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COMPARING THE NUTRITIVE VALUE OF DRY HERBAGE AND SILAGE FROM FORAGE PEA (*PISUM SATIVUM* SSP. *ARVENSE* (L.) POIR.) AND TRITICALE (*X TRITICOSECALE* WITTM.) MIXTURES

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Abstract

Legume and cereal mixtures can combine high yield with good nutritional value. However, the mixing ratio and the method of preservation are critical factors that determine the quality of the feed provided to ruminants. This study evaluated the value of herbage and silage obtained from pure stands and mixtures -at ratios of 75:25, 50:50, and 25:75- of forage pea (*Pisum sativum* ssp. *arvense* (L.) Poir.; Taşkent and Zerre cultivars) and triticale (*x Triticosecale* Wittm.) under rainfed Mediterranean climatic conditions in Kahramanmaraş. The experiment was conducted during the 2022–2023 growing season using a randomized complete block design with nine treatments and three replications. Harvesting took place when the triticale reached the early dough stage. A portion of the harvested forage was dried, while another portion was ensiled in vacuum-sealed bags for 60 days. The mixing ratio significantly affected most of the examined parameters. Herbage yield ranged from 650.7 to 1437.7 kg da^{-1}, with the highest values obtained from the mixture of 25% forage pea (Zerre) + 75% triticale and from pure triticale; however, these treatments also yielded the lowest crude protein concentrations (11.90% and 10.07%, respectively). The inclusion of forage peas increased crude protein content (up to 26.03% in herbage and 20.47% in silage) and relative feed value (up to 161.63 and 170.42, respectively), while decreasing NDF and ADF concentrations. The pH values of the silage ranged from 4.12 to 4.64 and were not affected by the mixing ratios. While the mean relative feed value was similar for both herbage (144.17) and silage (144.24), the crude protein content in the silage was numerically lower (17.56% for herbage vs. 15.47% for silage).

Key words: Legume and cereal mixture; Seeding ratio; Crude protein; Relative feed value; Neutral detergent fiber; Forage preservation

Introduction

In regions dominated by a Mediterranean climate, forage production is largely dependent on winter precipitation; consequently, a shortage of high-quality forage occurs for a significant portion of the year due to summer drought. This situation increases the need for winter-grown forage cropping systems that offer both high yield and good nutritional value. Legume-cereal mixtures are widely used for this purpose, as they combine the high biomass production of cereals with the high protein content of legumes (Lithourgidis *et al.,* 2006, 2011).

The benefits expected from such mixtures vary depending on the combination of species used and the mixing ratio. A meta-analysis based on 49 publications reported that triticale-pea mixtures increase dry matter yield compared to sole crops, though they also decrease the crude protein content (Liu *et al.,* 2025). Similarly, there is a trade-off: as the proportion of cereals in the mixture increases, yield rises, while quality declines (Liu *et al.,* 2023). In forage pea-triticale mixtures, an increase in the proportion of forage peas has been shown to reduce NDF, ADF, and ADL contents, while improving digestibility, dry matter intake, and relative feed value (Kallida *et al.,* 2022; Górski & Płaza, 2023). It has also been reported that the performance of a mixture depends not only on the mixing ratio but also on the specific legume variety used and the timing of harvest (Önal Aşçı *et al.,* 2015; Seydoşoğlu & Bengisu, 2019). Therefore, when determining an appropriate mixture, it is necessary to consider not only the mixing ratio but also the specific variety of forage pea.

Another factor that determines nutritional value is how the harvested material is preserved. Herbage and silage are the two most common methods for preserving winter forage crops. The high protein content and buffering capacity of legumes, such as forage peas, make it more difficult to lower the pH during the ensiling process (McDonald *et al.,* 1991; Y. Ma *et al.,* 2025). Cultivating peas in combination with cereals increases the soluble sugar content of the material to be ensiled (Y. Ma *et al.,* 2025), and silage produced from such mixed cropping can exhibit better quality characteristics compared to silage from pure stands (Mirza & Çopur Doğrusöz, 2024). It has been reported that the mixing ratio in pea-cereal mixtures influences the crude protein and fiber content of the resulting silage (Mirza & Çopur Doğrusöz, 2024; Y. Ma *et al.,* 2025), and that in pea-barley mixtures, the nutritional composition of silage differs from that of herbage (Soufan & Al-Suhaibani, 2021).

However, there are limited studies that simultaneously evaluate the nutritional value of herbage and silage derived from the same forage pea–triticale mixtures. Furthermore, there is a notable scarcity of data regarding the influence of different forage pea varieties on such comparisons, as well as data specific to the rain-fed conditions of a Mediterranean climate. This study aims to determine the

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forage yield and herbage quality of forage pea and triticale grown in mixtures at different ratios, to assess the impact of these mixtures on the quality of the resulting silage, to evaluate the pH, dry matter content, chemical composition, and relative feed value of the silage, and to compare the nutritional value of the herbage and the silage.

Materials and Methods

Materials: In this study, two varieties of forage pea (*Pisum sativum* ssp. *arvense* (L.) Poir.) and one variety of triticale (*xTriticosecale* Wittm.) were used as the primary materials. The forage pea varieties selected were 'Taşkent' and 'Zerre', while the 'Mehmetbey' variety was chosen for triticale. The forage pea seeds were obtained from the private sector, and the triticale seeds were provided by the Eastern Mediterranean Transitional Zone Agricultural Research Institute in Kahramanmaraş.

Taşkent is a forage pea variety cultivated for herbage production. It features broad, dense foliage and a high capacity for branching. It also possesses a strong nitrogen-fixing ability. The plant height ranges from 140 to 180 cm. It is cold-hardy and winter-hardy. Sowing should coincide with the wheat planting season, at a depth of 2-3 cm. It is an early-maturing variety, reaching the harvest stage 15 days earlier than Hungarian vetch. Harvesting is typically performed during the 50% flowering stage, when the plants reach a height of 130-180 cm. The crude protein content of its herbage is 21% (Anon., 2008).

Zerre is a leguminous forage pea variety used both as animal feed and as green manure. Its crude protein content ranges between 22% and 24%, and it offers a high dry matter yield. The recommended seeding rate is 10-15 kg da^{-1}, with a row spacing of 20-40 cm. Sowing should be carried out at a depth of 2-3 cm. The plant height is 75-85 cm (Anon., 2022a).

Mehmetbey triticale variety is a cereal forage crop developed through hybridization; it grows to an average height of 120 cm and features thick leaves. It exhibits tolerance to cold climatic conditions, making it a preferred choice for regions with harsh winters. It offers a very high grain yield, and the grains are resistant to shattering (Anon., 2026).

Information regarding the trial site: This study was conducted during the 2022-2023 winter growing season at the experimental site belonging to the Department of Field Crops, Faculty of Agriculture, Kahramanmaraş Sütçü İmam University. Located in the Mediterranean region at 37°35′40.86″ N latitude and 36°48′47.51″ E longitude, the experimental site has a slope of 3-5%. Its elevation is 490 m above sea level (Fig. 1).

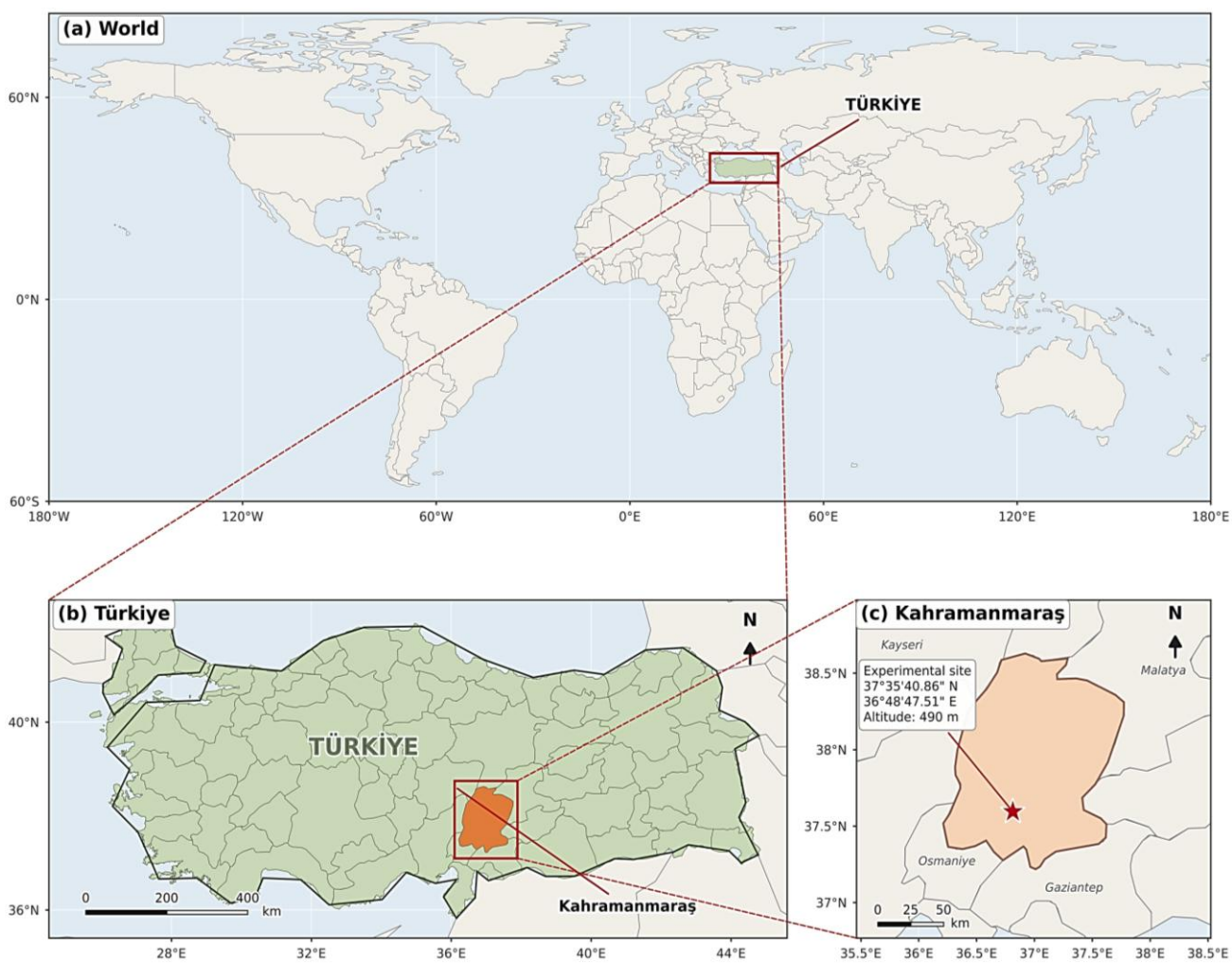


Fig. 1. Location of the experimental site: (a) Türkiye in the world, (b) Kahramanmaraş Province in Türkiye, and (c) the experimental site in Kahramanmaraş Province (37°35′40.86″ N, 36°48′47.51″ E; 490 m a.s.l.).

Table 1. Physical and chemical properties of soil samples taken from the experimental site.

Depth (cm)	Parameters analyzed							
	Saturation	pH	Salinity (%)	Lime (%)	Organic matter (%)	Nitrogen (%)	P_2O_5 (kg da^{-1})	K_2O (kg da^{-1})
0-30	59	7.3	0.08	1.9	2.3	0.08	16.0	55.51

Table 2. Climatic data for the 2022-2023 period and long-term averages, as recorded at the meteorological station in Kahramanmaraş province.

Months	Rainfall (mm)		Temperature (°C)		Relative humidity (%)	
	2022-2023	Long term	2022-2023	Long term	2022-2023	Long term
November	39.1	87.5	13.5	11.5	56.2	66.68
December	198.5	116.6	8.4	6.8	81.9	79.85
January	88.0	125.4	6.3	4.9	69.3	69.99
February	72.7	108.3	6.1	6.4	68.3	65.62
March	173.4	93.4	12.5	10.6	67.3	60.00
April	61.8	69.8	15.9	15.5	58.2	57.59
May	18.5	41.2	20.0	20.3	47.2	54.95
June	0.3	8.4	25.4	25.3	46.9	49.67
Tot./Avg.	652.3	650.6	13.5	12.7	61.91	63.04

Soil characteristics of the experimental site: Prior to sowing, a soil sample was collected from a depth of 0–30 cm at the study site. Soil analysis was performed to determine the physical and chemical properties of the sample. Certain physical and chemical characteristics of the soil -determined through analysis conducted at ÜSKİM on a sample taken from a depth of 0-30 cm- are presented in Table 1 (Anon., 2022b).

According to Table 1, the soil at the experimental site has a clay-loam texture, a neutral reaction (pH 7.3), is non-saline (0.08%), and contains a low level of lime (1.9%). It is moderately rich in organic matter (2.3%), low in total nitrogen (0.08%), very high in available phosphorus (16.0 kg P_2O_5 da^{-1}), and high in available potassium (55.51 kg K_2O da^{-1}) (Ülgen & Yurtsever, 1995).

Climatic characteristics of the experimental site: The study area, which is under the influence of a Mediterranean climate, experiences hot and dry summers, and mild and rainy winters. Table 2 presents the temperature and precipitation data for the Kahramanmaraş province for the 1930-2022 period, as well as for the 2022-2023 period during which the experiment was conducted (Anon., 2023).

As shown in Table 2, the long-term average total precipitation for the vegetation period (November-June) in Kahramanmaraş -the location where the research was conducted- is 650.6 mm. During the 2022–2023 growing season, in which the experiment took place, the total precipitation was 652.3 mm, which is 1.7 mm higher than the long-term average. For the same period, the long-term average temperature was 12.7°C, while the average temperature for the 2022–2023 season was 13.5°C, 0.8°C higher than the long-term average. The average relative humidity was recorded at 63.04% for the long-term period and 61.91% for the 2022–2023 season. Although the total precipitation was close to the long-term average, its monthly distribution varied. Precipitation levels in December (198.5 mm) and March (173.4 mm) exceeded the long-term averages, whereas in May -the month preceding harvest- the recorded precipitation (18.5 mm) was approximately half of the long-term average (41.2 mm).

Method: The research was established using a randomized complete block design with three replications. The field was plowed, followed by cultivation and leveling (using a harrow/tiller), to prepare the seedbed for sowing. Sowing was performed manually in six rows, each 4 meters long, with a spacing of 20 cm between rows. The calculated quantity of seed for each plot was distributed equally across the six rows; in each mixture, the forage pea variety and the triticale were sown together within the same rows. The plot size was 1.2 m × 4 m = 4.8 m². The mixtures were established based on the "replacement series" principle. For pure stands, the seeding rates used were 450 seeds m^{-2} for triticale (Yıldırım & Özaslan Parlak, 2016) and 80 seeds m^{-2} for forage pea (Carr *et al.,* 2004). In the mixtures, the seeding rate for each species was reduced in proportion to its share in the mixture ratio. Accordingly, the seeding rates were 60 seeds m^{-2} for forage pea and 112.5 seeds m^{-2} for triticale in the 75% forage pea + 25% triticale mixture; 40 and 225 seeds m^{-2} in the 50% + 50% mixture; and 20 and 337.5 seeds m^{-2} in the 25% + 75% mixture. For each plot, the calculated amounts of seeds were weighed, mixed, and distributed equally across 6 rows. Prior to sowing, a 20.20.0 compound fertilizer was applied to the experimental area to provide 6 kg da^{-1} of pure N and P_2O_5 (Doğan, 2013). Sowing took place on November 23, 2022. Throughout the growing season, all necessary maintenance practices, such as hoeing, were carefully carried out. Weed control was performed manually from the time of germination throughout the duration of the experiment. No irrigation was applied. Harvesting was conducted on May 12, 2023. In this study, the effects of different mixture ratios were examined separately for both herbage (dry forage) and silage applications.

Silage production: Triticale was harvested at the early dough stage (Zadoks GS83; Zadoks *et al.,* 1974), a phase that offers an optimal balance between dry matter yield and the dry matter content required for ensiling (Önal Aşçı *et al.,* 2015). This stage also coincides with the 50% flowering phase, which is the ideal harvest time for both forage pea varieties (Taşkent and Zerre). Following harvest, fresh herbage samples were dried at 70°C for 48 hours to determine their dry matter content and calculate the dry herbage yield. For the

ensiling process, approximately 5±1 kg of fresh herbage -carefully selected from each plot- was chopped into 2–3 cm pieces using a forage chopper. To prevent cross-contamination, the chopper was thoroughly cleaned with a brush after processing the samples from each individual plot. The chopped herbage from each plot was mixed thoroughly on a plastic sheet and then portioned into specialized polyethylene vacuum bags (500±20 g per bag). This process was carried out in triplicate for each plot, with the final data representing the mean value for that plot. The bags were then vacuum-sealed using a vacuum machine (Packtech PT-VKM-CPRO; equipped with a 70 L/min vacuum pump and a capacity of 4.2 m³/h) for 20 seconds to remove air, after which the openings were automatically sealed (Ferraretto *et al.,* 2015). The prepared silage samples were left to ferment at room temperature (~20°C) for 60 days. At the end of this period, the silages -considered to have completed their fermentation- were opened and mixed in a sterile container until a homogeneous composition was achieved. A 200 ±20 g fresh sample was taken from each silage and dried at 70 °C for 48 hours. These samples were used to determine the dry matter content, crude protein content, crude ash content, and cell wall components of the silage.

Chemical analyses: The pH values of the samples taken at the beginning of the ensiling process (T_0) and after 60 days of fermentation (T_{60}) were determined. The samples, which had been dried in an oven at 70°C for 48 hours, were ground using a mill equipped with a 1 mm sieve to prepare them for analysis. The total nitrogen (N) content of the samples was determined using the Kjeldahl method, and the resulting values were multiplied by 6.25 to calculate the crude protein content (Jones, 1931). Crude ash content was determined by incinerating the samples in a muffle furnace at 550°C for 4 hours. Neutral detergent fiber (NDF) and acid detergent fiber (ADF) contents were determined using an ANKOM 2000 Fiber Analyzer (ANKOM Technology, Macedon, NY, USA). Sodium sulfite was used in the NDF analysis, while heat-stable α-amylase was not. Acid detergent lignin (ADL) content was determined by treating the residue remaining from the ADF analysis with 72% sulfuric acid at room temperature for 3 hours (Van Soest *et al.,* 1991). Digestible dry matter (DDM) was determined using ADF values, while dry matter intake (DMI) was calculated based on NDF values. Once the DDM and DMI values were established, the relative feed value (RFV) -which estimates both the potential consumption of the feed by animals and the energy value it provides- was calculated using the formula developed by Rohweder *et al*., (1978):

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

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

$$\text{RFV} = \% \text{ DDM} \times \% \text{ DMI} \times 0.775$$

Statistical analysis

The experimental design was a randomized complete block design consisting of nine treatments and three replications. Data obtained for herbage and silage samples were analyzed using the SAS software program (SAS Institute, 2014). Differences between means were compared using Duncan's Multiple Range Test at the $p \leq 0.05$ level (Duncan, 1955). Relationships between the measured traits were examined via Pearson correlation analysis using treatment means (n = 9), while the relationship between NDF and RFV was analyzed using linear regression. Correlation analysis was performed using JMP® Pro 17 statistical software (SAS Institute, 2022).

Results and Discussion

Yield and quality characteristics of herbage: The mixing ratios of forage pea and triticale had a statistically significant effect ($p \leq 0.05$; Table 3) on all herbage characteristics examined, except for the crude ash content. Green herbage yield ranged from 3337.7 to 5303.0 kg da^{-1}. The three mixtures containing the 'Zerre' cultivar yielded the highest values and fell into the same statistical group: 25% forage pea ('Zerre') + 75% triticale (5303.0 kg da^{-1}), 50% + 50% (5057.3 kg da^{-1}), and 75% + 25% (5029.3 kg da^{-1}). The lowest green herbage yield was obtained from the mixture of 75% forage pea ('Taşkent') + 25% triticale (3337.7 kg da^{-1}).

Herbage yield ranged from 650.7 to 1437.7 kg da^{-1}. The highest values were obtained from the mixture of 25% forage pea ('Zerre') + 75% triticale (1437.7 kg da^{-1}) and from pure triticale (1308.7 kg da^{-1}); these two treatments were in the same statistical group. For treatments consisting of pure forage pea and mixtures with the 'Taşkent' cultivar where the forage pea proportion was 50% or higher, herbage yield remained between 650.7 and 799.7 kg da^{-1}. At the same mixing ratio, combinations containing the 'Zerre' cultivar provided higher herbage yields than those containing the 'Taşkent' cultivar. For instance, at a 50% + 50% ratio, these values are 1031.3 and 666.0 kg da^{-1}, respectively.

The crude protein content ranged from 10.07% to 26.03%. The highest values were obtained from the pure forage pea stands (Taşkent, 26.03%; Zerre, 23.80%), which did not differ significantly, while the lowest value was obtained from pure triticale (10.07%). In mixtures containing 50% or more forage pea, the crude protein content was found to be between 16.50% and 18.77%. The crude protein content of the mixture consisting of 25% forage pea (Zerre) + 75% triticale was 11.90%. Crude protein yield varied between 109.87 and 208.77 kg da^{-1}. The highest values were obtained from pure forage pea (Taşkent, 208.77 kg da^{-1}) and the mixture of 50% forage pea (Zerre) + 50% triticale (183.50 kg da^{-1}), while the lowest value was recorded for the mixture of 50% forage pea (Taşkent) + 50% triticale (109.87 kg da^{-1}). The crude ash content ranged from 6.10% to 8.60% and was not statistically affected by the mixing ratios.

The NDF content varied between 39.30% and 50.50%. The highest value was observed in pure triticale (50.50%), while the lowest values were recorded in the mixture of 75% forage pea (Taşkent) + 25% triticale (39.30%) and in pure forage pea (Zerre, 39.75%). The ADF content ranged from 25.46% (pure forage pea, Zerre) to 34.20% (pure triticale). The ADL content varied between 3.73% (50% forage pea 'Taşkent' + 50% triticale) and 7.10% (25% forage pea 'Zerre' + 75% triticale), though it did not show a consistent trend in relation to the mixing ratio.

Table 3. Yield, chemical composition and feed value of dry herbage from forage pea–triticale mixtures sown at different ratios.

Mixture	GHY	DHY	CPR	CPY	CAR	NDF	ADF	ADL	DDM	DMI	RFV	DDMY
PFP (Taşkent)	4617.3 ab[1]	799.7 c[1]	26.03 a[1]	208.77 a[1]	8.00[ns]	40.55 e[1]	27.46 d[1]	5.42 b[1]	67.51 b[1]	2.96 b[1]	154.87 c[1]	540.01 d[1]
PFP (Zerre)	4649.0 ab	672.0 c	23.80 a	161.47 abcd	6.97	39.75 f	25.46 e	5.08 bc	69.06 a	3.02 a	161.63 a	464.18 d
PT	3596.0 cd	1308.7 a	10.07 d	129.20 bcd	6.10	50.50 a	34.20 a	5.13 bc	62.26 e	2.38 f	114.69 g	815.04 ab
75% FP (Taşkent) + 25% T	3337.7 d	650.7 c	18.77 b	121.97 cd	8.60	39.30 f	28.20 d	4.62 cd	66.93 b	3.05 a	158.43 b	435.61 d
50% FP (Taşkent) + 50% T	3468.3 cd	666.0 c	16.50 b	109.87 d	6.83	40.60 e	27.60 d	3.73 e	67.40 b	2.96 b	154.44 c	448.94 d
25% FP (Taşkent) + 75% T	4162.3 bc	1104.7 b	15.20 bc	167.10 abc	6.67	45.10 b	32.20 b	5.09 bc	63.82 d	2.66 e	131.65 f	705.16 bc
75% FP (Zerre) + 25% T	5029.3 a	839.7 c	17.90 b	150.30 bcd	7.33	41.74 d	28.90 d	4.17 de	66.39 b	2.87 c	147.96 d	557.55 cd
50% FP (Zerre) + 50% T	5057.3 a	1031.3 b	17.83 b	183.50 ab	7.20	42.50 c	30.57 c	4.90 bc	65.09 c	2.82 d	142.47 e	670.28 c
25% FP (Zerre) + 75% T	5303.0 a	1437.7 a	11.90 cd	172.13 abc	6.47	45.40 b	31.80 bc	7.10 a	64.13 cd	2.64 e	131.39 f	922.27 a
Means	4357.8	945.6	17.56	156.03	7.13	42.83	29.60	5.03	65.84	2.82	144.17	617.67
CV(%)	9.15	11.34	11.81	18.40	13.10	0.70	2.60	6.70	0.91	0.74	0.88	12.09

PFP, pure forage pea; PT, pure triticale; FP, forage pea; T, triticale; GHY, green herbage yield (kg da^{-1}); DHY, dry herbage yield (kg da^{-1}); CPR, crude protein ratio (%); CPY, crude protein yield (kg da^{-1}); CAR, crude ash ratio (%); NDF, neutral detergent fiber (%); ADF, acid detergent fiber (%); ADL, acid detergent lignin (%); DDM, digestible dry matter (%); DMI, dry matter intake (% of body weight); RFV, relative feed value; DDMY, digestible dry matter yield (kg da^{-1}); CV, coefficient of variation. Chemical composition is expressed on a dry matter basis. [1] Within a column, means followed by different letters differ significantly at $p \leq 0.05$ according to Duncan's multiple range test; ns, not significant

Table 4. Fermentation characteristics, chemical composition and feed value of silages from forage pea–triticale mixtures sown at different ratios (60 days of ensiling).

Mixture	T_0pH	T_{60}pH	DMR	CPR	CAR	NDF	ADF	ADL	DDM	DMI	RFV
PFP (Taşkent)	6.76[ns]	4.31[ns]	20.95 g[1]	20.27 a[1]	8.33 [ns]	39.50 d[1]	25.11 d[1]	2.43 cd[1]	69.34 a[1]	3.04 a[1]	163.40 a[1]
PFP (Zerre)	6.53	4.19	22.30 f	20.47 a	7.73	38.64 d	23.38 d	2.33 d	70.69 a	3.11 a	170.42 a
PT	6.44	4.19	37.32 a	9.10 c	7.23	52.61 a	32.20 ab	3.49 b	63.81 cd	2.28 d	112.78 d
75% FP (Taşkent) + 25% T	6.31	4.64	23.99 e	16.83 ab	9.33	38.43 d	27.79 c	3.24 bc	67.25 b	3.12 a	162.65 a
50% FP (Taşkent) + 50% T	6.41	4.12	26.70 d	16.07 ab	7.37	42.12 c	29.08 c	3.71 ab	66.25 b	2.85 b	146.36 b
25% FP (Taşkent) + 75% T	6.40	4.27	29.22 c	13.80 abc	7.27	42.80 c	31.64 b	2.44 cd	64.26 c	2.80 b	139.47 b
75% FP (Zerre) + 25% T	6.28	4.35	20.24 g	18.23 ab	8.13	43.71 c	30.97 b	2.39 cd	64.77 c	2.75 b	138.08 b
50% FP (Zerre) + 50% T	6.25	4.22	24.47 e	11.97 bc	7.43	44.13 bc	29.16 c	3.31 b	66.19 b	2.72 bc	139.56 b
25% FP (Zerre) + 75% T	6.17	4.13	32.46 b	12.47 bc	7.37	46.50 b	33.90 a	4.42 a	62.49 d	2.59 c	125.46 c
Means	6.39	4.27	26.41	15.47	7.80	43.16	29.25	3.08	66.12	2.81	144.24
CV(%)	3.63	7.16	2.85	22.97	13.61	3.35	3.47	15.5	1.19	3.12	3.95

PFP, pure forage pea; PT, pure triticale; FP, forage pea; T, triticale; T_0pH, pH before ensiling; T_{60}pH, pH after 60 days of ensiling; DMR, silage dry matter ratio (%); CPR, crude protein ratio (%); CAR, crude ash ratio (%); NDF, neutral detergent fiber (%); ADF, acid detergent fiber (%); ADL, acid detergent lignin (%); DDM, digestible dry matter (%); DMI, dry matter intake (% of body weight); RFV, relative feed value; CV, coefficient of variation. Chemical composition is expressed on a dry matter basis. [1] Within a column, means followed by different letters differ significantly at $p \leq 0.05$ according to Duncan's multiple range test; ns, not significant

The digestible dry matter content ranged from 62.26% (pure triticale) to 69.06% (pure forage pea, 'Zerre'). Dry matter intake was highest for the mixture of 75% forage pea ('Taşkent') + 25% triticale (3.05%) and for pure forage pea ('Zerre', 3.02%), while it was lowest for pure triticale (2.38%). The relative feed value ranged from 114.69 (pure triticale) to 161.63 (pure forage pea, 'Zerre'). Values above 150 were observed for pure forage pea treatments and mixtures containing 75% or 50% forage pea ('Taşkent'); values between 131.39 and 147.96 were found for mixtures involving 'Zerre' and the mixture with 25% forage pea ('Taşkent'), while a value of 114.69 was recorded for pure triticale. Digestible dry matter yield ranged from 435.61 to 922.27 kg da^{-1}. The highest values were obtained from the mixture of 25% forage pea ('Zerre') + 75% triticale (922.27 kg da^{-1}) and from pure triticale (815.04 kg da^{-1}). The increase in dry herbage yield in mixtures with a high proportion of triticale can be attributed to the high biomass production capacity of cereals. Research on mixtures of triticale and legumes grown at varying ratios has indicated that both the mixing ratio and the plant variety influence dry matter yield, with some mixtures potentially outperforming monocultures. Büyükburç & Karadağ (2002) achieved high dry matter yields in certain legume-triticale mixtures, while Hall and Kephart (1991) demonstrated that yields in forage pea-triticale mixtures vary depending on the variety, mixing ratio, and harvest time. In the present study, the finding that a mixture of 25% forage pea (cv. Zerre) and 75% triticale falls into the same dry herbage yield category as pure-stand triticale is consistent with these results. Önal Aşçı *et al*., (2015) also reported that the total digestible dry matter and crude protein yields in forage pea-triticale mixtures vary based on the mixing ratio and harvest time. The fact that mixtures containing the 'Zerre' variety -at the same mixing ratios- produced higher green and dry herbage yields suggests that the specific forage pea variety, in addition to the seeding ratio, must be taken into account when determining an optimal mixture.

The increase in crude protein content as the proportion of forage pea rises is explained by the ability of legumes to synthesize more protein by fixing atmospheric nitrogen through their symbiotic relationship with Rhizobium bacteria. In roughages, a crude protein content falling below approximately 7% limits rumen microbial activity and feed intake (Van Soest, 1994). In this study, all treatments contained crude protein levels above this threshold; however, the values for pure triticale (10.07%) and the mixture of 25% forage pea (cv. Zerre) + 75% triticale (11.90%) were notably lower than those of the other treatments. Since crude protein yield depends on both dry herbage yield and crude protein content, the highest values were obtained from pure forage pea -which has a high protein content- and the mixture of 50% forage pea (cv. Zerre) + 50% triticale, which balances yield and protein content. The fact that the crude protein yield was lowest in the mixture containing the 'Taşkent' cultivar (at the same inclusion rate) is attributed to the low dry herbage yield of this specific mixture. The observation that the crude ash content remained unaffected by the mixing ratios indicates that the mineral content was similar across all treatments in this study.

Neutral detergent fiber (NDF) -a component of the plant cell wall- is generally desired to be present at low levels in rations because it slows down digestion (Van Soest, 1994). Increased ADF and NDF contents indicate a higher concentration of fibers that are difficult to digest, which may reduce energy availability for ruminants (Bainard *et al.,* 2020; Marković *et al.,* 2020). Increasing the ADF level in rations induces a sense of satiety in animals, thereby limiting feed intake (Van Soest, 1994). Variations in NDF and ADF values depend on the proportions of species within a mixture and the stage of harvest (Önal Aşçı *et al.,* 2015; Górski and Płaza, 2023). In this study, the observation of the highest NDF and ADF values in pure triticale and the lowest values in treatments dominated by forage peas aligns with the general understanding that legumes possess lower fiber content and higher digestibility compared to cereals. The fact that the ADL (acid detergent lignin) proportion does not follow a consistent trend in relation to the mixing ratio suggests that lignin accumulation may depend not only on the species but also on the specific cultivar and the proportions of different plant parts.

Digestible dry matter and dry matter intake -due to the methods used for their calculation- showed an inverse relationship with ADF and NDF, respectively. Consequently, both values were found to be higher in treatments dominated by forage peas, which have a lower fiber content. Relative Feed Value (RFV) is a concept used to estimate both the intake potential and the energy value of forages. According to this classification system, an RFV above 150 indicates "prime" (best) quality; 125–150 indicates "grade 1"; 103–124 indicates "grade 2"; 87–102 indicates "grade 3"; 75–86 indicates "grade 4"; and a value below 75 indicates "grade 5" (Rohweder *et al.,* 1978). Based on these results, the pure forage pea treatments and the mixtures containing 75% and 50% forage pea (cv. Taşkent) were classified as having the best quality; the mixtures involving the cultivar 'Zerre' along with the 25% forage pea (cv. Taşkent) mixture were classified as 1st quality, while pure triticale fell into the 2nd quality category. The finding that digestible dry matter yield -unlike other quality parameters- was higher in treatments dominated by triticale can be attributed to the high biomass production of these treatments.

In general, increasing the proportion of forage pea in the mixture enhanced the crude protein content, digestibility, and relative feed value, whereas increasing the proportion of triticale boosted the dry herbage yield. This indicates a clear trade-off between yield and quality. The mixture of 25% forage pea (cv. Zerre) + 75% triticale yielded the highest amount of dry herbage; however, its crude protein content was significantly lower than that of the other treatments. When yield and quality are evaluated together, the mixture of 50% forage pea (cv. Zerre) + 50% triticale emerges as the superior option. This mixture provided a dry herbage yield of 1031.3 kg da^{-1}, a crude protein content of 17.83%, a crude protein yield statistically equivalent to the highest-performing group, and a relative feed value (142.47) that places it in the 1st quality category.

Quality characteristics of matured silages: The mixing ratios of forage pea and triticale had a statistically significant effect ($p \leq 0.05$; Table 4) on all silage characteristics examined, apart from pH and crude ash content. The pH values prior to ensiling (T_0) ranged from 6.17 to 6.76, while the pH values

after 60 days of fermentation (T_{60}) ranged from 4.12 to 4.64. Silage pH was not statistically affected by the mixing ratios; the highest numerical value (4.64) was observed in the mixture consisting of 75% forage pea (Taşkent) and 25% triticale. The dry matter content of the silages varied between 20.24% and 37.32%, increasing as the proportion of triticale rose. The highest value was obtained from pure triticale (37.32%), while the lowest values were recorded for the mixture of 75% forage pea (Zerre) + 25% triticale (20.24%) and the pure forage pea (Taşkent) silage (20.95%).

The crude protein content of the silages ranged from 9.10% to 20.47%. The highest values were found in the pure forage pea silages (Zerre: 20.47%; Taşkent: 20.27%), whereas the lowest value was observed in the pure triticale silage (9.10%). The crude protein content of the mixed silages ranged from 11.97% to 18.23%, with the majority falling into the same statistical group. The crude ash content varied between 7.23% and 9.33% and was not statistically affected by the mixing ratios. The NDF content ranged from 38.43% (75% forage pea 'Taşkent' + 25% triticale) to 52.61% (pure triticale). The lowest ADF content was found in pure forage pea ('Zerre') silage (23.38%), while the highest levels were observed in the mixture of 25% forage pea ('Zerre') + 75% triticale (33.90%) and in pure triticale (32.20%). The ADL content varied between 2.33% (pure forage pea, 'Zerre') and 4.42% (25% forage pea 'Zerre' + 75% triticale), though it did not show a consistent trend in relation to the mixing ratio. In fact, the ADL content in the silages consisting of 25% forage pea ('Taşkent') + 75% triticale (2.44%) and 75% forage pea ('Zerre') + 25% triticale (2.39%) was found to be similar to that of the pure forage pea silages.

The digestible dry matter content ranged from 62.49% (25% forage pea 'Zerre' + 75% triticale) to 70.69% (pure forage pea, 'Zerre'). Dry matter intake was highest for the mixture of 75% forage pea ('Taşkent') + 25% triticale (3.12%) and the pure forage pea silages (3.04–3.11%), while it was lowest for the pure triticale silage (2.28%). The relative feed value ranged from 112.78 (pure triticale) to 170.42 (pure forage pea, 'Zerre'). Silage made from pure forage pea (163.40–170.42) and a mixture of 75% forage pea (cv. Taşkent) + 25% triticale (162.65) fell into the same statistical group and yielded the highest values. For other mixed silages, the relative feed value ranged between 125.46 and 146.36.

When plants with different chemical compositions and dry matter contents are mixed, the components of the resulting silage may increase or decrease depending on the mixing ratio (Öztürk *et al.,* 2006). In this study, the dry matter, crude protein, and fiber contents of the silage varied according to the proportions of forage pea and triticale in the mixture.

The silage pH values, ranging from 4.12 to 4.64, are consistent with the range reported for well-fermented silages (Kung *et al.,* 2018). It has been reported that increasing the proportion of cereals in legume-cereal silage mixtures lowers the pH (Lima *et al.,* 2010). In the present study, however, the pH was not affected by the mixing ratios. This may be due to the fact that the triticale was harvested at the early dough stage, which limited the differences in fermentable carbohydrates among the mixtures. Nevertheless, this interpretation requires further verification, as the water-soluble carbohydrate content and fermentation products were not determined.

The increase in the dry matter content of the silage as the proportion of triticale rises can be explained by the fact that cereals have a lower water content than legumes. An appropriate dry matter content is a critical factor for silage quality (Weinberg and Ashbell, 2003). In this study, the dry matter content of pure forage pea silages ranged from 20.95% to 22.30%, indicating that dry matter content must be considered when ensiling material dominated by forage peas.

The increase in crude protein content as the proportion of forage peas rises is linked to the capacity of legumes to fix atmospheric nitrogen and their inherently high protein content. It has been reported that increasing the proportion of legumes in mixed silages -composed of various plant species- enhances the crude protein content of the silage (Parra *et al.,* 2019). While a clear difference in crude protein content was observed between pure forage pea silage and pure triticale silage in this study, most of the differences among the mixed silages were not found to be statistically significant. This is attributed to the high variation in the crude protein content of the silages (CV = 22.97%). The finding that the crude ash content was unaffected by the mixing ratios differs from reports in the relevant literature, which suggest that crude ash content tends to increase alongside the proportion of legumes (Parra *et al.,* 2019).

The decrease in NDF and ADF content as the proportion of legumes increased contributed to improved silage intake and digestibility. Since NDF is inversely related to feed intake and ADF is inversely related to digestibility, both dry matter intake and the proportion of digestible dry matter were found to be higher in silages with a greater share of forage peas. The lack of a consistent trend in ADL (acid detergent lignin) content relative to the mixing ratio suggests that lignin levels depend not only on the proportion of each species in the mixture but also on the specific variety and the ratio of different plant parts.

In terms of relative feed value, pure forage pea silages and the mixture of 75% forage pea (cv. Taşkent) + 25% triticale fell into the highest quality category (>150). Other mixed silages were classified as 1st quality (125–150), while pure triticale silage was classified as 2nd quality (103–124). These results highlight the decisive role of fiber components, such as NDF and ADF, in determining silage quality. Overall, increasing the proportion of forage peas enhanced the crude protein content, digestibility, dry matter intake, and relative feed value of the silage, whereas increasing the proportion of triticale raised the dry matter content. Therefore, when determining the mixing ratio for silage production, both nutritional value and the dry matter content -which is critical for successful ensiling- should be considered together.

The chemical composition of mixed silages varies depending on the proportions of the plants included in the mixture, their initial chemical composition, and their dry matter content (Öztürk *et al.,* 2006). Differences in dry matter, protein, and fiber content among plants stem from factors such as genetic makeup, the ratios of leaves, stems, and spikes (or heads), and the stage of maturity (Ball *et al.,* 2001). In this study, as the proportion of forage pea increased in both materials, the crude protein content, digestible dry matter (DDM), dry matter intake (DMI), and relative feed value (RFV) all rose, while neutral detergent fiber (NDF) and acid detergent fiber (ADF) levels decreased (Fig. 2). This aligns with the general trend reported for legume-cereal mixtures (Caballero *et al.,* 1995; Anil *et al.,* 1998).

Silage Quality in Comparison to Herbage: An Assessment of Nutritional and Feed Value

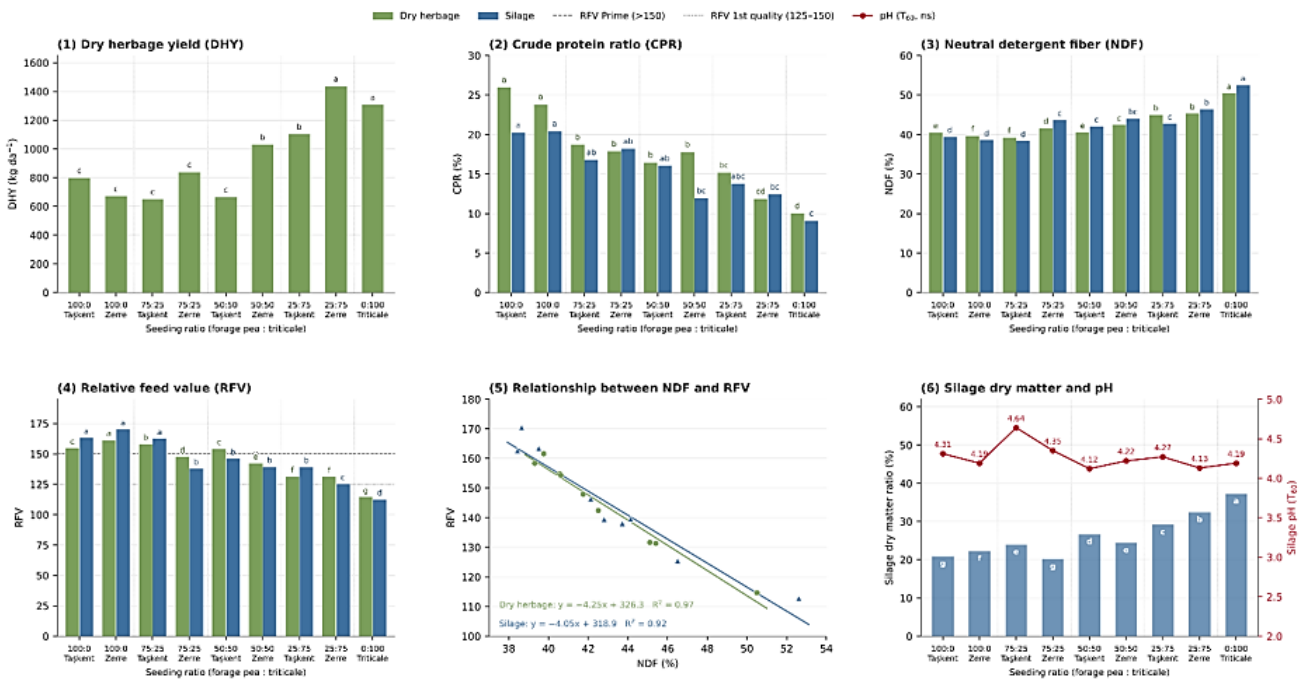


Fig. 2. Effects of forage pea–triticale seeding ratio on dry herbage (green) and silage (blue) traits: (1) dry herbage yield (DHY), (2) crude protein ratio (CPR), (3) neutral detergent fiber (NDF), (4) relative feed value (RFV), (5) linear relationship between NDF and RFV and (6) silage dry matter ratio and pH. Within each material, means sharing a letter do not differ significantly according to Duncan's test ($p > 0.05$). Silage pH was not affected by seeding ratio (ns). Dashed and dotted horizontal lines indicate the prime (>150) and first-quality (125–150) RFV limits.

The mean crude protein content of the silage (15.47%) was found to be numerically lower than that of the herbage (17.56%). This decline in crude protein was most pronounced in the mixture consisting of 50% forage pea (cv. Zerre) and 50% triticale (dropping from 17.83% to 11.97%). A decrease of approximately 5.8 percentage points was also observed in the silage made from pure forage pea (cv. Taşkent). In contrast, for the mixture of 25% forage pea (cv. Zerre) and 75% triticale, the crude protein content of the silage remained close to that of the herbage (11.90% versus 12.47%). Protein degradation and the loss of volatile nitrogenous compounds during the ensiling process are among the potential reasons for this discrepancy (McDonald *et al.,* 1991). However, as ammonia nitrogen and soluble nitrogen were not measured, this interpretation requires further verification. The mean ADL content in silage (3.08%) was found to be approximately 39% lower than that in herbage (5.03%). Since lignin does not undergo significant microbial degradation under anaerobic conditions (Odier and Monties, 1983), this difference cannot be attributed to the breakdown of lignin in the silage. During high-temperature drying, Maillard reactions -occurring between soluble carbohydrates and proteins- can lead to the formation of "artifact lignin," which is measured as lignin within the ADL fraction (Van Soest, 1965). In this study, both materials were dried at 70 °C; however, because a large portion of the soluble carbohydrates in the silage was consumed during fermentation, the formation of artifact lignin during the drying process may have been more limited in the silage. The lack of a significant correlation for ADL between herbage and silage ($r = 0.39$; Fig. 3) further supports the notion that this fraction is sensitive to analytical artifacts.

For other parameters, the overall means for herbage and silage were found to be quite similar. The relative feed value was 144.17 for herbage and 144.24 for silage; DDM values were 65.84% and 66.12%, respectively, while NDF values were 42.83% and 43.16%. It has been reported that partial degradation of cell wall components can occur during silage fermentation (McDonald *et al.,* 1991). In the present study, however, the NDF and ADF contents of the silage did not show a marked decrease compared to the herbage. Furthermore, the relative ranking of the treatments remained largely consistent across both preservation methods. For both herbage and silage, the correlations between the same parameters -specifically NDF, RFV, DMI, and crude ash- are at a level of $r \geq 0.92$ (Fig. 3). This indicates that the effect of the mixing ratio on quality follows a similar trend, regardless of the preservation method. However, since the two preservation methods were not compared statistically, the significance of any differences between them cannot be assessed based on the data from this study.

Relationships between herbage and silage characteristics: The relationships between herbage and silage characteristics were evaluated using Pearson correlation analysis based on treatment means ($n = 9$), and the results are presented in Fig. 3. Herbage yield (DHY) showed a negative correlation with crude protein content (CPR; $r = -0.75$) and positive correlations with NDF ($r = 0.87$) and ADF ($r = 0.89$). Strong negative correlations were also identified between herbage yield and relative feed value

(RFV; r = −0.91), dry matter intake (DMI; r = −0.90), and digestible dry matter (DDM; r = −0.89). Crude protein content was negatively correlated with NDF (r = −0.81) and ADF (r = −0.85), and positively correlated with DDM (r = 0.85), DMI (r = 0.81), and RFV (r = 0.84). The relationship between NDF and ADF was positive and strong (r = 0.93). Crude protein yield (CPY) showed a significant correlation only with green herbage yield (GHY; r = 0.74). ADL was found to be positively correlated with herbage yield (r = 0.71) and digestible dry matter yield (DDMY; r = 0.74), but showed no significant correlation with quality indices. Crude ash content (CAR) was negatively correlated with NDF (r = −0.76) and positively correlated with DMI (r = 0.77) and RFV (r = 0.72).

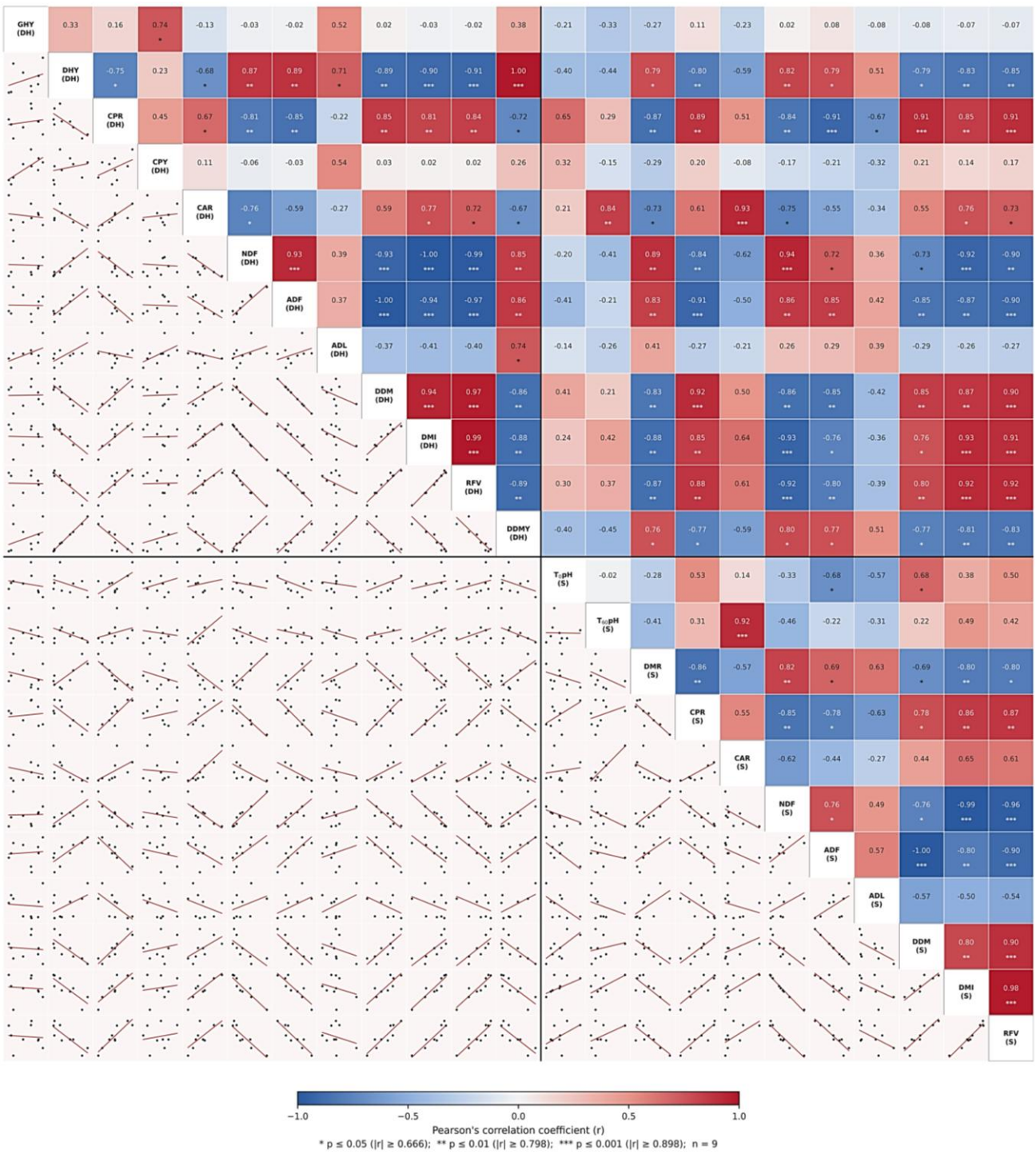


Fig. 3. Pearson correlation coefficients among dry herbage (DH) and silage (S) traits of forage pea-triticale mixtures. The upper triangle shows correlation coefficients, and the lower triangle shows scatter plots of treatment means with fitted regression lines. Coefficients were calculated from treatment means (n = 9). *, ** and *** indicate significance at $p \leq 0.05$ ($|r| \geq 0.666$), $p \leq 0.01$ ($|r| \geq 0.798$) and $p \leq 0.001$ ($|r| \geq 0.898$), respectively. Because DDM, DMI and RFV are calculated from ADF and NDF, and DDMY from DHY, correlations among these variables partly reflect their computational dependence. GHY, green herbage yield; DHY, dry herbage yield; CPR, crude protein ratio; CPY, crude protein yield; CAR, crude ash ratio; NDF, neutral detergent fiber; ADF, acid detergent fiber; ADL, acid detergent lignin; DDM, digestible dry matter; DMI, dry matter intake; RFV, relative feed value; DDMY, digestible dry matter yield; T_0pH and T_{60}pH, pH before and after 60 days of ensiling; DMR, silage dry matter ratio.

Strong positive correlations were identified between the same characteristics in herbage and silage. These correlations were found to be significant for NDF (r = 0.94), crude ash (r = 0.93), dry matter intake (r = 0.93), relative feed value (r = 0.92), crude protein (r = 0.89), ADF (r = 0.85), and DDM (r = 0.85), whereas the correlation for ADL was not significant (r = 0.39). Herbage yield was found to be positively correlated with the dry matter content of the silage (r = 0.79), and negatively correlated with crude protein content (r = -0.80) and relative feed value (r = -0.85). Due to the calculation methods employed, perfect or near-perfect correlations were observed between ADF and DDM (r = -1.00), between NDF and DMI (r = -1.00 for herbage; r = -0.99 for silage), and between herbage yield and digestible dry matter yield (r = 1.00).

The fact that herbage yield shows a negative correlation with crude protein content and relative feed value, but a positive correlation with fiber fractions, indicates that the balance between yield and quality is determined by the proportion of triticale in the mixture. As the proportion of triticale increased, biomass and fiber content rose, while the protein contribution from the forage pea decreased. Meta-analyses on legume–cereal mixtures have similarly reported a trade-off relationship where an increase in the cereal component leads to higher yield but lower quality. It has been demonstrated that triticale–pea mixtures increase dry matter yield compared to sole crops, while simultaneously decreasing the crude protein content (Liu *et al.,* 2023, 2025). Similarly, it has been determined that in forage pea–triticale mixtures, an increase in the proportion of the legume component leads to a reduction in fiber content and an improvement in forage quality (Kallida *et al.,* 2022). The lack of a significant correlation between crude protein yield and most other traits stems from the fact that this parameter is the product of dry forage yield and crude protein content, two variables that tend to change in opposite directions. This suggests that crude protein yield can reach its peak in well-balanced mixtures.

The strong negative correlations between fiber fractions and digestibility, dry matter intake, and relative feed value indicate that cell wall components are the primary factors limiting forage quality in both herbage and silage. This finding is consistent with studies reporting that NDF, ADF, and ADL contents decrease -and digestibility increases- as the proportion of peas in forage pea–triticale mixtures rises (Kallida *et al.,* 2022; Górski & Płaza, 2023). It also aligns with research on oat-forage pea mixtures, which indicates that ADF and NDF are negatively correlated with relative feed value, and that crude protein is negatively associated with ADF (W. Ma *et al.,* 2026). However, since DDM (digestible dry matter), DMI (dry matter intake), and RFV (relative feed value) are indices derived from ADF and NDF (Rohweder *et al.,* 1978), the magnitude of the relationships between these variables is, in part, a function of the calculation method employed. Therefore, more biologically meaningful information is derived from the relationships between crude protein and fiber fractions -which are not derived from one another- as well as from the relationships between herbage yield and fiber fractions.

The lack of a significant correlation between ADL and quality indices can be explained by the fact that ADL is not directly included in the calculation of relative feed value. The positive correlation of ADL with herbage yield and digestible dry matter yield suggests that lignin accumulation increases in high-biomass systems dominated by triticale. However, unlike the other traits examined, ADL did not show a consistent relationship between herbage and silage. Given that the ADL fraction is known to be sensitive to thermal effects during the drying process (Van Soest, 1965), it is possible that this result stems from analytical factors.

The strong positive correlations observed between the same characteristics in herbage and silage indicate that the quality ranking of the treatments is largely maintained even after the ensiling process. In other words, mixtures that exhibited high nutritional value as herbage also provided high nutritional value as silage. It has been reported that the proportion of legumes in triticale–pea–vetch mixtures influences the nutritional characteristics of both fresh and ensiled material in a similar manner; mixtures with a higher legume proportion showed greater crude protein content and digestibility in both forms (Maxin *et al.,* 2017). Similarly, in pea-barley mixtures, an increase in the proportion of peas was found to enhance both crude protein content and digestibility -while reducing fiber content- in both herbage and silage (Soufan & Al-Suhaibani, 2021). These findings suggest that a consistent approach can be adopted when determining mixture proportions, regardless of the intended preservation method.

The negative correlation of dry matter content in silage with crude protein and relative feed value, alongside its positive correlation with fiber fractions, indicates that variations in the dry matter content of the silage are primarily driven by the share of triticale within the mixture. Indeed, a positive correlation was also identified between herbage yield and the dry matter content of the silage. Furthermore, it has been reported that in silage derived from forage pea-triticale mixtures, the crude protein content increases as the proportion of legumes rises (Mirza and Çopur Doğrusöz, 2024). However, given that an appropriate dry matter content is critical for silage quality (Weinberg & Ashbell, 2003), the low dry matter content of legume-dominant silages must be considered when ensiling such mixtures.

It is noteworthy that the final pH after fermentation shows no correlation with fiber, crude protein, or dry matter content, but exhibits a strong positive correlation with the crude ash content. Mineral substances and their associated cations in the ensiled material can buffer the organic acids produced during fermentation, thereby limiting the decline in pH (McDonald *et al.,* 1991). It has been reported that forage peas possess a higher buffering capacity than cereals (Pursiainen & Tuori, 2008), which complicates the ensiling process for peas (Y. Ma *et al.,* 2025). Since buffering capacity and organic acids were not measured in this study, the observed relationship between pH and crude ash should be considered a potential explanation linked to this mechanism. Furthermore, the relationships between pre-ensiling pH and the ADF (acid detergent fiber) and DDM (digestible dry matter) content of the silage should be interpreted with caution, as they fall near the threshold of statistical significance.

Overall, the correlation analysis reveals that cell wall components are the primary determinants of forage quality under both preservation methods; that the balance between yield and quality is shaped by the proportion of triticale in the mixture; and that the relative ranking of the treatments in terms of quality remains consistent even after the ensiling process.

Conclusion

In this study, the effects of different mixing ratios of forage pea (*Pisum sativum* ssp. *arvense* (L.) Poir.) and triticale (*xTriticosecale* Wittm.) -grown under rainfed conditions in a Mediterranean climate- on herbage and silage quality were investigated. The mixing ratio significantly influenced both the yield and quality characteristics of the herbage and silage.

A distinct trade-off between yield and quality was observed in the herbage. The highest herbage yields were obtained from a mixture of 25% forage pea (cv. Zerre) + 75% triticale (1437.7 kg da^{-1}) and from pure triticale (1308.7 kg da^{-1}). Although the crude protein content of these treatments (11.90% and 10.07%, respectively) remained above the approximately 7% threshold below which rumen microbial activity and feed intake are limited (Van Soest, 1994), it was markedly lower than that of the other treatments. Pure forage pea and mixtures containing at least 50% forage pea yielded higher crude protein content (16.50%–26.03%) and relative feed value (142.47–161.63), though their herbage yields ranged from 650.7 to 1031.3 kg da^{-1}. When considering both yield and quality, the mixture of 50% forage pea (cv. Zerre) + 50% triticale emerged as the most favorable option. This mixture provided a herbage yield of 1031.3 kg da^{-1}, a crude protein content of 17.83%, a crude protein yield (183.50 kg da^{-1}) statistically equivalent to the highest-performing group, and a relative feed value (142.47) that places it in the first quality class. In all treatments, the pH values of the silages ranged from 4.12 to 4.64. As the proportion of triticale increased, the dry matter content of the silage rose (20.24%–37.32%), while the crude protein content and relative feed value (RFV) decreased. The highest relative feed values were observed in silages consisting of pure forage pea and a mixture of 75% forage pea (cv. Taşkent) + 25% triticale (162.65–170.42). Pure triticale silage exhibited the lowest crude protein content (9.10%) and the lowest relative feed value (112.78). At the same mixing ratios, combinations containing the 'Zerre' cultivar generally yielded higher quantities of green and dry herbage compared to those containing the 'Taşkent' cultivar. This suggests that the specific forage pea cultivar may influence the performance of the mixture; however, the effect of the cultivar was not explicitly tested in this study.

In conclusion, to produce dry forage under similar ecological conditions, a mixture of 50% forage pea (cv. Zerre) + 50% triticale is recommended, as it provides a balance between yield and quality. In scenarios where yield is the primary objective, mixtures with a higher proportion of triticale may be preferred; however, depending on the class and production level of the animals, the ration may need to be supplemented with protein. For silage production, mixtures with a higher proportion of forage pea yielded a superior nutritional value. Nevertheless, given the low dry matter content of these mixtures, it is advisable to wilt the forage prior to ensiling.

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Conflict of Interest: The authors declare that there is no conflict of interest.

Ethical Consideration: Ethics committee approval was not required for this study, as it did not involve animals or human subjects.

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References

Anil, L., J. Park, R.H. Phipps and F.A. Miller. 1998. Temperate intercropping of cereals for forage: A review of the potential for growth and utilization with particular reference to the UK. *Grass Forage Sci*., 53: 301-317. https://doi.org/10.1046/j.1365-2494.1998.00144.x

Anonymous. 2008. Çeşit tescil raporları 2008. T.C. Tarım ve Orman Bakanlığı, Tohumluk Tescil ve Sertifikasyon Merkezi Müdürlüğü (TTSM), Ankara, Turkey. https://www.tarimorman.gov.tr/BUGEM/TTSM/Belgeler/Yay% C4% B1nlar/1999-2014% 20Tescil% 20Raporlar% C4% B1/% C3% 87e% C5% 9Fit% 20Tescil% 20Raporlar% C4% B1% 202008.pdf (Accessed 15 August 2026). (in Turkish).

Anonymous. 2022a. Yem bezelyesi-2 tescil raporu 2022. T.C. Tarım ve Orman Bakanlığı, Tohumluk Tescil ve Sertifikasyon Merkezi Müdürlüğü (TTSM), Ankara, Turkey. https://www.tarimorman.gov.tr/BUGEM/TTSM/Belgeler/Yay% C4% B1nlar/Tescil% 20Raporlar% C4% B1/2022/Tarla% 20Bitkileri% 20T% C3% BCrleri/% C3% 87ay% C4% B1r% 20Mera% 20ve% 20Yem% 20Bitkileri/Yem% 20Bezelyesi-2% 20Tescil% 20Raporu% 202022.pdf (Accessed 15 August 2026). (in Turkish)

Anonymous. 2022b. Soil analysis results. Kahramanmaraş Sütçü İmam University, University-Industry-Public Cooperation Development Application and Research Center (ÜSKİM), Kahramanmaraş, Turkey.

Anonymous. 2023. Climate data of Kahramanmaraş meteorological station. Turkish State Meteorological Service (Meteoroloji Genel Müdürlüğü), Ankara, Turkey.

Anonymous. 2026. Tritikale çeşit lifleti. Doğu Akdeniz Geçit Kuşağı Tarımsal Araştırma Enstitüsü (DAGTEM), Kahramanmaraş, Turkey. https://arastirma.tarimorman.gov.tr/dagtem/Belgeler/CesitLifletleri/Tritikale_Liflet.pdf (Accessed 15 August 2026). (in Turkish).

Bainard, L.D., B. Evans, E. Malis, T. Yang and J.D. Bainard. 2020. Influence of annual plant diversity on forage productivity and nutrition, soil chemistry, and soil microbial communities. *Front. Sustain. Food Syst*., 4: 560479. https://doi.org/10.3389/fsufs.2020.560479

Ball, D.M., M. Collins, G.D. Lacefield, N.P. Martin, D.A. Mertens, K.E. Olson, D.H. Putnam, D.J. Undersander and M.W. Wolf. 2001. Understanding forage quality. American Farm Bureau Federation Publication 1-01, American Farm Bureau Federation, Park Ridge, IL, USA.

Büyükburç, U. and Y. Karadağ. 2002. The amount of NO_3^--N transferred to soil by legumes, forage and seed yield, and the forage quality of annual legume + triticale mixtures. *Turk. J. Agric. For*., 26: 281-288.

Caballero, R., E.L. Goicoechea and P.J. Hernaiz. 1995. Forage yields and quality of common vetch and oat sown at varying seeding ratios and seeding rates of vetch. *Field Crops Res*., 41: 135-140. https://doi.org/10.1016/0378-4290(94)00114-R.

Carr, P.M., R.D. Horsley and W.W. Poland. 2004. Barley, oat, and cereal-pea mixtures as dryland forages in the northern Great Plains. *Agron. J*., 96: 677-684. https://doi.org/10.2134/agronj2004.0677

Doğan, B.İ. 2013. Yem bezelyesi (*Pisum sativum* L.) + buğday (*Triticum aestivum* L.) karışımlarının verim unsurları ve yem değerlerinin belirlenmesi. M.Sc. Thesis, Namık Kemal University, Graduate School of Natural and Applied Sciences, Department of Field Crops, Tekirdağ, Turkey. (in Turkish).

Duncan, D.B. 1955. Multiple range and multiple F tests. Biometrics, 11: 1-42. https://doi.org/10.2307/3001478.

Ferraretto, L.F., P.M. Crump and R.D. Shaver. 2015. Effect of ensiling time and exogenous protease addition to whole-plant corn silage of various hybrids, maturities, and chop lengths on nitrogen fractions and ruminal *In vitro* starch digestibility. *J. Dairy Sci*., 98: 8869-8881. https://doi.org/10.3168/jds.2015-9511

Górski, R. and A. Płaza. 2023. The proportion of components in field pea and spring triticale mixtures and harvest stage affect crude fiber content and forage digestibility. *Agron. Sci*., 78: 111-122. https://doi.org/10.24326/as.2023.5132

Hall, M.H. and K.D. Kephart. 1991. Management of spring-planted pea and triticale mixtures for forage production. *J. Prod. Agric*., 4: 213-218. https://doi.org/10.2134/jpa1991.0213

Jones, D.B. 1931. Factors for converting percentages of nitrogen in foods and feeds into percentages of proteins. USDA Circular No. 183, United States Department of Agriculture, Washington, DC, USA, pp. 1-21.

Kallida, R., N. Benbrahim, F. Gaboun and M. Ibriz. 2022. Forage yield and quality of vetch-triticale and pea-triticale mixtures under Moroccan conditions. *Acta Fytotech. Zootech*., 25: 294-302. https://doi.org/10.15414/afz.2022.25.04.294-302

Kung, L. Jr., R.D. Shaver, R.J. Grant and R.J. Schmidt. 2018. Silage review: Interpretation of chemical, microbial, and organoleptic components of silages. *J. Dairy Sci*., 101: 4020-4033. https://doi.org/10.3168/jds.2017-13909

Lima, R., M. Lourenço, R.F. Díaz, A. Castro and V. Fievez. 2010. Effect of combined ensiling of sorghum and soybean with or without molasses and lactobacilli on silage quality and *In vitro* rumen fermentation. *Anim. Feed Sci. Technol*., 155: 122-131. https://doi.org/10.1016/j.anifeedsci.2009.10.008

Lithourgidis, A.S., D.N. Vlachostergios, C.A. Dordas and C.A. Damalas. 2011. Dry matter yield, nitrogen content, and competition in pea-cereal intercropping systems. *Eur. J. Agron*., 34: 287-294. https://doi.org/10.1016/j.eja.2011.02.007

Lithourgidis, A.S., I.B. Vasilakoglou, K.V. Dhima, C.A. Dordas and M.D. Yiakoulaki. 2006. Forage yield and quality of common vetch mixtures with oat and triticale in two seeding ratios. *Field Crops Res*., 99: 106-113. https://doi.org/10.1016/j.fcr.2006.03.008

Liu, H., P.C. Struik, Y. Zhang, J. Jing and T.-J. Stomph. 2023. Forage quality in cereal/legume intercropping: A meta-analysis. *Field Crops Res*., 304: 109174. https://doi.org/10.1016/j.fcr.2023.109174

Liu, H., P.C. Struik, Y. Zhang, J. Jing and T.-J. Stomph. 2025. Species combination determines whether forage mixtures gain in dry matter yield or crude protein concentration. A meta-analysis. *Agron. Sustain. Dev*., 45: 39. https://doi.org/10.1007/s13593-025-01035-0

Ma, W., Z. Ju, L. Duan, J. Pan, X. Ma, Z. Jia and X. Ma. 2026. Effects of different mixed sowing ratios of oat and forage pea on forage yield and quality in alpine region. *Front. Plant Sci*., 17: 1803106. https://doi.org/10.3389/fpls.2026.1803106

Ma, Y., C. Xu, G. Lin, Y. Zhao, J. Xiang and T. Wu. 2025. The influence of different oat-pea mixed cropping ratios in a corral coupled with lactic acid bacteria inoculation on silage quality. *Fermentation*, 11: 81. https://doi.org/10.3390/fermentation11020081

Marković, J., S. Andjelković, V. Zornić, I. Kostić, M. Blagojević, T. Vasić and S. Živković. 2020. Cell wall components and *In vitro* dry matter digestibility of ensiled pea:oat mixtures. *Biotechnol. Anim. Husb*., 36: 477-485. https://doi.org/10.2298/BAH2004477M

Maxin, G., D. Andueza and R. Baumont. 2017. Effect of intercropping vetch (*Vicia sativa* L.), field pea (*Pisum sativum* L.) and triticale (×*Triticosecale*) on dry-matter yield, nutritive and ensiling characteristics when harvested at two growth stages. *Grass Forage Sci*., 72: 777-784. https://doi.org/10.1111/gfs.12277

McDonald, P., A.R. Henderson and S.J.E. Heron. 1991. The biochemistry of silage. 2nd Ed. Chalcombe Publications, Marlow, UK.

Mirza, A. and M. Çopur Doğrusöz. 2024. Silage yield and quality of forage peas and Hungarian vetch and triticale binary mixtures. *Selcuk J. Agric. Food Sci*., 38: 434-444. https://doi.org/10.15316/sjafs.2024.039

Odier, E. and B. Monties. 1983. Absence of microbial mineralization of lignin in anaerobic enrichment cultures. *Appl. Environ. Microbiol*., 46: 661-665. https://doi.org/10.1128/aem.46.3.661-665.1983

Önal Aşçı, Ö., Z. Acar and Y. Kaşko Arıcı. 2015. Hay yield, quality traits and interspecies competition of forage pea-triticale mixtures harvested at different stages. *Turk. J. Field Crops*, 20: 166-173. https://doi.org/10.17557/tjfc.83484

Öztürk, D., M. Kızılşimşek, A. Kamalak, Ö. Canbolat and Ç.Ö. Özkan. 2006. Effects of ensiling alfalfa with whole-crop maize on the chemical composition and nutritive value of silage mixtures. *Asian-Aust. J. Anim. Sci*., 19: 526-532. https://doi.org/10.5713/ajas.2006.526

Parra, C.S., D.C. Bolson, F.A. Jacovaci, L.G. Nussio, C.C. Jobim and J.L.P. Daniel. 2019. Influence of soybean-crop proportion on the conservation of maize-soybean bi-crop silage. *Anim. Feed Sci. Technol*., 257: 114295. https://doi.org/10.1016/j.anifeedsci.2019.114295

Pursiainen, P. and M. Tuori. 2008. Effect of ensiling field bean, field pea and common vetch in different proportions with whole-crop wheat using formic acid or an inoculant on fermentation characteristics. *Grass Forage Sci*., 63: 60-78. https://doi.org/10.1111/j.1365-2494.2007.00614.x

Rohweder, D.A., R.F. Barnes and N. Jorgensen. 1978. Proposed hay grading standards based on laboratory analyses for evaluating quality. *J. Anim. Sci*., 47: 747-759. https://doi.org/10.2527/jas1978.473747x

SAS Institute. 2014. SAS 9.4 User's guide. SAS Institute Inc., Cary, NC, USA.

SAS Institute. 2022. JMP® Pro, Version 17. SAS Institute Inc., Cary, NC, USA.

Seydoşoğlu, S. and G. Bengisu. 2019. Effects of different mixture ratios and harvest periods on grass quality of triticale (×*Triticosecale* Wittmack) - forage pea (*Pisum sativum* L.) intercrop. *Appl. Ecol. Environ. Res*., 17: 13263-13271. https://doi.org/10.15666/aeer/1706_1326313271

Soufan, W. and N.A. Al-Suhaibani. 2021. Optimizing yield and quality of silage and hay for pea-barley mixtures ratio under irrigated arid environments. *Sustainability*, 13: 13621. https://doi.org/10.3390/su132413621.

Ülgen, N. and N. Yurtsever. 1995. Türkiye gübre ve gübreleme rehberi. Toprak ve Gübre Araştırma Enstitüsü Müdürlüğü Yayınları, Ankara, Turkey. (in Turkish).

Van Soest, P.J. 1965. Use of detergents in analysis of fibrous feeds. III. Study of effects of heating and drying on yield of fiber and lignin in forages. *J. Assoc. Off. Agric. Chem*., 48: 785-790. https://doi.org/10.1093/jaoac/48.4.785.

Van Soest, P.J. 1994. Nutritional ecology of the ruminant. 2nd Ed. Cornell University Press, Ithaca, NY, USA. https://doi.org/10.7591/9781501732355.

Van Soest, P.J., J.B. Robertson and B.A. Lewis. 1991. Methods for dietary fiber, neutral detergent fiber, and nonstarch polysaccharides in relation to animal nutrition. *J. Dairy Sci*., 74: 3583-3597. https://doi.org/10.3168/jds.S0022-0302(91)78551-2.

Weinberg, Z.G. and G. Ashbell. 2003. Engineering aspects of ensiling. *Biochem. Eng. J*., 13: 181-188. https://doi.org/10.1016/S1369-703X(02)00130-4.

Yıldırım, S. and A. Özaslan Parlak. 2016. Tritikale ile bezelye, bakla ve fiğ karışım oranlarının belirlenerek yem verimi ve kalitesine etkileri. *ÇOMÜ Zir. Fak. Derg*., 4: 77-83. (in Turkish).

Zadoks, J.C., T.T. Chang and C.F. Konzak. 1974. A decimal code for the growth stages of cereals. *Weed Res*., 14: 415-421. https://doi.org/10.1111/j.1365-3180.1974.tb01084.x