Yield and Quality Characteristics of Forage Pea Varieties at Different Phenological Stages

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Abstract: Agricultural areas that rely on a single crop for production experience negative soil characteristics, while the benefits of these locations are further diminished by short-term winter fallows. In the ecological conditions of the Aegean Region, cotton-cotton and maize-maize production patterns can be given as examples of this type of production. With the adoption of a sustainable agriculture approach in recent years, the use of winter annual forage crops is quite important in terms of preventing this situation. The inclusion of forage pea in the production patterns both contributes positively to the soil properties and is a potential source of quality roughage. In line with this information, 8 different forage pea varieties (Kirazlı, Ulubatlı, Ürünlü, Gölyazı, Özkaynak, Töre, Taşkent, GAP Pembesi) were harvested at 3 different phenological stages (10%, 50%, 100% flowering) in Aydın ecological conditions. Some agronomic characteristics such as plant height (cm), stem diameter (mm), herbage yield (kg da^{-1}) were measured in the experiment. After the measurements, ADF (%), NDF (%), ADL (%), protein properties and relative feed value were determined. While lower values were found in terms of yield and fiber values in early mowing, higher values were found in terms of crude protein ratio and relative feed value. At the same time, the variety-environment interactions showed differences in both years. Our results demonstrated that 100% flowering is preferable in terms of yield. Differences were observed among the varieties according to yield and quality characteristics. In terms of herbage and crude protein yields, Töre, Taşkent and GAP Pembesi were the most prominent common varieties. In terms of relative feed value, Ulubatlı and Ürünlü are the varieties with high values.

Keywords: Moving time, forage quality, legume forage crops, forage yield

Yem bezelyesi çeşitlerinin farklı fenolojik dönemlerdeki verim ve kalite özellikleri

Öz: *Tek ürüne dayalı üretim yapılan tarımsal alanlarda toprağın bazı özelliklerinde görülen olumsuzluklar yanında kış aylarında kısa süreli nadas yapılması bu alanlardan elde edilecek faydayı azaltmaktadır. Ege Bölgesi ekolojik koşullarında bu tür üretime pamuk-pamuk ve mısır-mısır üretim deseni örnek verilebilir. Son yıllarda sürdürülebilir tarım anlayışının benimsenmesi ile kışlık tek yıllık yem bitkilerinin kullanılması bu durumu önleme açısından oldukça önemlidir. Yem bezelyesinin üretim desenlerine alınması ile yılda ikili üretimin tercih edilmesi hem toprağın özelliklerine hem de kaliteli kaba yem kaynağı varlığımıza olumlu katkı sağlamaktadır. Bu bilgiler doğrultusunda Aydın ekolojik koşullarında 8 farklı yem bezelyesi çeşidi (Kirazlı, Ulubatlı, Ürünlü, Gölyazı, Özkaynak, Töre, Taşkent, GAP Pembesi) 3 farklı fenolojik dönemde (%10, %50, %100 çiçeklenme) biçim uygulamasına tabi tutulmuştur. Denemede bitki boyu (cm), gövde çapı (mm), kuru ot verimi (kg da^{-1}) gibi bazı agronomik özellikler incelenmiştir. Bu ölçümlerin ardından ADF, NDF, ADL, protein özellikleri ve nispi yem kalitesi belirlenmiştir. Erken dönem yapılan biçimlerde verim ve lif değerleri bakımından daha düşük değerler tespit edilirken ham protein oranı ve nispi yem değeri açısından daha yüksek değerler tespit edilmiştir. Aynı zamanda çeşitlerin çevre interaksyonu her iki yılda da farklılıklar göstermiştir. Netice olarak %100 çiçeklenmenin verim bakımından tercih edilebilir değerlerde olduğu görülmektedir. Verim ve kalite özelliklerine göre çeşitler arasından farklılıklar görülmektedir. Kuru ot ve ham protein verimleri açısından Töre, Taşkent ve GAP Pembesi öne çıkan ortak çeşitler olmuştur. Nispi yem değeri açısından Ulubatlı ve Ürünlü yüksek değerlere sahip çeşitler olma özelliği taşımaktadır.*

Anahtar kelimeler: *Biçim zamanı, yem kalitesi, baklagil yem bitkileri, yem verimi*

INTRODUCTION

Population growth, increasing temperature, changing climate and rainfall irregularities indicate that the ongoing systems in agricultural production need to change (Yaraşır et. al. 2018; Yiğit et. al. 2021). In Türkiye, a few traditional forage crops such as alfalfa, sainfoin and common vetch from legumes are cultivated. Livestock farming is largely based on natural rangelands, stubble and cereal straw. In the country, forage crops have the opportunity to be cultivated as the main and second crops in coastal regions, and central-transitional regions due to various climatic and soil characteristics (Dok et. al. 2016). While legume forage crops stand out with many advantages such as nitrogen fixation, soil improvement, and positive contribution to the main crop, they are also a source of quality roughage (İleri et. al. 2020). Forage pea is one of these species. Grown for grain or hay production in temperate climatic zones, forage pea (*Pisum sativum* ssp. *arvense* (L.) Moench.) is a major cool season leguminous forage species. The plant could be produced as an intermediate crop in addition to the main crop in cool climates (Sarıkaya et. al. 2023). Forage pea offer a flexible option to the producer in double-annual sowing environments due to their fast growth in a short time, tasty and rich nutritional value for livestock (Koivisto et. al. 2003). Mowing time in forage pea cultivation has an important effect on the forage production process. Early mowing time

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usually coincides with a period when the pea plant is young and tender. Peas harvested at this time have a finer and softer texture, making them more easily digestible as roughage (Türk and Albayrak, 2012). The degree of digestion of forages decreases due to the increase in the amount of cellulose and lignin as the plant ages. The protein content of the plant in the vegetative stage is higher than the plants that have completed their growth. Because as the plant matures, the ratio of protein-rich leaves to protein-poor stems decreases. Therefore, protein content decreases as the plant matures (Aydoğan et. al. 2014). In general, dry matter yield and stalk ratio of legume forage crops increase as the harvest period is delayed, while the leaf ratio decreases. Decreased leaf/stem ratio also decreases the quality, and the crude cellulose ratio increases in parallel with the increase in the stem ratio (Gürsoy and Macit, 2020). Indigestible substances such as ADF and NDF increase with maturation while crude protein ratio decreases (Özen, 1999). The optimum mowing time should be carefully selected to both increase the amount of forage and maximize its nutritional value. This process may vary depending on the feeding habits of the livestock, climatic conditions and the variety of peas grown. Pea mowing periods is an important factor in determining the strategy of forage producers to obtain a good quality and digestible forage to be used in feeding animals. Forage pea as a winter intermediate use is very popular, especially in the Aegean Region where maize-maize and cotton-cotton production patterns are common. In this study, the most suitable mowing period of forage pea to be grown as winter crops was determined depending on the yield and quality characteristics of the varieties.

MATERIAL AND METHODS

Study site

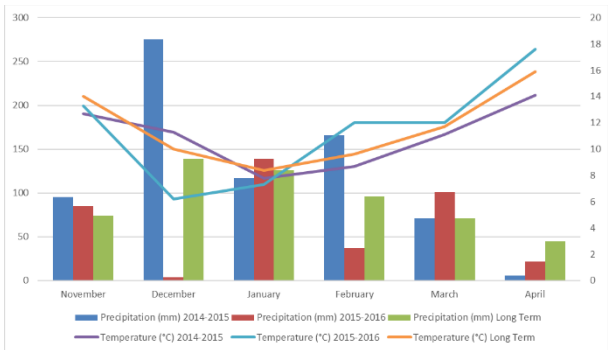
The two-year field study was conducted at Aydın Adnan Menderes University research and experimental fields (37° 45' 51'' N, 27° 45' 32'' E, 27 m altitude) as a split-plot experiment in randomized block design with three replications in 2014-2015 and 2015-2016. The soil in which the experiment was conducted had an alkaline, sandy-loamy texture, low organic matter content, and an adequate amount of mineral matter, based on samples taken before to the experiment (Table 1.)

Table 1. Soil traits of the experiment field (0-30 cm)

P ppm	K ppm	Ca ppm	Mg ppm	Na ppm	Fe ppm	pH	Total Salt (%)	Organic Matter (%)
19	903	2740	1164	46	8.32	8.16	0.0093	1.20

In terms of climatic data, significant differences were found between the years in which the experiment was carried out and the long years in terms of both temperature averages and precipitation values. According to the climatic characteristics of the long-term means, the precipitation regime, which increases in winter months, has shown great irregularities in both years. According to monthly temperature averages, this irregularity is quite noticeable (Figure 1).

Figure 1. Monthly temperature means and total amount of precipitation over the long-term as well as in the growing seasons 2014/15 and 2015/16.



Experimental design and measurements

Eight different forage pea genotypes (Kirazlı, Ulubatlı, Gölyazı, Özkaynak, Töre, Taşkent, GAP Pembesi) were selected as material in the experiment. Six rows formed a plot with an inter-row distance of 20 cm. Three different phenological periods (10%, 50%, 100% flowering) were used as sub-plots. The experiment was performed in two growth seasons, the first growth season from October 2014 to April 2015, and the second growth season from October 2015 to April 2016. As base fertilization, 3 kg da^{-1} N and 7 kg da^{-1} P were applied. Cultivation was carried out under rainfed conditions. Harvesting was performed manually and samples were kept for further analysis. The biomass yield of the forage from each plot was recorded, immediately. For each variety, forage samples were oven-dried (MST, Mikrotest, Ankara, Türkiye) at 70°C to constant weight for 48 hours (Cook and Stubbendieck, 1986), and weighed for herbage yield. Then the samples were ground to 1 mm screen. Plant height (cm) and stem diameter (mm) were observed with 10 plant samples taken from each plot. The Kjeldahl method was used to measure the crude protein (CP) content of dried forage samples (Nelson and Sommers, 1980).

Neutral detergent fiber (NDF) and acid detergent fiber (ADF) contents were analyzed with ANKOM Fiber Analyzer (ANKOM Technology Corp., Fairport, NY, USA) according to the procedure described by Van Soest et al. (1991). Acid detergent lignin (ADL) analysis was made according to the method reported by Robertson and Van Soest (1977). Following these results, crude protein yield and relative feed value were calculated. Using the methods outlined by

Van Dyke and Anderson (2002), the relative feed value (RFV) characteristics of the forage samples were determined.

DMD (%) = 88.9–(0.779×ADF %); DMI (%) = 120/NDF; % RFV = DMD %×DMI %×0.775

In the experiment, the analysis of variance was performed with the LSD multiple comparison method (*p<0.05*) using the 'agricolae' package (de Mendiburu and de Mendiburu, 2019) in R Studio (V4.1.2). Heat map was made in R Studio using the heatmap.2 command within the 'gplots' package (Warnes et. al. 2022). Boxplot graphics were made with PAST v4.

RESULTS AND DISCUSSION

The mean plant height of pea varieties was 150.68 cm and the effects of years and mowing periods on plant height were found to be statistically significant (P≤0.01) (Table 2.). Among the genotypes, Töre (160.16 cm) and Taşkent (158.01 cm) had the highest mean plant height, and the highest plant height was measured in 100% flowering period as 172.84 cm. These differences were also effective in the significance of the year × genotype × mowing time interaction (Table 3.). When the years were analyzed separately, although Taşkent had the highest plant height in both years among the varieties, many varieties had different mean values in both years (Figure 3.).

Table 2. Variance analysis results of forage pea genotypes mowed at different phenological stages

	PH	SD	HY	NDF	ADF	ADL	CPR	CPY	RFV
Year	**	**	**	**	ns	ns	**	**	**
Genotypes	**	**	**	**	**	**	**	**	**
Mowing	**	**	**	**	**	**	**	**	**
YxG	**	**	**	**	**	*	**	**	**
YxMow	**	ns	ns	**	**	ns	**	**	**
GxMow	**	**	**	**	**	**	ns	**	**
YxGxMow	**	**	**	**	**	ns	**	**	**

*: P≤0,05 **: P≤0,01 ns: non-significant

In terms of stem diameter, although similar grouping was observed in terms of mowing time, differences were observed between years and genotypes in terms of plant height. While Taşkent and GAP Pembesi had a thicker stem diameter compared to the average of two years, in the first year, Özkan, Töre and GAP Pembesi genotypes at 100% flowering time stood out. In the second year, this situation was observed in Taşkent and GAP Pembesi varieties. This made the interactions between genotypes and the time of mowing significant. These differences among the genotypes may be due to the irregular rainfall in both years and the formation of thicker or thinner stems due to the different determination of plant height. Thickening of the stem diameter can also lead to fibre accumulation such as ADF and NDF.

Pea is a plant with unlimited growth (Biddle, 2017) and does not require cold weather for the best development (Sattell et al., 1998). In the second year of the experiment, a fluctuating average temperature according to the climate data of the first year of the experiment and long term data may have caused differences in plant height. Variations in plant height and stem diameter may cause differences in yield and quality (Ball et. al. 2001). At the same time, the high fibre contents in the stem compared to the leaf brought low values in the forage quality in the second year. Herbage yield showed a statistically significant difference (P≤0.01) among all levels of the factors considered, and the average dry herbage yield was determined as 914.11 kg $da^{-1.}$ As a result of the analysis of variance, year × genotypes, year × mowing and year × genotypes × mowing interactions were found to be significant (Table 2.). In the second year of the study, herbage yield was higher than the first year (902.96 kg da^{-1}) with 925.26 kg da^{-1}, while the highest value was observed in the mowing at 100% flowering time with 1133.34 kg da^{-1}. Among the genotypes, Töre (964.17 kg da^{-1}) and Taşkent (951.97 kg da^{-1}) were the prominent ones according to the two-year average. When the data obtained for two years are analyzed separately, similar genotypes stand out in general (Table 3, Figure 2,3). As the phenological period progressed, yield increased due to dry matter accumulation.

Temel and Yazıcı (2021) mentioned that Kirazlı and Ürünlü varieties stood out in terms of herbage yield in a cooler ecological condition, while Kavut et al. (2016) found Taşkent variety to be highly productive in an ecology dominated by the coastal Aegean climate. Uzun et al. (2012) reported that Kirazlı variety had the highest herbage yield average (794.7 kg da^{-1}) between varieties in their study. The adaptation ability of the varieties may greatly vary depending on the spatial ecological variations and therefore, significant findings should be achieved by local studies to determine the proper genotypes. NDF, ADF and ADL represent cell fiber values and their percentages in the cell wall increase as maturation (Tenikecier and Ateş, 2021; Borreani et. al. 2007). It was determined that ADF and ADL contents did not change significantly between years. It was observed that cell wall contents significantly differed depending on harvest period and genotypes. In terms of NDF, there was a

statistically significant difference (P≤0.01) between all levels of the factors considered and the average value was 45.25 % (Table 3.). The reason for the higher NDF mean value of 47.11% in the second year may be related to the significant difference in stem diameter. Indeed, plant stems contain more extracellular substances such as cellulose, hemicellulose and lignin than leaves (Aşcı and Acar, 2018).

Table 3. Agronomic and fiber quality characteristics of different forage pea genotypes with different mowing stages

	Plant height (cm)	Stem Diameter (mm)	Herbage Yield (kg da^{-1})	NDF (%)	ADF (%)	ADL (%)
Years						
2014-15	153.53 A	6.03 B	902.96 B	43.39 B	32.26	5.51
2015-16	147.84 B	6.38 A	925.26 A	47.11 A	32.87	5.61
Mowing Time						
10% Flowering	129.53 C	4.93 C	703.63 C	38.68 C	26.13 C	4.39 C
%50 Flowering	149.69 B	6.39 B	905.35 B	45.52 B	32.72 B	5.71 B
100% Flowering	172.84 A	7.28 A	1133.34 A	51.54 A	38.86 A	6.57 A
Genotypes						
Kirazlı	145.29 D	5.88 D	891.05 C	46.35 A	34.48 AB	5.33 C
Ulubatlı	145.70 D	6.19 BC	899.15 C	43.18 C	31.78 DE	5.40 BC
Gölyazı	145.82 D	6.15 BC	850.08 D	46.26 A	32.75 CD	5.47 BC
Ürünlü	142.35 E	5.85 D	898.92 C	44.46 B	30.14 F	5.60 AB
Özkaynak	156.81 B	6.29 B	926.31 B	45.02 B	31.27 EF	5.51 BC
Töre	160.16 A	6.09 C	964.17 A	45.53 AB	35.03 A	5.48 BC
Taşkent	158.01 AB	6.57 A	951.97 AB	44.66 B	33.22 BC	5.85 A
GAP Pembesi	151.35 C	6.60 A	931.24 B	46.53 A	31.88 CE	5.83 A
Mean	150.68	6.20	914.11	45.25	32.57	5.56

Differences can be observed among genotypes in terms of these three fiber parameters (Figure 2, 3.). Since ADL makes up a large portion of ADF, the impact of applications on ADL was comparable to that of ADF content. The study found that the herbage yield changed in a similar way depending on the years for both ADF and ADL contents. In the present study, the crude protein content showed significant differences between mowing periods and genotypes (Table 4.). In terms of mowing periods, it was observed that the crude protein content of forage pea genotypes decreased by the maturation.

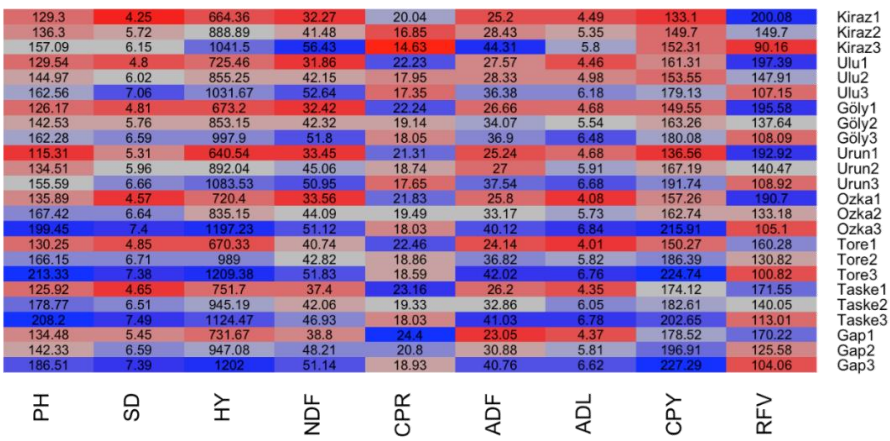


Figure 2. Heatmap of relationships between genotypes mowed different stages and growth parameters of 2014-2015 growing season (PH: plant height; SD: stem diameter; HY: herbage yield; CPR: crude protein ratio; CPY: Crude protein yield; RFV: relative feed value. The numbers 1,2,3 next to the varieties indicate the flowering time at 10%, 50% and 100% flowering, respectively)

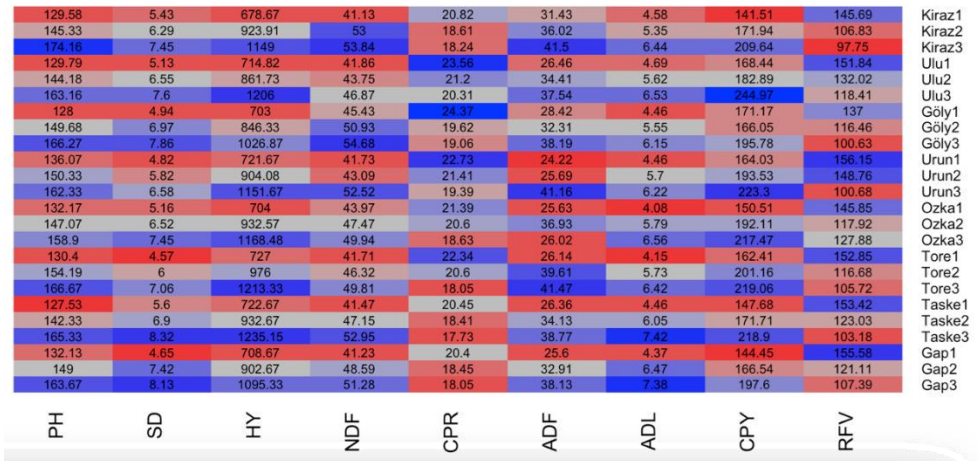


Figure 3. Heatmap of relationships between genotypes mowed different stages and growth parameteres of 2015-2016 growing season PH: plant height; SD: stem diameter; HY: herbage yield; CPR: crude protein ratio; CPY: Crude protein yield; RFV: relative feed value. The numbers 1,2,3 next to the varieties indicate the flowering time at 10%, 50% and 100% flowering, respectively.).

While all factors were statistically significant, the average CP content was calculated as 19.88%. The lowest values were obtained at 100% flowering in both years, while the mowing at 10% flowering period stood out with 22.1% (Figure 2.;3.). According to the statistical differences between genotypes, year × genotype ×mowing time interaction was significant. All genotypes were in the same statistical grouping except Kirazlı, which had the lowest crude protein ratio (18.19%). The values obtained are numerically similar to Temel and Yazıcı (2021), Temel et al. (2021), Uzun et al. (2012), Kır (2022), Sarıkaya et al. (2023). Crude protein yield and relative feed value are the parameters evaluated in terms of forage quality and optimum yield. These two traits showed inverse values to each other. While there were differences between years in both traits, the interactions between forms and genotypes were also significant. In terms of crude protein yield, the highest harvest time average was obtained from 100% flowering stage, while in terms of relative feed value, this situation was observed at 10% flowering. Among the genotypes, Töre stood out in terms of crude protein yield, while Ulubatlı and Ürünlü varieties were found to have higher averages in terms of relative feed value (Table 4.; Figure 2.;3.;4.).

Table 4. Crude protein content, crude protein yield and relative feed value characteristics of different forage pea genotypes with different mowing stages

	CPR (%)	CPY (kg da^{-1})	RFV
Years			
2014-15	19.58 B	174.03 B	142.55 A
2015-16	20.18 A	184.28 A	126.78 B
Mowing Time			
10% Flowering	22.10 A	155.68 C	167.32 A
50% Flowering	19.37 B	175.51 B	130.51 B
100% Flowering	18.16 C	206.28 A	106.18 C
Genotypes			
Kirazlı	18.19 C	159.70 D	131.70 CD
Ulubatlı	20.43 A	181.71 B	142.45 A
Gölyazı	20.41 A	170.98 C	132.56 BC
Ürünlü	20.20 A	179.39 B	141.31 A
Özkaynak	19.99 AB	182.66 B	136.77 B
Töre	20.15 A	190.67 A	127.86 D
Taşkent	19.51 B	182.94 B	134.04 BC
GAP Pembesi	20.17 A	185.21 AB	130.65 CD

Mean	19.88	179.16	134.67

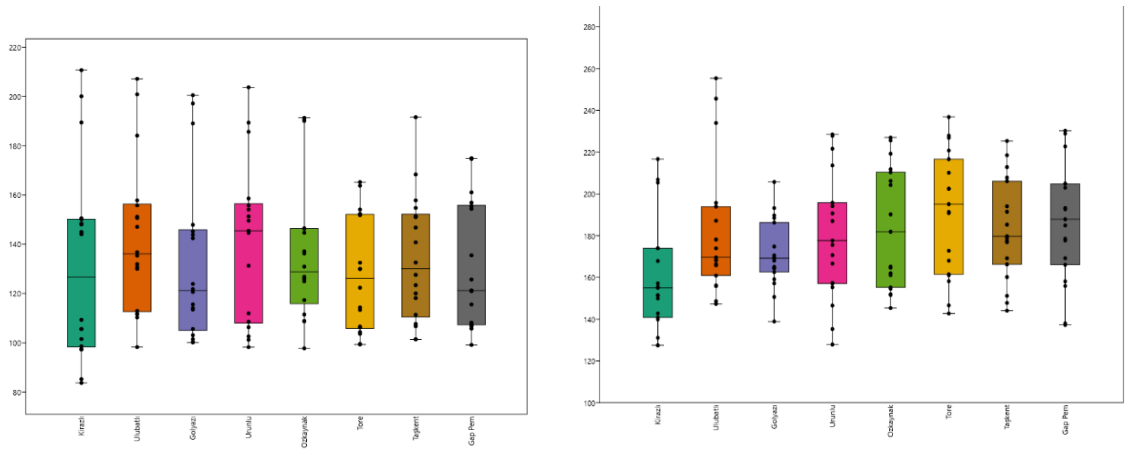


Figure 4. Boxplot graphics of relative feed value and crude protein yield, respectively. In the box plot, the band inside the box is the median, and the mean is plotted as an individual point

CONCLUSION

In the Aegean Region, where the livestock sector is very important, the importance of forage pea as a source of quality roughage is increasing. The most important criteria in terms of yield and quality are variety selection and mowing period. According to the results the most ideal mowing period was found to be at 100% flowering in terms of yield, while 10% flowering mowing period was found to have the highest values for crude protein ratio and relative feed value. However, in terms of crude protein yield, which is one of the indicator parameters of forage quality, 100% flowering stage was found to be the most ideal mowing period. In terms of genotypes, different values were obtained due to the differences in climatic data in both years. While Töre and Taşkent were the prominent varieties in terms of yield in both years, it was concluded that Ürünlü and Ulubatlı varieties had good values in addition to Töre variety in terms of quality characteristics.

Forage pea is a highly preferable species for the producers in the Aegean region due to its increasing importance and easy availability in the double-annual production system. However, in addition to the results obtained from the experiment, a variety of preferences can be made in line with soil characteristics and production objectives.

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