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Silage Quality and Economic Efficiency Analysis of Hungarian Vetch (*Vicia pannonica* Crantz) and Oats (*Avena sativa* L.) Mixed at Different Ratios

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ABSTRACT

Background: In this study, it was aimed to compare Hungarian vetch and oats mixed at different ratios not only in terms of silage quality but also in terms of their economic efficiency. "Anadolu Pembesi" Hungarian vetch variety and "Albatros" oat variety were used as plant material in the experiment.

Methods: Research was carried out during the winter of 2020-2021 on a farmer field in the Kızıltepe district of Mardin province (Turkiye). In the study, 100% Hungarian vetch, 100% oat, 70% Hungarian vetch + 30% oat, 60% Hungarian vetch + 40% oat, 50% Hungarian vetch + 50% oat, 30% Hungarian vetch + 70% oat silages were tested. Besides silage quality, input-cost analysis and comparison in terms of economic efficiency were also made in the study.

Result: Ph value, dry matter, crude protein ratio, acid detergent insoluble fiber, neutral detergent insoluble fiber, digestible dry matter, dry matter consumption, relative feed value and lactic acid ratio varied between 3.88-4.11; 25.02-29.24%; 12.17-19.64%; 31.34-40.24%; 45.27-55.14%; 57.55-64.49%; 2.18-2.65%; 97.15-132.58 and 1.82%-2.38%, respectively. When all the features are evaulated together, 70% Hungarian vetch + 30% oat silage mixture was recommended due to high crude protein ratio, high relative feed value and lactic acid ratio in between low acid detergent insoluble fiber and neutral detergent insoluble fiber ratios. On the other hand, 50% HVS + 50% OS and 60% HVS + 40% OS mixtures stand out as balanced options in terms of both economic gain and quality. This ratio represents the economic optimum point in roughage production and offers an important alternative in the creation of sustainable feed resources.

Key words: Economic analysis, Efficiency, Mixture ratios, Silage quality.

INTRODUCTION

In semi-arid regions of the world, livestock productivity is constrained by forage availability (Ibrahim *et al*., 2014). In summer, there is some residual dry standing pasture available, but the quality of the forage is only moderate; later in the season, there is a further fall in quality along with a decline in availability. In winter, pasture quality is often high but availability is low. To provide the additional energy (and crude protein, or CP), needed for maintenance and productivity, farmers supplement grazing animals with hay, silage, grain and/or meals (Piltz *et al*., 2011). Due to a lack of nutrient-rich fodder, livestock development is delayed in rainfed locations. Due to the lack of protein in cereals, mono-cropping systems can negatively affect forage productivity and nutrition (Sohail *et al*., 2021). Production of high-yielding quality forage remains a challenge in arid and semi-arid conditions (Sadeghpour *et al*., 2013).

Forage crops, as one of the basic inputs of animal production, are of great importance for sustainable productivity and profitability, especially in ruminant nutrition. Insufficient supply of quality roughage resources increases feeding costs and negatively affects the yield per animal (Açıkgöz, 2001). Therefore, it is necessary to increase the production of fodder crops and to utilize the available resources more efficiently. Especially in semi-arid regions, developing strategies to close the feed gap is a critical factor for the sustainability of animal production (Kandemir *et al*., 2010). Also, by growing appropriate plant species together, nutrient content is enriched and soil fertility is maintained, contributing to sustainable agriculture (Yılmaz *et al*., 2019). For this reason, fodder crops have a strategic role in strengthening not only the livestock sector but also the overall structure of the agricultural economy.

One of the most well-known ways to conserve fodder is ensiling (Fabiszewska *et al*., 2019). Ensilage is a fermentative technique that uses a number of different types

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of microorganisms to preserve animal feed (forage, cereal grains and byproducts). According to Ávila and Carvalho (2019), the primary species responsible for the pH decrease and preservation of the ensiled material is lactic acid bacteria. Ensiling's primary problem is preserving the feed through a fermentative process that produces food that is high in nutritional value and microbial purity while minimizing fermentative losses (Carvalho *et al*., 2021). The largest fermentation process in use today is silage. To generate more high-quality silage that is a good source of protein and energy for dairy and beef cow farmers. The key factors influencing the feeding value of silages include crop characteristics, stage of crop development at ensiling and the extent and type of fermentation achieved within the silo (Acosta Aragon *et al*., 2012).

Due to their high dry matter output and low price, cereals play a significant role in the nutrition of ruminant animals. However, the low protein level of cereals forage reveals their poor quality and nutritional worth. Legumes can be employed in animal nutrition due to their high protein content and potential cost savings in relation to high feed costs for protein supplements. Due to their low dry matter production, legumes can produce feed with a better yield and quality when combined with cereals than when grown as a solitary crop (Eskandari *et al*., 2009).

Legumes have larger intakes than grass silages with comparable digestibility because to the rapid rates of rumen fermentation, physical breakdown and passage from the rumen of legume silages (Dewhurst, 2013). Legume forages play a significant role in the production of ruminants in many nations and, with future development, might do so much more. Legumes have different cell structures than other plants, which when combined with high fermentation rates causes them to break down into minute particles in the rumen and leave the rumen more quickly than perennial ryegrass. This increased intake of legume silages reflects these characteristics. High rates of intake are caused by easy swallowing, which accounts for the greater intakes of grazed legumes. Legumes' slower rate of digestibility drop with maturation is an additional advantage. Legumes have often led to a reduction in methane production from the rumen and again, this relates to both physical and chemical differences between forage species. The high concentration of rapidly degraded protein in legumes also leads to inefficient utilisation of dietary N and increased urinary N output (Dewhurst *et al*., 2009).

In Türkiye, oats were planted on 3.740.583 decares in 2021, with a production of 3.752.850 tons. In the Southeastern Anatolia Region, oat cultivation covered 310 decares and produced 132 tons. Hungarian vetch was grown on 810.911 decares nationwide, producing 1.097.255 tons. In the same region, Hungarian vetch covered 9.500 decares and yielded 8.561 tons (TUIK, 2021).

Economic analyses are essential for identifying production models that provide sustainable income while ensuring efficient use of resources (Hazell and Norton, 1986; Erkuş *et al*., 2013). Particularly in semi-arid regions, the identification of high-quality and economically sustainable feed resources directly affects the profitability of livestock production.

The aim of this study was to investigate the silage and feed quality of whole-crop of Hungarian vetch (*Vicia pannonica* Crantz) and oat (*Avena sativa* L.) mixed in different ratios under semi-arid highland conditions of Türkiye. Additionally, forage crops need to be evaluated not only in terms of silage quality, but also in terms of feed yield obtained from unit area, input costs and economic return. Thus, it is important to evaluate the silage obtained by intercropping complementary forage crops such as Hungarian vetch and oats with economic indicators such as unit cost, gross income, net income and profitability ratios as well as feed quality. Thus, producers can be offered mix ratios that are not only nutritious but also economically advantageous. In this study, it is aimed to compare Hungarian vetch and oat grown by mixing at different rates in terms of input-cost analysis and economic efficiency as well as silage quality.

MATERIALS AND METHODS

Experimental design and silage quality analysis

The research was carried out in a farmer field in the Kızıltepe district of Mardin province of Turkiye in the winter season of 2020-2021. "Anadolu Pembesi" Hungarian vetch variety and "Albatros" oat variety were used as plant material in the experiment. Hungarian vetch and oats were planted as sole crops each on 0.5 ha field on 07.11.2020. Both crops were planted with a grain seeder. Oats seeding ratio was 200 kg per hectare. Oats recieved 36 kg ha^{-1} N and 92 kg ha^{-1} P_2O_5 in DAP (18.46.0) fertilizer form as base fertilizer applied at sowing. In the spring, 69 kg ha^{-1} N in urea (46% N) fertilizer form was applied on 01.03.2021. Hungarian vetch seeding ratios was 130 kg per hectare. Hungarian vetch recieved 2.7 kg da^{-1} N and 6.9 kg da^{-1} P_2O_5 in DAP (18.46.0) base fertilizer form at sowing. No topdressing fertilizer was applied. When climatic data of Mardin province was evaluated, it was determined that there was no extremety for cultivation of both crops.

The Hungarian vetch was harvested on 20.05.2016 during the flowering period of the oat ear emergence period. Hungarian vetch and oats were harvested separately on the same day with the help of reaping-hook in an area of 10 m^2 and plant materials were transported to the warehouse in bunches. Grass was kept in the shade for 3-4 hours to reduce humdity for an ideal silage. Then, all green plants were chopped in 0.5-1.0 cm sizes with the silage shredder machine working with the tail axle of the tractor. After the chopping process was completed, Hungarian vetch and oat varieties were weighted for the mixture ratios, filled into embossed bags (3 repetitions) in a homogeneous manner and the bags were closed by removing the air inside with a kitchen vacuum machine. 100% Hungarian vetch, 100% oats and mixture ratios of 70% Hungarian vetch + 30%

oats, 60% Hungarian vetch + 40% oats, 50% Hungarian vetch + 50% oats, 30% Hungarian vetch + 70% oats were the applications. Bags were left for fermentation in a dark room for 60 days.

In order to measure the pH of the silages, samples were taken from the watery parts at the bottom of the plastic drums and mixed with a blender and the pH of the obtained liquid was measured with a digital pH meter (Anonymous, 1993). Then, the silage dry matter ratio was calculated by pre-drying 500 g silage samples in a drying cabinet at 70°C for 12 hours (Bulgurlu and Ergül, 1978). After the silage was dried, grinding was applied. The determination of raw ash (Weender Analysis method), crude protein (Kjendahl Method), acid detergent insoluble fiber (ADF) and neutral detergent insoluble fiber (NDF) (Ankom fiber method) were conducted on these samples. Digestible dry matter (DDM), dry matter consumption (DMC) and relative feed value (RFV) in silage were calculated with the help of 1-3 equations (Morrison, 2003).

$$DDM = 88.9 - (0.779 \times \%ADF) \quad ... (1)$$

$$DMC = \frac{120}{\%NDF} \quad ... (2)$$

$$RFV = \frac{(DDM \times DMC)}{1.29} \quad ... (3)$$

For the statistical evaluation of the data obtained in the study, the statistical package program JUMP was used for analysis of variance according to the Random Plots Trial Design (Kalaycı, 2005).

Economic analysis and agricultural productivity assessment

In this study, not only the silage quality but also the economic performance in terms of agricultural production of Hungarian vetch (*Vicia pannonica* Crantz) and oat (*Avena sativa* L.) mixed at different rates were evaluated. As part of the economic analysis, input costs, yield, gross income, net income and profitability ratio were calculated for each mix ratio. Economic analysis is an important tool for analyzing the efficient use of resources in agriculture and determining production patterns that maximize farmers' income (Hazell and Norton, 1986; Erkuş *et al*., 2013).

For each mix ratio, all variable inputs such as seed quantities used, fertilizer consumption, irrigation (if any), labor, harvesting, transportation and silage making were recorded. Inputs prices were obtained from farmers in the region and market values during the 2024 production season. Economic data and pricing used in the study are expressed in Turkish Lira (₺).

Economic analysis included the calculation of the following economic indicators for each application:

Total production cost (₺/da)

Total cost of inputs such as seed, fertilizer, labor, machinery and silage production.

Gross income (₺/da)

It was obtained by multiplying the silage yield (tons/da) obtained per decare for each mixture treatment by the average silage sales price (₺/ton) in the region.

Gross income (₺/da)= Yield (tons/da) × Silage price (₺/ton)

Net Income (₺/da)

Calculated by subtracting total production cost from gross income.

Net income (₺/da) = Gross income - Total cost

Profitability ratio (%)

Calculated as the ratio of net income to total costs.

$$\text{Profitability ratio (\%)} = \frac{\text{Net income}}{\text{Total cost}} \times 100$$

Unit Cost (₺/ton)

It shows the total cost for one ton of silage production.

$$\text{Unit cost (₺/ton)} = \frac{\text{Total cost}}{\text{Yield}}$$

These indicators were used to provide a comparative picture of the possibilities for rural producers to obtain high quality forage at lower cost. Besides, it is also important in terms of developing sustainable forage crop production models in terms of agricultural economy and promoting the rational use of resources (Boz and Akbay, 2005; FAO, 2017).

RESULTS AND DISCUSSION

In the study, not only the silage quality but also the economic returns of mixtures of Hungarian vetch (*Vicia pannonica* Crantz) and oat (*Avena sativa* L.) plants in different ratios were evaluated together. This holistic approach aims both to determine the optimal mix ratios in terms of quality in animal nutrition and economic sustainability.

Effects of mixture ratios on silage quality parameters

When Table 1 is examined, the effect of mixing ratios on silage pH value was found to be significant. Silage pH value was reported as it is one of the most important factors affecting silage fermentation, where the most suitable pH range for lactic acid bacteria growth in acid environment is 3.80-4.20. Bacteria types that cause deterioration and decay cannot survive in silage with a value in this pH range (Ergün *et al*., 2013).

As the easily fermentable carbohydrate content increases, the appropriate acidity required for a good silage is provided. Therefore, as the oat content in the mixture increases, the pH of the silage decreases. This is an expected situation. Similar finding was reported (Altınok, 2002; Bengisu, 2019; Demirel *et al*., 2010; Seydosoglu, 2019). After extraction of water from plant tissues, the remaining part consists of dry matter and other nutrients (proteins, carbohydrates, minerals and vitamins). The feeding of ruminant animals is generally managed by considering the dry matter content of the feeds. This calculation allows to determine the required amount of feed per animal. In this respect, the dry matter ratio in roughage is of great importance. Açıkgöz (1995) reported that the dry matter ratio should be 23.5% and above in a good quality silage. In the study, it was determined that the effect of the mixing ratios on the dry matter ratio was significant (Table 1). While the highest dry matter content was obtained from 100% oat silage with 29.24%, the lowest dry matter value was obtained from 100% Hungarian vetch silage (23.42%). As the ratio of oats in the mixture increased, the dry matter ratio increased from 25.41% to 28.75%. The main reason for this change may be the high content of water-soluble carbohydrates in the tissues of grasses. Many researchers have reported that the dry matter ratio increases with the increase in the grain ratio in the mixture (Fayetörbay *et al*., 2011; Güre, 2016; Arslan *et al*., 2017). In this study, it was determined that the effect of the mixture ratios on the crude protein ratio was significant. While the highest crude protein value of silage was obtained from 100% Hungarian vetch silage with 19.64%, the lowest crude protein value of silage was obtained from 100% oat silage. It was determined that as the legume ratio in the mixture increased, the crude protein ratio increased. This is due to the high protein content of legumes. Findings from several researchers, Demirel *et al*. (2003) and Aykan and Saruhan (2018) indicate that crude protein ratios increase when legume ratio increases in cereal-legume silage mixtures.

ADF are poorly digestable or indigestible parts of fiber such as cellulose and lignin. When ADF is low, feed has a highly digestible feature and be defined as high quality feed (Anonymous, 2015a). As a result of the excessive amount of ADF given, the expected efficiency from the animals cannot be obtained due to the decrease in feed intake due to the energy density. On the other hand, administration of a small amount of ADF may cause serious fatal diseases such as acidosis, abomosum diplasia, laminitis, decreased milk fat ratio and decreased body condition due to the change in fermentation in the rumen (Avellaneda *et al*., 2009; Yang *et al*., 2009). NDF indicates the entire cell wall, that is, the total amount of digestible and non-digestible fiber in the feed. High NDF indicates a low level of feed intake and low NDF indicates a high level of feed intake. The higher the NDF, the thicker the plant cell wall (Anonymous, 2015b). In this study, it was determined that the mixture ratios was significantly effective on the ADF and NDF contents of silages. It was determined that the ADF content decreased from 34.81% to 37.25% and the NDF content decreased from 49.02% to 52.34% as the legume content in the mixture increased (Table 2). When the NDF ratio exceeds 32% on the basis of dry matter, feed intake is limited by rumen capacity and the flora in the rumen shifts towards cellulotic microorganisms. This is not a desired situation in the rumen flora (Khafipour *et al*., 2009; Tekce and Gul, 2014). The fact that legume forage plants have a high value in terms of protein is the

Table 1: Silage pH, Dry matter ratios and silage crude protein ratios of hungarian vetch and oat silages.

Applications	Silage pH values	Dry matter ratios	Silage crude protein ratio
100% Hungarian vetch	4.11[a]	23.42[d]	19.64[a]
100% Oat	4.02[ab]	29.24[a]	10.74[f]
60% Hungarian vetch + 40% oat	4.00[ab]	25.02[cd]	16.23[b]
70% Hungarian vetch + 30% oat	3.99[bc]	25.41[cd]	17.05[b]
30% Hungarian vetch + 70% oat	3.96[bc]	28.75[a]	12.17[e]
40% Hungarian vetch + 60% oat	3.93[bc]	27.49[ab]	13.38[d]
50% Hungarian vetch + 50% oat	3.88[c]	26.23[bc]	14.82[c]
Average	3.98	26.51	14.86
CV	1.51	4.3	9.87
LSD (Aplication)	0.11	1.99	0.83

Table 2: ADF, NDF and digestible dry matter contents of hungarian vetch and oat silages.

Applications	ADF ratios of silages	NDF ratios of silages	Digestable dry matter content
100% Hungarian vetch	31.34[c]	45.27[e]	64.49[a]
100% Oat	40.24[a]	55.14[a]	57.55[c]
60% Hungarian vetch + 40% oat	35.47[b]	49.26[d]	61.27[b]
70% Hungarian vetch + 30% oat	34.81[b]	49.02[d]	61.78[b]
30% Hungarian vetch + 70% oat	37.25[b]	51.76[bc]	59.88[b]
40% Hungarian vetch + 60% oat	36.12[b]	52.34[b]	60.76[b]
50% Hungarian vetch + 50% oat	36.28[b]	50.48[cd]	60.64[b]
Average	35.93	50.46	60.91
CV	3.95	2.04	1.80
LSD (aplication)	2.48	1.79	1.92

Table 3: Dry matter intake, relative feed value and lactic acid content of hungarian vetch and oat silages.

Applications	Dry matter consumption	Relative feed value	Lactic acid
100% Hungarian vetch	2.65[a]	132.58[a]	1.82[c]
100% Oat	2.18[d]	97.15[d]	2.38[a]
60% Hungarian vetch + 40% Oat	2.44[b]	115.72[b]	2.34[a]
70% Hungarian vetch + 30% Oat	2.45[b]	117.26[b]	2.02[bc]
30% Hungarian vetch + 70% Oat	2.32[c]	107.65[c]	2.20[ab]
40% Hungarian vetch + 60% Oat	2.29[c]	108.00[c]	2.18[ab]
50% Hungarian vetch + 50% Oat	2.38[bc]	111.80[bc]	2.24[ab]
Average	2.39	112.88	2.17
CV	1.68	2.90	7.41
LSD (aplication)	0.09	5.71	0.28

Table 4: Market unit prices of inputs used (2024).

Input	Price (₺/quantity)
Silage price	2.800 ₺/ton
Oat seeds	17 ₺/kg
Hungarian vetch seed	60 ₺/kg
DAP fertilizer (18-46-0)	23 ₺/kg
Urea fertilizer (46% N)	20 ₺/kg
Irrigation (if available)	50 ₺/da
Labor (planting/harvesting)	500 ₺/da
Diesel + machine depreciation	350 ₺/da
Silage making (chopping, vacuum, bagging)	200 ₺/da
Transportation	150₺ /ton
Other	500₺/da

References: TOB, (2024a).

* Based on market conditions in Mardin province and its surroundings.

explaination of this situation. Because proportionally, the ratio of substances forming the cell wall decreases depending on the increase in intracellular content (Carr *et al*., 2004). It was reported that the ADF ratio of barley harvested during the milking period is lower than the forage pea plant harvested during the flowering period (Aykan and Saruhan, 2018). In terms of digestible dry matter ratios, which is one of the most important quality indicators of roughage, the highest was obtained from 100% Hungarian vetch, while the lowest DDM ratio was obtained from 100% oat silage (Table 2). As other examples; Aydin *et al.* (2015), reported that approximately 65% of some wild annual alfalfa species collected from different geographical locations which supports our findings.

When the DMC values are examined (Table 2), the highest DMC ratio was obtained from 100% Hungarian vetch silage with 2.65%, while the lowest DMC ratio was obtained from 100% oat silage with 2.18%. In the hay trade, the picture has not changed in terms of relative feed values by Redfearn *et al*. (2012), which is the most important criterion in determining the price of hay. While the highest relative feed value was obtained from 100% Hungarian vetch silage with 132.58, the lowest relative feed value was obtained from 100% oat silage with 97.15 (Table 3).

Lactic acid bacteria are the most important members of microorganisms in silage during fermentation period. The amount and composition of organic acids during silage fermentation determines the quality of fermentation (Filya, 2002). It was reported by many investigators that lactic acid ratio should be higher than 2% in a quality silage (Kilic, 1986; Alcicek and Ozkan, 1997). The results obtained were close to 2%.

Economic analysis of feed mixtures

In the study, in addition to silage quality, economic efficiency of Hungarian vetch (*Vicia pannonica* Crantz) and oat (*Avena sativa* L.) planted at different mixture ratios was also evaluated. Accordingly, basic economic indicators such as total production cost, gross income, net income, unit cost and profitability ratio were calculated for each mix treatment. Profitability ratio was calculated as the ratio of net income to total costs and reflected the economic efficiency of production. Also, the unit cost (₺ /ton) value allowed an evaluation in terms of cost-effectiveness by expressing the expenditure made for one ton of silage production.

All prices used in the economic analysis are based on market conditions in and around Mardin province as of 2024 (Table 4). Especially seed, fertilizer and service inputs are important items that directly affect the cost of production. Hungarian vetch seed (60 ₺ /kg) is a high-cost input, while oat seed (17₺ /kg) is lower cost. Other fixed inputs include labor, diesel, silage making and transportation costs.

The total costs of production in 1 decare area according to different mixture ratios are presented in Table 5. According to the findings, total production cost decreases as the Hungarian vetch ratio decreases. While the total cost was 2,825₺ /ha in the scenario with 100% Hungarian vetch, this value decreased to 2,685₺ /ha in the 100% oat mixture (Table 5). This difference is mainly due to the cost of seed.

Gross income was calculated based on the yield (tons/ha) obtained for each mix ratio, taking into account the silage sale price (Table 6). The lowest yield was obtained from 100% Hungarian vetch (2.25 tons/ha) and the highest yield was obtained from 100% oat (100% OS) (3.6 tons/ha). Along with yields, gross income and net income values also increased. According to these results, the highest net income was obtained in 100% oat cultivation.

The profitability ratio shows the economic efficiency of production. While this ratio was 123% for 100% Hungarian vetch, it reached 275.4% for 100% oat mixture. Increasing oats in the mix ratios significantly increased profitability. Unit cost (₺ /ton) represents the total expenditure for one ton of silage production and was the lowest (746₺/ton) in the 100% oats scenario. This shows the cost-effectiveness of oats. Additionally, as the proportion of Oats increases, both yield and net income increase, thus increasing the rate of profitability.

Additionally, as the proportion of Oats increases, both yield and net income increase, thus increasing the rate of profitability. As a result of the economic analysis, 100% oat mixture was the most economically advantageous option with both the highest net income (7,395₺/da) and the lowest unit cost (746₺ /ton). However, an integrated approach should be adopted when determining mixing ratios, taking into account both nutritional value and cost-effectiveness analysis.

In the study, 100% Hungarian vetch had the highest values in terms of silage quality, but offered the lowest economic profitability. While 100% oats are the most economically profitable option, they are of lower quality, especially in terms of protein, digestibility and RFV. On the other hand, 50% HVS + 50% OS and 60% HVS + 40% OS mixtures stand out as balanced options in terms of both economic gain and quality. Moreover, these mixtures provide adequate protein levels, acceptable digestibility and high economic returns (Table 7).

Considering both cases together, a 50% HVS + 50% OS mix offers the optimal balance in terms of both efficiency and quality. Such stabilizing mixtures are important for quality-sensitive livestock enterprises such as milk and meat production. For producers focused solely on reducing feed costs, 100% oats may be economically attractive, but this may negatively impact animal performance in the long term.

Table 5: Production costs according to mix ratios.

Mixing ratio (HVS*+OS**)	Seed (₺)	DAP (₺)	Urea (₺)	Other inputs (₺)	Total cost (₺/da)
100% HVS	780	345	0	1.700	2.825
70% HVS+ 30% OS	651	345	90	1.700	2.786
60% HVS + 40% OS	606	345	120	1.700	2.771
50% HVS+ 50% OS	560	345	150	1.700	2.755
30% HVS + 70% OS	470	345	210	1.700	2.725
100% OS	340	345	300	1.700	2.685

* Hungarian vetch seed= Calculated as 13 kg/da × 60 ₺ /kg.

** Oat seed= Calculated as 20 kg/da × 17 ₺ /kg.

Table 6: Economic evaluation according to different mixtures (for 1 decare).

Mixing ratio (HVS* + OS**)	Yield (ton/da)	Silage price (₺ /ton)	Gross revenue (₺)	Total cost (₺)	Net income (₺)	Profitability ratio (%)	Unit cost (₺/ton)
100% HVS	2.25	2.800	6.300	2.825	3.475	123.0	1.256
70% HVS + 30% OS	2.80	2.800	7.840	2.786	5.054	181.5	995
60 HVS% + 40% OS	3.10	2.800	8.680	2.771	5.909	213.2	894
50% HVS + 50% OS	3.35	2.800	9.380	2.755	6.625	240.4	822
30% HVS + 70% OS	3.50	2.800	9.800	2.725	7.075	259.6	779
100% OS	3.60	2.800	10.080	2.685	7.395	275.4	746

* Hungarian vetch seed.

** Oat seed.

Table 7: Effect of different mixture ratios on silage quality and economic performance.

Mixing ratio	Net income (₺/da)	Profitability (%)	CP (%)	RFV	DM (%)	DDM	Unit cost (₺/ton)
100% HVS	3.475	123	19.64	132.58	23.42	Highest	1.256
70% HVS + 30% OS	5.054	181.5	High	>120	Middle	High	995
60% HVS + 40% OS	5.909	213.2	Middle+	>115	Middle+	Middle+	894
50% HVS + 50% OS	6.625	240.4	Middle	>110	27.22	Middle	822
30% HVS + 70% OS	7.075	259.6	Low+	~100	28.75	Low+	779
100% OS	7.395	275.4	Lowest	97.15	29.24	Lowest	746

CP: Crude protein; RFV: Relative feed value; DM: Dry matter; DDM: Digestible dry matter.

An economic assessment in the relation to sustainable agriculture and livestock policies

Livestock sustainability in semi-arid regions is directly related not only to feed efficiency but also to economic production processes (Koç and Gül, 2018). In this study, when the technical and economic performances of different mixture ratios are considered, it is seen that especially the 50% Hungarian vetch + 50% oat mixture stands out with both high net income and low unit cost. This ratio represents the economic optimum point in roughage production and offers an important alternative in the creation of sustainable feed resources.

In Türkiye, it is reported that there is an annual roughage deficit of approximately 8-10 million tons (TAGEM, 2022). Thus, such economically advantageous mix models at the regional level can play a strategic role in reducing the feed deficit and reducing dependence on feed imports. Especially in areas with high livestock potential but limited feed production, such as Eastern and Southeastern Anatolia, such mixtures can be considered as a cost-effective and local solution (Duru *et al*., 2019). Also, silage production with legume and cereal mixtures contributes to sustainable production systems both in terms of increasing soil fertility (biological nitrogen fixation) and providing protein balance in animal nutrition (Kacar and Katkat, 2010; Dewhurst *et al*., 2009). Accordingly, increasing the incentives of agricultural policies to support fodder crops production will increase both producer income and the quality of animal production by disseminating economically optimum mixing ratios (TOB, 2024b).

Using forage crops as a mixture provides both balanced silage production in terms of nutritional value and supports economic sustainability. In the literature, it is reported that it is appropriate to use legumes at a maximum rate of 75% in order to increase the crude protein content in silages and this ratio is also advantageous in terms of the plants having similar vegetation periods (Kavut *et al*., 2014). In different legume-grain mixtures, legume ratios ranging between 50-75% give optimum results both technically (feed quality) and economically (cost/profitability). Therefore, the use of legumes in certain proportions with cereals can be considered an important strategy for sustainable livestock production (Avci and Koç, 2021; Aydın *et al*., 2015).

In this study, Hungarian vetch and oat mixtures were evaluated; although the highest crude protein rate was obtained in 100% vetch treatment, the highest net income and balanced feed quality were obtained in 50% Hungarian vetch + 50% oat ratio. However, it is seen that mixtures containing 60-70% Hungarian vetch are also preferable for producers who want to obtain silage richer in protein.

CONCLUSION

As a result, it can be concluded that, a maximum of 75% legumes will be required in order to increase the crude protein content of the silages obtained by mixing the barley and grass pea. These two crops get mature close to each other during the vegetation periods. In terms of quality, the best result was obtained from 75% Hungarian Vetch + 25% oat. Besides, as a result of the economic analysis, cereal-legume mixtures stand out as an important alternative feed source to support sustainable animal husbandry activities in semi-arid areas by providing advantages in terms of both silage quality and economic performance. In particular, a 50% vetch + 50% oat mix could be specially promoted in fodder crop support programs as a strategic combination that provides both economic sustainability and feed quality together. Moreover, agricultural production planning in areas with limited rainfall can be revised based on this model.

Conflıct of ınterest

The authors declare that they have no conflict of interest.

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