**Anadolu Tarım Bilimleri Dergisi,**
Anadolu Journal of Agricultural Sciences

e-ISSN: 1308-8769, ANAJAS Ocak 2026, 41: 327-339

# Hay Yield and Quality of Different Mixtures of Forage Turnip (Brassica rapa L.) and Triticale (X Triticosecale Wittmack)

# Yem Şalgamı (Brassica rapa L.) ile Tritikale (X Triticosecale Wittmack) Karışımlarının Kuru Ot Verimi ve Kalitesi

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**Makale Bilgisi/Article Information**

**Makale Türü/Article Types:** Araştırma Makalesi/Research Article
**Geliş Tarihi/Received:** 11 Şubat/February 2026
**Kabul Tarihi/Accepted:** 02 Nisan/April 2026
**Yıl/Year:** 2026 | **Cilt-Volume:** 41 | **Sayfa/Pages:** 327-339

**Atıf/Cite as:** Söyler, U., Yıldırım, İ., Gülümser, E. "Hay Yield and Quality of Different Mixtures of Forage Turnip (Brassica rapa L.) and Triticale (X Triticosecale Wittmack)" Anadolu Journal of Agricultural Sciences, 41, January 2026: 327-339.

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https://doi.org/10.7161/omuanajas.1887005

# HAY YIELD AND QUALITY OF DIFFERENT MIXTURES OF FORAGE TURNIP (BRASSICA RAPA L.) AND TRITICALE (X TRITICOSECALE WITTMACK)

## ABSTRACT

This study aimed to determine the hay yield and quality of mixtures (100:0%, 75:25%, 50:50%, 25:75%, and 0:100%) of forage turnip (*Brassica rapa* L. "FT") and triticale (*xTriticosecale wittmack*, "T") under the ecological conditions of Bilecik. The study was conducted over two years (2023–2024 and 2024–2025) at the Agricultural Research and Application field of Bilecik Şeyh Edebali University, and it using a Randomized Complete Block Design with three replications. Sole forage turnip and mixtures were harvested at the flowering stage, based on forage turnip, while the triticale was harvested at the milk stage. Botanical composition, hay and protein yield, acid detergent fiber, neutral detergent fiber, potassium (K), phosphorus (P), calcium (Ca), and magnesium (Mg) contents were determined. According to the two-year results of the study, the highest hay and crude protein yields were obtained from the mixtures of 75FT+25T% (1338.78–210.52 kg da$^{-1}$), 50FT+50T% (1415.18–206.49 kg da$^{-1}$), and 25FT+75T% (1362.77–188.37 kg da$^{-1}$). The K, P, Ca, and Mg contents of the mixtures ranged between 2.37-2.01%, 0.47-0.22%, 1.25-0.22%, and 0.25-0.12%, respectively. As a result of the study, it was concluded that all mixtures of forage turnip and triticale are suitable for cultivation under the ecological conditions of Bilecik in terms of both hay yield and quality.

***Keywords:*** Forage Turnip, Triticale, Intercropping, Hay Yield, Hay Quality.

# YEM ŞALGAMI (BRASSİCA RAPA L.) İLE TRİTİKALE (X TRİTİCOSECALE WİTTMACK) KARIŞIMLARININ KURU OT VERİMİ VE KALİTESİ

## ÖZ

Bu çalışma Bilecik ekolojik koşullarında yem şalgamının (*Brassica rapa* L. "YŞ") ile tritikalenin (*xTriticosecale Wittmack*, "T") karışımlarının (yem şalgamı:tritikale sırasıyla %100:0, %75:25, %50:50, %25:75 ve %0:100) kuru ot verimi ile kalitesinin belirlenmesi amacıyla yürütülmüştür. Çalışma Bilecik Şeyh Edebali Üniversitesi Tarımsal Araştırma ve Uygulama arazisinde iki yıl (2023-2024 ve 2024-2025) süreyle ve tesadüf blokları deneme deseniğine göre 3 tekrarlamalı olarak yürütülmüştür. Bitkilerde hasat yalın yem şalgamı ve karışımlarda yem şalgamının çiçeklenme, yalın tahıllarda ise süt olum döneminde yapılmıştır. Karışımlarda, botanik kompozisyon, kuru ot ve protein verimi, asit deterjanda çözünmeyen lif, nötr deterjanda çözünmeyen lif, potasyum (K), fosfor (P), kalsiyum (Ca) ve magnezyum (Mg) içerikleri belirlenmiştir. Çalışmada iki yıllık sonuçlara göre; en yüksek kuru ot ve protein verimi %75YŞ+25T (1338.78-210.52 kg/da), %50YŞ+50T (1415.18-206.49 kg/da) ve %25YŞ+75T (1362.77-188.37 kg/da) karışımlarından elde edilmiştir. Karışımların K, P, Ca ve Mg içerikleri sırasıyla %2.37-2.01, %0.47-0.22, %1.25-0.22 ve %0.25-0.12 arasında değişmiştir. Çalışma sonucunda, Bilecik ekolojik koşullarında yem şalgamı ile tritikalenin tüm karışımlarının ekilmesinin kuru ot verimi ve kalitesi açısından uygun olacağı sonucuna varılmıştır.

***Anahtar Kelimeler:*** Yem Şalgamı, Tritikale, Karışık Ekim, Kuru Ot Verimi, Kuru Ot Kalitesi.

## 1. INTRODUCTION

Although the total livestock population in Türkiye is considered sufficient, the quality and productivity levels of animal products obtained from these animals have not yet reached the desired standards. One of the main reasons for this situation is the insufficient supply of high-quality roughage in adequate quantities. In Türkiye, the area cultivated with forage crops is approximately 2.75 million hectares, corresponding to only about 14% of the total agricultural land. However, this proportion is insufficient to establish a sustainable agricultural and livestock production system. Indeed, while the annual roughage requirement of the existing livestock population in Türkiye is estimated at 351.3 million tons on a green forage basis, the total roughage production obtained from forage crop cultivation and pasture–rangeland areas amounts to only 116.2 million tons. This level of production meets merely 33% of the requirement, indicating a high-quality roughage deficit of approximately 67% (Acar et al., 2025). To reduce this deficit, it is essential to utilize existing agricultural lands more efficiently and to incorporate alternative forage crops into animal rations.

One of the most effective ways to maximize the use of existing agricultural land is intercropping. Intercropping is the simultaneous cultivation of two or more plant species in the same field (Ker, 1976). This cropping system has the potential to increase both total yield and the economic returns for producers. In intercropping systems, plant species utilize natural resources such as soil, water, light, and nutrients more efficiently, thereby improving resource-use efficiency and reducing environmental impacts (Fordham, 1983; Francis, 1985; Hook and Gascho, 1988; Akman and Kara, 2001; Bauman et al., 2002).

Intercropping, which is considered one of the key strategies for increasing forage crop production, is widely practiced, particularly in tropical and subtropical regions. In addition to enabling more efficient use of available resources, this system reduces production risks by leveraging the ecological complementarities of different plant species grown together. If one species fails to develop adequately, the other can continue its growth, thereby enhancing system stability and sustainability. Moreover, intercropping practices contribute to the conservation of soil fertility, prevent erosion through dense vegetation cover, and increase economic profitability by enabling more efficient use of family labor, especially in small-scale farming systems (Tansı, 1987). Considering forage yield and quality characteristics, determining the appropriate mixing ratio is regarded as the most effective approach. In intercropping systems, interspecific interactions are among the primary factors directly influencing productivity. Cereals generally exhibit stronger competitive ability than legumes in mixed cropping systems. However, environmental conditions can substantially modify the intensity of this competition. Therefore, forage yield and quality in intercropping systems are significantly influenced by the proportion of cereal and legume species included in the mixture (Erol et al., 2009). Brassica species) They are considered promising alternative forage sources due to their high protein and energy contents and their adaptability to cool-season conditions. Among these, forage-type turnip (*Brassica rapa* L.) occupies an important place in ruminant nutrition owing to its tolerance to low temperatures, rapid production of high biomass, and high digestibility. According to data from Türkiye, the cultivation area of forage turnip is 43.645 decares, with a total green forage production of 214,410 tons (TÜİK, 2024).

For cereals used as roughage, growth stages play a decisive role in determining forage yield and quality. As plant development progresses, green and hay yields generally increase, whereas quality parameters such as crude protein content and digestibility tend to decline. Therefore, delaying harvest solely to achieve higher yields may result in significant losses in forage quality. In particular, as plants approach maturity, reductions in crude protein content and digestibility become more pronounced. However, the increased hay yield obtained from late harvesting can partially compensate for these quality losses. In this context, harvesting cereals grown for forage purposes up to the milk stage is recommended as a balanced approach in terms of both yield and quality (Bishnoi et al., 1978; Tükel et al., 1993). In Türkiye, triticale is cultivated on 666.266 hectares, with a total green forage production of 1.273,98 tons and an average yield of 1.910 kg/ha (TUIK, 2024). Based on the above considerations, the aim of this study was to determine the effects of different mixtures of forage turnip and triticale on hay yield and quality.

https://doi.org/10.7161/omuanajas.1887005

## 2. MATERIAL AND METHODS

In this study, the forage turnip (*Brassica rapa* L.) cultivar 'Lenox' and the triticale (×*Triticosecale* Wittmack) cultivar 'Karma 2000' were used as plant materials. The experiment included five different mixture ratios of forage turnip and triticale (100:0%, 75:25%, 50:50%, 25:75%, and 0:100%, respectively). According to temperature and precipitation data obtained from the Bilecik Meteorological Directorate for the long-term averages and the 2023–2024 and 2024–2025 vegetation periods, the long-term mean temperature of the province was 9.3 °C, while the mean temperatures were 12.1 °C in the 2023–2024 season and 10.3 °C in the 2024–2025 season. Total precipitation amounts recorded for the long-term average and for the 2023–2024 and 2024–2025 vegetation periods were 365.2, 365.3, and 121.7 mm, respectively.

The soil texture of the experimental area was clay–loam, with moderate lime (11.21%) and organic matter contents (2.15%). The potassium and phosphorus contents of the soil were determined as 1.72 kg $da^{-1}$ (low) and 19.22 kg $da^{-1}$ (moderate), respectively. The study was conducted at the Agricultural Research and Application Farm of Bilecik Şeyh Edebali University during the 2023–2024 and 2024–2025 vegetation periods. The experimental site is located at an altitude of approximately 500 m above sea level. The experiment was established on 1 November 2023 in the first year and on 10 December 2024 in the second year, following a randomized complete block design with three replications. Sowing was performed manually.

In the experiment, row spacing was 20 cm, row length was 2 m, and each plot consisted of six rows. Seeding rates were calculated as 1 kg $da^{-1}$ for forage turnip and 20 kg $da^{-1}$ for triticale. At sowing, diammonium phosphate (DAP) fertilizer was applied at a rate corresponding to 8 kg P $da^{-1}$. Harvesting was carried out at the flowering stage of forage turnip in sole cropping and mixture plots, and at the milk stage in sole triticale plots.

**Table 1.** Climate data for Bilecik long-term and experimental year*

| Months | Temperature (°C) | | | Precipitation (mm) | | |
|---|---|---|---|---|---|---|
| | LT** | 2023-2024 | 2024-2025 | LT** | 2023-2024 | 2024-2025 |
| November | 9.1 | 11.6 | 8.1 | 37.4 | 112.3 | 55.1 |
| December | 4.7 | 8.2 | 6.3 | 55.2 | 53.6 | 42.2 |
| January | 2.5 | 4.6 | 5.9 | 50.8 | 85.5 | 7.6 |
| February | 3.8 | 7.8 | 2.1 | 42.5 | 23.4 | 2.4 |
| March | 6.4 | 9.2 | 10.8 | 47.2 | 31.1 | 4.8 |
| April | 11.5 | 16.0 | 10.5 | 41.6 | 7.8 | 3.9 |
| May | 16.1 | 15.1 | 16.6 | 47.4 | 51.3 | 5.6 |
| June | 19.9 | 24.5 | 22.1 | 43.1 | 0.3 | 0.1 |
| ***Average / Total*** | ***9.3*** | ***12.1*** | ***10.3*** | ***365.2*** | ***365.3*** | ***121.7*** |

*: Bilecik Regional Directorate of Meteorology; **: Long-term average (1939–2024)

### 2.1. Hay Yield (kg da$^{-1}$)

Harvested samples were dried in a forced-air drying oven at 60 °C until constant weight was achieved. The weights of the dried forage samples were then recorded, and forage turnip and triticale hay yields were calculated on a plot basis after applying the necessary conversions. The sum of the hay yields of forage turnip and triticale determined for each plot was considered as the total hay yield of that plot. Subsequently, plot-level hay yields were converted to hay yield per decare.

### 2.2. Botanical Composition (%)

Botanical composition was calculated by determining the proportion of forage turnip and triticale hay yields in each mixture plot relative to the total hay yield of the respective plot.

### 2.3. Crude protein content (%) and protein yield (kg da$^{-1}$)

After harvest, the samples were dried at 60 °C until constant weight was reached and then ground in the laboratory using a mill equipped with a 1-mm sieve to prepare them for analysis. Crude protein contents of the samples were determined using Near Infrared Reflectance Spectroscopy (NIRS) (Foss 6500) with the IC-0904FE calibration package. In forage turnip (FT) and triticale (T) mixtures, the mean crude protein content was calculated using the formula given below by multiplying the crude protein contents of each species by their respective botanical composition ratios on a weight basis. Protein yield was calculated by multiplying the obtained crude protein contents by hay yield per decare.

*CP%: ((FT% x CP%) + (T% x CP%))/100*

### 2.4. Acid Detergent Fiber (ADF), Neutral Detergent Fiber (NDF), and Nutrient Composition (%)

The dried samples were ground in a mill to pass through a 1-mm sieve. Subsequently, the contents of acid detergent fiber (ADF), neutral detergent fiber (NDF), potassium (K), phosphorus (P), calcium (Ca), and magnesium (Mg) were determined using Near Infrared Reflectance Spectroscopy (NIRS) (Foss 6500) with the IC-0904FE calibration package. In the mixtures, mean ADF, NDF, and macronutrient contents were calculated using the formula given below by multiplying the ADF, NDF, and macronutrient (K, P, Ca, and Mg) contents of each species by their respective botanical composition ratios on a weight basis.

ADF%: ((FT% × ADF%) + (T% × ADF%))/100

NDF%: ((FT% x NDF%) + (T% x NDF%))/100

K%: ((FT% x K%) + (T% x K%))/100

P%: ((FT% x P%) + (T% x P%))/100

Ca%: ((FT% x Ca%) + (T% x Ca%))/100

Mg%: ((FT% x Mg%) + (T% x Mg%))/100

### 2.5. Data Analysis

The obtained data were analyzed using a randomized complete block design in the MSTAT-C statistical software package. Differences among treatments were determined using Duncan's multiple range test.

## 3. RESULT AND DISCUSSION

The botanical composition ratios of forage turnip and triticale mixtures determined on a hay yield basis are presented in Table 2. In the first year of the experiment, the proportion of forage turnip in the botanical composition ranged from 35.33% to 56.45%, while in the second year it varied between 28.27% and 40.92%. In the combined analysis, forage turnip proportions ranged from 31.80% to 48.68%. The proportion of triticale in the botanical composition ranged from 43.55% to 64.67% in the first year, from 59.08% to 71.73% in the second year, and from 51.32% to 68.20% in the combined years (Table 2).

The results indicate that forage turnip was more dominant in the mixtures during the first year, whereas triticale was more dominant in the second year (Table 2). This difference is presumed to be associated with the drier conditions prevailing in the second year. Compared to forage turnip, triticale, as a cereal species, exhibits earlier emergence and a high tillering capacity, which likely enabled it to utilize the limited soil moisture more effectively, thereby negatively affecting the growth of forage turnip. In contrast, the higher precipitation observed in the first year promoted better growth and competitiveness of forage turnip (Çopur et al., 2019; Yavuz and Gülümser, 2022). Gülümser (2016) evaluated the botanical composition of Hungarian vetch mixtures with different cereals (barley, wheat, and triticale), reporting that cereals were generally dominant and that triticale performed better than wheat under mixed cropping conditions. The differences between the findings of the present study and those reported may be attributed to variations in cultivar characteristics, ecological conditions, mixture ratios, and applied cultural practices.

**Table 2**. Botanical composition of forage turnip and triticale in mixtures

| Mixtures | 2023-2024 | | 2024-2025 | | Average | |
|---|---|---|---|---|---|---|
| | FT | T | FT | T | FT | T |
| **75FT+25T%** | 56.45 | 43.55 | 40.92 | 59.08 | 48.68 | 51.32 |
| **50FT+50T%** | 43.63 | 56.37 | 34.06 | 65.94 | 38.85 | 61.15 |
| **25FT+75T%** | 35.33 | 64.67 | 28.27 | 71.73 | 31.80 | 68.20 |
| ***Average*** | ***45.14*** | ***54.86*** | ***34.42*** | ***65.58*** | ***39.78*** | ***60.22*** |

FT: Forage turnip; T: Triticale

Hay yield and crude protein yields of different forage turnip–triticale mixtures under the ecological conditions of Bilecik are presented in Table 3. Accordingly, statistically significant differences in hay yield among mixtures were observed in the first year of the study ($P \leq 0.05$), while highly significant differences were detected in the second year and in the combined analysis ($P \leq 0.01$). No statistically significant differences were found between years. The effects of both individual years and the combined years on crude protein content of forage turnip–triticale mixtures were highly significant ($P \leq 0.01$). In addition, year-to-year differences were also significant at the 1% probability level.

In the combined analysis, the highest hay yields were obtained from the mixtures 75 FT + 25 T% (1338.78 kg $da^{-1}$), 50 FT + 50 T% (1415.18 kg $da^{-1}$), and 25 FT + 75 T% (1362.77 kg $da^{-1}$), which were placed in the same statistical group, whereas the lowest hay yield (780.38 kg $da^{-1}$) was recorded from sole forage turnip. These results indicate that mixtures were superior to sole crops in terms of hay yield. The mean hay yields in the first and second years were determined as 1245.46 kg $da^{-1}$ and 1122.89 kg $da^{-1}$, respectively (Table 3).

Although no statistically significant difference was observed between years, higher precipitation was recorded during the vegetation period in the first year of the experiment (Table 1). Based on field observations, forage turnip performed better and produced higher hay yields in both sole and mixed cropping systems during the first year with higher rainfall, whereas triticale exhibited superior performance and higher hay yields in the second, drier year. Yavuz (2022) evaluated the performance of forage turnip (FT) mixed with barley (B), wheat (W), and oat (O), reporting the highest hay yields from sole barley (8.62 t $ha^{-1}$), sole oat (8.62 t $ha^{-1}$), 75 FT + 25 B% (8.91 t $ha^{-1}$), 75FT + 25O% (8.67 t $ha^{-1}$), 50FT + 50B% (8.93 t $ha^{-1}$), 50FT + 50O% (10.27 t $ha^{-1}$), 25FT + 75B% (9.35 t $ha^{-1}$), and 25FT + 75O% (9.50 t $ha^{-1}$), while the lowest hay yield (5.45 t $ha^{-1}$) was obtained from the 75FT + 25W% mixture. The differences between the findings of the present study and those reported by Yavuz (2022) are mainly attributed to the cereal species used. Besides, the higher yield observed in mixed cropping compared to sole cropping can be attributed to species complementarity, which enables more efficient use of light, water, and nutrients, as well as differences in root systems and growth patterns that balance resource utilization. In addition, mixtures form a denser canopy structure, improving light interception and reducing weed competition (Martins et al., 2024).

The highest crude protein yields were obtained from the mixtures 75 FT + 25 T% (210.52 kg da$^{-1}$), 50 FT + 50 T% (206.49 kg da$^{-1}$), and 25 FT + 75 T% (188.37 kg da$^{-1}$), whereas the lowest protein yield (107.98 kg da$^{-1}$) was observed in sole triticale (Table 3). Protein yield is calculated as the product of crude protein content and hay yield. Crude protein content was higher in sole forage turnip and in the mixtures compared to sole triticale. However, the higher hay yields of the mixtures relative to sole crops were reflected in greater protein yields. Consequently, in the combined analysis, mixtures exhibited superior performance in terms of protein yield compared to sole forage turnip and sole triticale. Çopur Doğrusöz et al. (2019) reported protein yields ranging from 0.41 to 1.09 t ha$^{-1}$ in rapeseed–legume mixtures, while Yavuz and Gülümser (2022) reported protein yields between 0.97 and 1.80 t ha$^{-1}$ for forage turnip mixed with different cereals. The protein yields obtained in the present study were higher than those reported by these researchers. These differences may be attributed to variations in environmental conditions, cultural practices, and the plant species used. Kahlor Monfared et al. (2023) reported that intercropping forage turnip and basil at a 70:30 ratio with 18.5 t ha$^{-1}$ vermicompost and biochar increased dry matter yield, crude protein, and digestibility compared to sole crops, while ADF and NDF were higher in monoculture, indicating that this mixture improves forage yield and quality over individual planting.

**Table 3.** Hay and protein yield of mixtures

| Mixtures | Hay yield (kg da$^{-1}$) | | | Protein yield (kg da$^{-1}$) | | |
|---|---|---|---|---|---|---|
| | **2023-2024*** | **2024-2025**** | **Average **** | **2023-2024**** | **2024-2205**** | **Average **** |
| **100FT%** | 936.16b | 624.61c | 780.38c | 199.54a | 129.21b | 164.38b |
| **100T%** | 981.34b | 1066.19b | 1023.77b | 106.02b | 109.95b | 107.98c |
| **75FT+25T%** | 1428.03a | 1249.52ab | 1338.78a | 239.04a | 181.99a | 210.52a |
| **50FT+50T%** | 1485.59a | 1344.78a | 1415.18a | 227.21a | 185.77a | 206.49a |
| **25FT+75T%** | 1396.18a | 1329.36a | 1362.77a | 200.93a | 175.80a | 188.37ab |
| ***Average*** | ***1245.46*** | ***1122.89*** | | ***194.55a**** | ***156.55b*** | |

*: Significant at the P ≤0.05 **: Significant at the P≤0.01 level. FT: Forage turnip; T: Triticale.

The acid detergent fiber (ADF) and neutral detergent fiber (NDF) contents determined in different forage turnip and triticale mixtures are presented in Table 4. According to the results, the effects of both individual years and the combined analysis on both parameters were highly significant (P ≤ 0.01). In addition, year-to-year differences were also statistically significant at the 1% probability level (Table 4). In the combined analysis, the highest ADF and NDF contents were recorded in sole triticale (40.50% and 56.36%, respectively), whereas the lowest values (32.50% ADF and 48.85% NDF) were determined in sole forage turnip (Table 4). In the mixtures, increasing the proportion of forage turnip decreased ADF content. This indicates that forage turnip is more digestible than triticale due to its lower fiber content at the time of cutting (Yavuz and Gülümser, 2022). The levels of ADF and NDF in forage are of great importance in terms of feed intake, digestibility, and animal health. Insufficient levels of NDF and ADF in ruminant diets may lead to disorders such as fatty liver, rumen acidosis, vitamin A deficiency, and gastric ulcers (Calsamiglia et al., 2008), whereas excessive levels reduce digestibility, increase methane production in the rumen, and cause energy losses (Tekce and Gül, 2014). Accordingly, desirable forage quality is generally associated with ADF contents of 30% or lower and NDF contents below 40% (Rohweder et al., 1978; Tekce and Gül, 2014). Although the treatments in the present study exceeded these threshold values, they exhibited relatively close ranges (Table 4).

**Table 4.** The ADF and NDF contents of mixtures

| Mixtures | Acid detergent fiber content (ADF, %) | | | Neutral detergent fiber content (NDF, %) | | |
|---|---|---|---|---|---|---|
| | **2023-2024*** | **2024-2025**** | **Average **** | **2023-2024**** | **2024-2205**** | **Average **** |
| **100FT%** | 31.78e | 33.25d | 32.50e | 47.99c | 49.72d | 48.85d |
| **100T%** | 39.98a | 41.02a | 40.50a | 55.28a | 57.43a | 56.36a |
| **75FT+25T%** | 35.34d | 37.85c | 36.59d | 51.17b | 54.28c | 52.73c |
| **50FT+50T%** | 36.39c | 38.38bc | 37.38c | 52.00b | 54.81bc | 53.41bc |
| **25FT+75T%** | 37.07b | 38.82b | 37.95b | 52.63b | 55.25b | 53.94b |
| ***Average*** | ***36.10b**** | ***37.87a*** | | ***51.82b**** | ***54.30a*** | |

*: Significant at the P ≤0.05 **: Significant at the P≤0.01 level. FT: Forage turnip; T: Triticale

The potassium (K) and phosphorus (P) contents of different forage turnip–triticale mixtures are presented in Table 5. The effects of both individual years and the combined analysis on K and P contents were highly significant ($P \leq 0.01$). In addition, year-to-year differences were also statistically significant at the 1% probability level (Table 5). In the combined analysis, the highest K and P contents were obtained from sole forage turnip (2.37% K and 0.47% P), whereas the lowest values were observed in sole triticale (2.01% K and 0.22% P). As the proportion of triticale increased in the mixtures, potassium content gradually decreased. This trend can be attributed to differences in mixture ratios and the mineral-uptake capacities of the species in the mixtures. Intercropping systems may help balance interspecific differences in mineral composition among forage crops. On the other hand, mean K and P contents were 2.33% and 0.38% in the first year, respectively, and declined to 2.02% and 0.29% in the second year. This indicates that annual environmental factors, such as precipitation and temperature, may have a significant influence on mineral composition (Fageria et al., 2002; Ye et al., 2023).

Potassium plays a key role in maintaining acid–base balance in animals (Başbağ et al., 2011; Gürsoy and Macit, 2017), whereas phosphorus is essential for skeletal development and reproductive performance (Dua and Care, 1999; Sardans and Peñuelas, 2021). To meet animal nutritional requirements, forage K and P contents should be at least 0.8% and 0.21%, respectively (Kidambi et al., 1989: Ashworth et al., 2019). In the present study, K and P contents of all treatments exceeded these minimum requirements. Yavuz and Gülümser (2022) reported K and P contents ranging from 1.75% to 3.06% and from 0.37% to 0.51%, respectively, in forage turnip mixed with barley, wheat, and oat. The differences among studies may be attributed to variations in climatic conditions, plant species, cultural practices, and mixture ratios.

**Table 5**. The potassium and phosphorus contents of mixtures

| Mixtures | Potassium content (%) | | | Phosphorus content (%) | | |
|---|---|---|---|---|---|---|
| | **2023-24**** | **2024-25**** | **Average** ** | **2023-24**** | **2024-25**** | **Average** ** |
| **100FT%** | 2.64a | 2.10a | 2.37a | 0.52a | 0.42a | 0.47a |
| **100T%** | 2.06d | 1.98b | 2.01c | 0.25e | 0.20e | 0.22e |
| **75FT+25T%** | 2.38b | 2.02ab | 2.20b | 0.41b | 0.29b | 0.35b |
| **50FT+50T%** | 2.31bc | 2.01ab | 2.16b | 0.37c | 0.28c | 0.32c |
| **25FT+75T%** | 2.26c | 2.00ab | 2.13b | 0.35d | 0.26d | 0.31d |
| ***Average*** | ***2.33a******* | ***2.02b*** | | ***0.38a******* | ***0.29b*** | |

**: Significant at the P≤0.01 level. FT: Forage turnip; T: Triticale

The calcium (Ca) and magnesium (Mg) contents of different forage turnip–triticale mixtures are presented in Table 6. The effects of both individual years and the combined analysis on Ca and Mg contents were highly significant ($P \leq 0.01$). However, no statistically significant differences were observed between years in terms of treatment effects (Table 6). Among the macronutrients that are critically important for ruminant health, calcium plays a major role in skeletal and bone development as well as in milk production, while magnesium, together with calcium, is essential for the development and maintenance of skeletal and bone tissues (Başbağ et al., 2011; Gürsoy and Macit, 2017). Considering the normal nutritional requirements of cattle, forage Ca and Mg contents are generally recommended to be within the ranges of 0.18–0.44% and 0.04–0.10%, respectively (Yozgatlı, 2017). In the present study, the Ca and Mg contents of all treatments exceeded these recommended minimum levels (Table 6). Mut et al. (2020) reported that Ca and Mg contents of alfalfa–forage turnip mixtures ranged from 0.506% to 1.110% and from 0.09% to 0.49%, respectively. The results of the present study are consistent with those of these authors.

**Table 6.** The calcium and magnesium contents of mixtures

| Mixtures | Calcium Content (%) | | | Magnesium Content (%) | | |
|---|---|---|---|---|---|---|
| | 2023-2023** | 2024-2025** | Average ** | 2023-2024** | 2024-2205** | Average ** |
| **100FT%** | 1.35a | 1.15a | 1.25a | 0.23a | 0.26a | 0.25a |
| **100T%** | 0.22d | 0.22c | 0.22d | 0.15e | 0.11e | 0.12e |
| **75FT+25T%** | 0.86b | 0.60b | 0.73b | 0.20b | 0.17b | 0.19b |
| **50FT+50T%** | 0.71c | 0.54b | 0.63c | 0.19c | 0.16c | 0.18c |
| **25FT+75T%** | 0.62c | 0.49b | 0.55c | 0.18d | 0.15d | 0.17d |
| ***Average*** | ***0.75*** | ***0.60*** | | ***0.19*** | ***0.17*** | |

**: Significant at the P≤0.01 level. FT: Forage turnip; T: Triticale

## 4. CONCLISIONS AND RECOMMENDATIONS

This study aimed to determine the yield and quality characteristics of forage turnip and triticale mixtures under the ecological conditions of Bilecik and was conducted over two vegetation periods (2023–2024 and 2024–2025). As a results, forage turnip–triticale mixtures exhibited superior dry matter yield and forage quality compared with sole cropping systems. Accordingly, it was concluded that all forage turnip–triticale mixtures (25:75%, 50:50%, and 75:25%) are suitable for cultivation under the ecological conditions of Bilecik in terms of both hay yield and quality.

### Conflict of Interest

The authors declare that they have no conflict of interest.

### Ethics

This study does not require ethics committee approval.

### Author Contribution Rates

Design of Study: US (25%), İY (25%), EG (50%)

Data Acquisition: US (25%), İY (25%), EG (50%)

Data Analysis: US (15%), İY (15%), EG (70%)

Writing up: US (10%), İY (15%), EG (75%)

Submission and Revision: US (20%), İY (20%), EG (60%)

### Acknowledgements

This study was derived from the master's thesis conducted by Uğur Söyler at the Graduate School of Bilecik Şeyh Edebali University.

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