contribution of oat-based mixtures and lower proportions of barley-heavy mixtures to forage quality, which is influenced by species composition, mixture ratios, and environmental factors.

Table 7. Average values of crude protein yield and relative feed value of mixtures and the resulting groups

Genotypes	CPY (Crude protein yield, kg ha <sup>-1</sup> )						RFV (Relative feed value)					
	First year (2023)		Second year (2024)		Mean		First year (2023)		Second year (2024)		Mean	
Barley % 100	988.60	a-c	1191.70	de	1090.10	c-e	77.51	fg	57.76	67.64	e	
HV % 25 + B % 75	1114.80	ab	994.50	e	1054.60	d-f	83.24	e-g	115.18	99.21	bc	
HV % 25 + T % 75	749.00	cd	1168.80	de	958.90	d-f	87.66	d-f	90.28	88.97	cd	
HV % 25 + O % 75	689.60	d	2161.40	a	1425.50	ab	122.51	a	116.30	119.40	a	
HV % 50 + B % 50	912.50	b-d	1235.80	de	1074.20	c-e	92.07	de	112.42	102.25	a-c	
HV % 50 + T % 50	700.50	d	1013.10	de	856.80	f	117.07	ab	111.42	114.24	ab	
HV % 50 + O % 50	709.90	d	1624.60	bc	1167.30	cd	111.01	ab	123.40	117.21	ab	
HV % 75 + B % 25	774.80	cd	475.80	f	625.30	g	83.19	e-g	99.83	91.51	cd	
HV % 75 + T % 25	844.40	cd	1059.20	de	951.80	ef	122.51	a	92.15	107.33	a-c	
HV % 75 + O % 25	1193.90	a	1335.80	d	1264.80	bc	96.86	cd	105.75	101.30	a-c	
Hung. vetch % 100	1150.00	ab	975.30	e	1062.70	c-f	107.81	bc	114.03	110.92	ab	
Triticale % 100	897.90	b-d	1060.10	de	979.00	d-f	75.16	g	83.46	79.31	de	
Oat % 100	1212.70	a	1790.70	b	1501.70	a	110.06	b	110.06	110.06	ab	
Mean	918.30	B	1237.40	A	1077.9		98.97		102.46	100.72		
LSD	25.82		33.04		20.86		12.36		-		18.42	
CV	16.71		15.88		16.75		7.43		10.99		15.84	

The difference between the averages indicated by the same letter in the same group is not statistically significant.

\*\* : Significant difference at P<0.01 level, CV: Variation coefficient, LSD: Least Significant Difference, Ca: Calcium, P: Phosphor, Mg: Magnesium, K: Potassium, CP: Crude protein.

### Phosphor (P) and crude protein (CP) rates

Variance analysis showed that the differences P and CP contents of the roughage were statistically significant (P < 0.01). As presented in Table 8, crude protein content ranged from 10.98% to 18.85%, with an overall average of 15.54%.

The highest average CP was obtained from pure Hungarian vetch (18.85%) and several mixtures including HV 25% + O 75%, HV 25% + B 75%, HV 50% + O 50%, and HV 50% + B 50%, which did not differ statistically among themselves. In contrast,

the lowest CP content was observed in pure triticale (10.98%). According to the quality classification of Rohweder et al. (1978), the CP content of these forages falls between the 1<sup>st</sup> and 3<sup>rd</sup> quality classes.

These findings align with previous studies of Gummadov and Acar (2007), who reported the highest CP in a Hungarian vetch + barley mixture (11.86%) and the lowest in a hairy vetch + triticale mixture (9.2%) in Konya during the 2003-2004 production season. Similarly, Yildirim and Parlak (2016) determined an average CP content of 16.33% for Triticale, faba bean, pea, and Hungarian

vetch, alone and in three different mixture ratios with triticale. Compared with these studies, the CP content observed in this research is generally similar, higher than some, and lower than others, with differences likely attributable to harvest periods and plant species used.

The average P content of the roughage, across both pure and mixed feeds, was

0.34%, with no statistically significant differences between genotypes. According to Kidambi et al. (1989), feed for regular and rational animal nutrition should contain at least 0.21% P. Therefore, the phosphorus content in the tested roughages exceeds this requirement, indicating no nutritional deficiencies with respect to phosphorus for large ruminants.

Table 8. Average values of crude protein content and phosphorus content of the mixtures and the resulting groups (%)

Genotype	P			Protein Rate						
	First year (2023)		Second year (2024)	Mean	First year (2023)		Second year (2024)		Mean	
Barley % 100	0.31	b-d	0.37	0.34	10.58	fg	18.38	ab	14.48	cd
HV % 25 + B % 75	0.33	a-c	0.39	0.36	14.25	b-d	19.33	ab	16.79	a-c
HV % 25 + T % 75	0.33	a-c	0.37	0.35	14.15	b-e	15.24	bc	14.69	b-d
HV % 25 + O % 75	0.37	a	0.38	0.37	15.14	bc	19.46	ab	17.30	ab
HV % 50 + B % 50	0.30	cd	0.36	0.33	12.86	c-f	19.70	ab	16.28	a-d
HV % 50 + T % 50	0.30	cd	0.38	0.34	11.70	e-g	18.57	ab	15.14	b-d
HV % 50 + O % 50	0.31	b-d	0.37	0.34	11.48	fg	21.67	a	16.58	a-d
HV % 75 + B % 25	0.32	b-d	0.34	0.33	12.57	d-f	15.61	bc	14.09	d
HV % 75 + T % 25	0.28	d	0.40	0.34	11.39	fg	17.07	a-c	14.23	cd
HV % 75 + O % 25	0.33	a-c	0.38	0.36	12.68	c-f	19.37	ab	16.02	b-d
Hung. vetch % 100	0.31	b-d	0.35	0.33	18.94	a	18.76	ab	18.85	a
Triticale % 100	0.30	b-d	0.35	0.33	9.35	g	12.61	c	10.98	e
Oat % 100	0.34	ab	0.34	0.34	16.60	ab	16.60	bc	16.60	a-d
Mean	0.32		0.37	0.34	13.21	B	17.88	A	15.54	
LSD	0.04**		-	-	2.45**		4.78**		2.64**	
CV	7.81		5.41	7.05	11.05		15.89		14.74	

The difference between the averages indicated by the same letter in the same group is not statistically significant.

\*\* : Significant difference at  $P < 0.01$  level, CV: Variation coefficient, LSD: Least Significant Difference, Ca: Calcium, P: Phosphor, Mg: Magnesium, K: Potassium, CP: Crude protein.

### Calcium (Ca), Potassium (K) and Magnesium (Mg) rates

Variance analysis revealed that the differences in Ca, K, and Mg contents of roughage obtained from different mixture ratios of Hungarian vetch, barley, and triticale were statistically significant ( $P < 0.01$ ) in the first year. In the second year, however, the differences in magnesium content were not statistically significant (Table 9).

The average Ca, K, and Mg levels across all mixtures were 0.59%, 4.21%, and 0.14%, respectively. The highest Ca and K contents were recorded in pure oat (Oat 100%), pure

Hungarian vetch (Hungarian vetch 100%), and in mixtures HV 25% + O 75% and HV 25% + B 75%, which were statistically grouped together. Magnesium levels showed less variation, and no significant difference was observed in the second-year samples.

Mineral nutrients play crucial roles in both forage plants and animal nutrition and can vary depending on plant species, genotype, and whether the plants are grown in pure stands or mixtures (Ozyazici and Acikbas, 2019). According to Kidambi et al. (1989), feed for regular and rational animal nutrition should contain at least 0.31% Ca, 0.65% K, and 0.1% Mg. Based on these requirements,

the roughage evaluated in this study meets or exceeds the necessary levels of Ca (0.59%), K (4.21%), and Mg (0.14%), indicating that there is no nutritional limitation regarding these minerals for cattle. The observed differences between the mineral contents in

this study and literature values may be attributed to variations in ecological conditions, including soil type and climate, sowing time, and the genotypic characteristics of the forage species used.

Table 9. Average values of Ca, K, and Mg rates in the mixtures and the resulting groups (%)

Genotypes	Ca						K						Mg				
	First year (2023)		Second year (2024)		Mean		First year (2023)		Second year (2024)		Mean		First year (2023)	Second year (2024)	Mean		
Barley % 100	0.14	e	0.56	a-d	0.35	fg	3.12	f	4.28	b-d	3.7	f	0.07	f-h	0.15	0.11	d
HV %25 + B %75	0.57	bc	0.91	a	0.74	a-d	4.47	a-c	5.01	a	4.74	a	0.14	b-d	0.18	0.16	a-c
HV %25 + T %75	0.54	bc	0.39	cd	0.46	e-g	4.23	bc	4.03	d	4.13	de	0.11	c-e	0.12	0.12	cd
HV %25 + O %75	0.74	ab	0.86	ab	0.80	a-c	4.76	a	4.94	ab	4.85	a	0.15	a-c	0.18	0.17	ab
HV %50 + B %50	0.38	cd	0.71	a-d	0.55	d-g	3.53	ef	4.52	a-d	4.03	d-f	0.13	b-e	0.20	0.17	ab
HV %50 + T %50	0.36	c-e	0.64	a-d	0.50	d-g	3.57	d-f	4.42	a-d	4.00	d-f	0.06	gh	0.22	0.14	b-d
HV %50 + O %50	0.45	cd	0.89	ab	0.67	b-e	3.69	de	4.82	a-c	4.25	b-d	0.09	e-g	0.23	0.16	a-c
HV %75 + B %25	0.39	cd	0.57	a-d	0.48	e-g	4.07	cd	4.09	d	4.08	d-f	0.11	d-f	0.18	0.14	b-d
HV %75 + T %25	0.41	cd	0.44	b-d	0.43	e-g	4.06	cd	4.30	b-d	4.18	c-e	0.09	e-g	0.18	0.13	b-d
HV %75 + O %25	0.45	cd	0.69	a-d	0.57	c-f	3.11	f	4.25	cd	3.68	f	0.13	b-e	0.19	0.16	a-c
Hung.vetch % 100	0.89	a	0.82	a-c	0.86	ab	4.83	a	4.33	a-d	4.58	a-c	0.19	a	0.21	0.20	a
Triticale % 100	0.26	de	0.35	d	0.31	g	3.60	d-f	4.05	d	3.82	ef	0.04	h	0.09	0.06	e
Oat % 100	0.95	a	0.95	a	0.95	a	4.67	ab	4.67	a-d	4.67	ab	0.17	ab	0.17	0.17	ab
Mean	0.50	B	0.68	A	0.59		3.98	B	4.44	A	4.21		0.11	B	0.18	A	0.14
LSD	0.24**		0.45**		0.25**		0.53**		0.68**		0.42**		0.04**		Ö.D		0.04**
CV	8.01		9.03		11.29		7.79		9.00		8.55		12.72		15.55		15.00

The difference between the averages indicated by the same letter in the same group is not statistically significant.

\*\* : Significant difference at  $P < 0.01$  level, CV: Variation coefficient, LSD: Least Significant Difference, Ca: Calcium, P: Phosphor, Mg: Magnesium, K: Potassium, CP: Crude protein.

## CONCLUSIONS

This study assessed the quality and chemical composition of roughage produced from different mixtures of Hungarian vetch (Aegean white) with cereals - barley, oat, and triticale - at varying ratios. In terms of green and dry forage yield, pure oat produced the highest amounts, while the mixture of HV 50% + Oat 50% exhibited the most favorable ADF and digestible dry matter (DDM) values. For fiber content, the HV 25% + Oat 75% mixture showed the best performance in terms of NDF and NDF digestibility. Crude protein yield was highest in both pure oat and the HV 25% + Oat 75% mixture. Overall, incorporating moderate to high proportions of oat with Hungarian vetch resulted in

roughage with superior nutritional quality, highlighting the value of oat-vetch mixtures for producing high-quality forage.

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