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# EVALUATION OF ADAPTATION, HERBAGE YIELD, AND FORAGE QUALITY OF SELECTED BARLEY (*HORDEUM VULGARE* L.) VARIETIES UNDER MEDITERRANEAN ECOLOGICAL CONDITIONS

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***ABSTRACT***

*This study was conducted during the 2020–2021 growing season at the experimental field of the Department of Field Crops, Faculty of Agriculture, Kahramanmaraş Sütçü İmam University. The objective was to evaluate the adaptation, herbage yield, and forage quality of selected barley (Hordeum vulgare L.) varieties under the ecological conditions of Kahramanmaraş province. Ten barley cultivars (Compagne, Ibaona, Arconda, Yalın, Çetin 2000, Asil, Aydan Hanım, Bozlak, Misket, and Akar) were used in the experiment. The experiment was arranged in a randomized complete block design (RCBD) with three replications. The results revealed no statistically significant differences among the varieties for the traits evaluated, except for crude ash content. Green herbage yield ranged from 1046 to 1506 kg/da, while dry herbage yield varied between 334 and 484 kg/da. Dry matter content ranged from 29.66% to 33.30%, crude protein content from 11.9% to 14.0%, and crude ash content from 6.48% to 8.67%. Neutral detergent fiber (NDF) and acid detergent fiber (ADF) ratios ranged from 62.30% to 68.17% and 32.05% to 36.58%, respectively. Digestible dry matter (DDM) values ranged from 59.58% to 64.42%, dry matter intake (DMI) from 1.76% to 1.93%, and relative feed value (RFV) from 83.28 to 95.34. Among the cultivars, Compagne had the highest green herbage yield, Yalın had the highest crude protein content, and Asil showed the highest relative feed value.*

***Keywords**: barley, NDF, ADF, herbage yield, forage quality, Mediterranean ecology*

## INTRODUCTION

Barley (*Hordeum vulgare* L.) is one of the first cultivated plants in world agriculture and holds a significant place in animal nutrition. In Türkiye, barley ranks second after wheat in terms of cultivated area and production among field crops and is widely grown in almost all regions of the country. Currently, approximately 65% of the barley produced is used in the feed industry. One of the major challenges in Turkish livestock production is the insufficient

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quantity and quality of roughage. The current forage production meets only about half of the total national demand. This shortage leads to decreased animal productivity and limits the growth of the livestock sector. Forage crop cultivation in Türkiye has not developed adequately and is generally practiced as an intercrop, by-product, or secondary crop rather than a main crop. To enhance livestock productivity, it is essential to develop and utilize new barley varieties with high yield potential, good adaptation to local conditions, high forage quality, and resistance to diseases and pests. Testing these varieties across different ecological zones will help identify genotypes that meet the needs of both producers and the feed industry. Due to its early maturity, barley is more suitable than wheat for areas with low and irregular rainfall. It is also highly tolerant to salinity and alkalinity and shows rapid early growth, allowing it to compete effectively with weeds. As of 2018, Türkiye's barley cultivation area was approximately 2.6 million hectares. For forage use, barley should have high digestibility, optimal levels of neutral detergent fiber (NDF), and low levels of acid detergent fiber (ADF) and husk content (Sadeghpour et al. 2013). Feed costs constitute about 75–80% of total production expenses in livestock enterprises. Therefore, low-cost and high-quality feed sources are vital, and barley can be a strong candidate due to its high forage yield and nutritional quality. Among cool-season cereals, barley is one of the fastest growing species and is commonly used in mixture sowing systems in advanced agricultural countries. The main advantages of cultivating barley as a forage crop include high biomass yield per unit area, high-quality forage rich in carbohydrates, and reliable stand establishment. Given the increasing global demand for roughage, it is crucial to improve both the yield and quality of forage crops per unit area. In this context, determining barley varieties suitable for regional conditions and applying appropriate agronomic practices are necessary. Breeding efforts in Türkiye have led to yield improvements in barley over time. However, to fully utilize this potential, proper variety selection and correct agronomic practices, including seeding rates, must be implemented. In Kahramanmaraş province, barley is commonly cultivated as a forage crop, but seed selection is often made arbitrarily without consideration of variety performance. This study was the first of its kind conducted in the region and aimed to investigate the effects of different barley varieties on forage yield and quality under the ecological conditions of Kahramanmaraş. Ten barley varieties were evaluated under Mediterranean conditions to determine their forage yield and quality performance, with the goal of identifying high-yielding and high-quality cultivars adapted to the local environment.

## MATERIALS AND METHODS

### *Materials*

#### *Experimental Site*

This study was conducted at the experimental field of the Department of Field Crops, Faculty of Agriculture, Kahramanmaraş Sütçü İmam University during the 2020–2021 autumn growing season. The experiment was established on November 18, 2020, within the Mediterranean climatic zone characteristic of the region.

### *Soil Properties of the Experimental Site*

Prior to sowing, soil samples were collected from the 0–30 cm soil layer to assess the physical and chemical properties of the experimental site. These analyses are summarized in Table 1. The soil of the experimental area is characterized by a clay-loam texture with a neutral pH (7.3). Organic matter content was moderate at 2.3%, lime content was low (1.9%), and salinity was negligible (0.08%). The available phosphorus concentration measured 16 mg/kg, indicating a moderate level.

**Table 1.** Selected physical and chemical soil properties of the experimental site

| Parameter | Unit | Value | Interpretation |
|---|---|---|---|
| Field Capacity | % | 59 | Clay-loam texture |
| pH | - | 7.3 | Neutral |
| Organic Matter Content | % | 2.3 | Moderate |
| Lime Content (Ca $CO_3$) | % | 1.9 | Low |
| Salinity | % | 0.08 | Non-saline |
| Available Phosphorus ($P_2O_5$) | mg/kg | 16.0 | Moderate |

Source: Anonymous, 2021a

### *Climatic Conditions of the Experimental Site*

Kahramanmaraş is in the eastern part of the Mediterranean Region of Türkiye and is influenced by a Mediterranean climate. Summers are hot and dry, while winters are mild and rainy. The temperature and precipitation data for the years 2020 and 2021, during which the study was conducted, are presented in Table 2 (Anonymous, 2021b). As shown in Table 2, during the 2020–2021 growing season, the average monthly temperatures ranged between 11.30°C and 23.15°C. Regarding precipitation, the highest rainfall was recorded in January 2021 with 226.60 mm, and the lowest in May 2021 with 12 mm. In terms of relative humidity, the highest value was measured in January 2021 at 84.58%, and the lowest in May 2021 at 47.76%. Compared to long-term averages, the experimental year was warmer and wetter.

**Table 2.** Meteorological data recorded at Kahramanmaraş Meteorological Station for the years 2020–2021 and long-term averages

| Month | Year | Average Temperature (°C) | Precipitation (mm) | Relative Humidity (%) |
|---|---|---|---|---|
| November | 2020 | 11.30 | 62.60 | 84.58 |
| | Long-term | 11.51 | 87.50 | 66.68 |
| December | 2020 | 7.31 | 57.60 | 73.50 |
| | Long-term | 6.52 | 116.60 | 79.85 |
| January | 2021 | 6.19 | 226.60 | 78.70 |
| | Long-term | 4.66 | 125.40 | 69.99 |
| February | 2021 | 8.25 | 32.60 | 70.04 |
| | Long-term | 6.08 | 108.30 | 65.62 |
| March | 2021 | 10.13 | 135.20 | 69.03 |
| | Long-term | 10.24 | 93.40 | 60.00 |
| April | 2021 | 16.29 | 16.20 | 63.49 |
| | Long-term | 14.90 | 69.80 | 57.59 |
| May | 2021 | 23.15 | 12.00 | 47.76 |
| | Long-term | 19.70 | 41.20 | 54.95 |

Source: Anonymous, 2021a

### *Varieties Used in the Study*

Table 3 shows some characteristics of the barley varieties used in this study along with the seed quantities applied. Ten barley (*Hordeum vulgare* L.) varieties were used as the main plant material in the study. The commercial names of the seeds are Compagne, Ibaiona, Arconda, Yalın, Çetin 2000, Asil, Aydan Hanım, Bozlak, Misket, and Akar. These varieties have been registered through commercial seed companies, which also hold production licenses and sales rights. Information about some characteristics of the varieties and the seed quantities used are given in Table 3.

**Table 3.** Some characteristics of the barley varieties used in this study

| Variety No | Variety Name | Thousand Seed Weight (g) | Seed Purity (%) | Seed Rate per Plot (g) |
|---|---|---|---|---|
| 1 | Compagne | 52 | 100 | 93.6 |
| 2 | Ibaiona | 44 | 100 | 79.2 |
| 3 | Arconda | 50 | 100 | 90.0 |
| 4 | Yalın | 50 | 100 | 90.0 |
| 5 | Çetin 2000 | 44 | 100 | 79.2 |
| 6 | Asil | 50 | 100 | 90.0 |
| 7 | Aydan Hanım | 50 | 100 | 90.0 |
| 8 | Bozlak | 58 | 100 | 104.4 |
| 9 | Misket | 59 | 100 | 106.2 |
| 10 | Akar | 50 | 100 | 90.0 |

## *Methods*

### *Experimental Design and Sowing Method*

The experiment was established on November 18, 2020, using a randomized complete block design with three replications. Sowing was done manually in six rows, each 3 m long, with 20 cm spacing between rows. The planting density was calculated as 500 plants/m² for all varieties, and the exact seed amounts used per plot are presented in Table 3.3. At sowing, basal fertilization was applied using 20.20.0 compound fertilizer providing 6 kg/da of pure nitrogen and phosphorus. The study was conducted between November 2020 and June 2021 to evaluate the herbage yield and quality of ten barley varieties under the conditions of the experimental area. No irrigation was applied during the experiment period. The harvest was performed on June 1, 2021.

### *Examined Characteristics*

Green herbage yield was determined at flowering by harvesting border rows and 0.5 m sections to avoid edge effects, then weighed and converted to kg/da (Karabulut and Çaçan, 2018). Dry matter content (%) was calculated by drying 500 g fresh samples at 70 °C for 48 hours and dividing dry weight by fresh weight. Dry herbage yield (kg/da) was obtained by multiplying green herbage yield by dry matter content (Anonymous, 2021c). Crude protein (%) was measured via the Kjeldahl method on 0.3–0.5 g ground dry samples, multiplying total nitrogen by 6.25 (AOAC, 1990), while crude ash (%) was determined by incinerating 2 g dried samples at 550 °C for 3 hours (Kaçar, 1972). Neutral detergent fiber (NDF, %) and acid detergent fiber (ADF, %) contents were analyzed using ANKOM fiber analyzer by boiling 0.5 g samples in respective detergent solutions, followed by rinsing, drying at 105 °C, and weighing; both were calculated using the formula (Kutlu, 2008):

$$NDF\ or\ ADF\ (\%) = [(W3 - W1 \times C) / W2] \times 100 \tag{1}$$

where:

- W1 is tare weight,
- W2 is sample weight,
- W3 is post-analysis dry weight,
- C is a correction factor.

Relative Feed Value (RFV, %) was calculated as:

$$RFV = (Digestible\ Dry\ Matter \times Dry\ Matter\ Intake) / 1.29 \tag{2}$$

$$Digestible\ Dry\ Matter = 88.9 - (0.779 \times \%ADF) \tag{3}$$

$$Dry\ Matter\ Intake = 120 / \%NDF \tag{4}$$

RFV serves as a combined forage quality index though it does not directly measure physical or protein properties (Sheaffer et al., 1995; Henning et al., 2000; Ball et al., 1996; Tremblay, 1998).

### *Data Analysis*

The data obtained from the study were subjected to analysis of variance (ANOVA) according to a randomized complete block design (RCBD) using the General Linear Model (GLM) procedure in SAS software (SAS, 2013). For traits showing statistically significant differences, means were compared using the Least Significant Difference (LSD) test.

## FINDINGS

The barley varieties examined in this study showed no statistically significant differences in green herbage yield, which ranged from 1046 kg/da (Yalın) to 1506 kg/da (Compagne), with Aydan Hanım (1424 kg/da) and Misket (1376 kg/da) also demonstrating high yields. Dry matter content varied between 29.66% (Aydan Hanım) and 33.30% (Arconda), without significant differences among varieties. Correspondingly, dry matter yield ranged from 334 kg/da (Akar) to 484 kg/da (Compagne), followed by Misket (424 kg/da) and Aydan Hanım (421 kg/da). Crude protein content fluctuated between 11.9% (Akar) and 14.0% (Yalın), again showing no significant differences. However, crude ash content exhibited statistically significant variation, ranging from 6.48% (Arconda) to 8.67% (Ibaiona), with Bozlak (7.87%) also displaying a relatively high ash content. This parameter reflects the mineral nutrient content of the plants, which is crucial for their growth and quality. Overall, while biomass and protein contents were relatively uniform across varieties, differences in mineral content suggest varietal selection should consider specific forage quality traits based on production goals (Table 4).

**Table 4.** Means of green herbage yields (GHY), dry matter content (DMC), dry matter yield (DMY), crude protein content (CPC) and crude ash content (CAC) of different barley varieties

| Barlet variety | GHY (kg/da) | DMC (%) | DMY (kg/da) | CPC (%) | CAC (%) |
|---|---|---|---|---|---|
| Compagne | 1506 | 32.18 | 484 | 13.7 | 7.49 bc[1] |
| Ibaiona | 1195 | 31.91 | 383 | 13.9 | 8.67 a |
| Arconda | 1157 | 33.30 | 390 | 13.6 | 6.48 d |
| Yalın | 1046 | 32.75 | 338 | 14.0 | 6.76 cd |
| Çetin2000 | 1187 | 31.05 | 372 | 13.5 | 7.23 bcd |
| Asil | 1224 | 30.03 | 367 | 13.1 | 6.82 cd |
| Aydan Hanım | 1424 | 29.66 | 421 | 13.8 | 6.74 cd |
| Bozlak | 1350 | 30.98 | 411 | 13.6 | 7.87 b |
| Misket | 1376 | 30.88 | 424 | 13.6 | 7.29 bc |
| Akar | 1078 | 31.24 | 334 | 11.9 | 6.90 cd |
| Ortalama | 1254 | 31.40 | 392 | 13.5 | 7.23 |

[1]) Means within the same column followed by the same letter are not significantly different from each other at the P≤0.01 level according to the Duncan test.

The barley varieties examined in this study did not show statistically significant differences in terms of neutral detergent fiber (NDF), acid detergent fiber (ADF), digestible dry matter (DDM), dry matter intake (DMI), or relative feed value (RFV). NDF content, which affects rumen fill and voluntary intake, ranged from 62.30% (Çetin 2000) to 68.17% (Compagne), with Ibaiona (67.97%) also displaying a high value. Similarly, ADF content, which negatively correlates with digestibility, ranged between 32.05% (Asil) and 36.58% (Yalın), with Compagne (36.40%) also among the higher values. Digestible dry matter values ranged from 59.58% (Misket) to 64.42% (Asil), with Akar (62.29%) being another variety with a relatively high digestibility. In terms of dry matter intake, values ranged from 1.76% (Compagne) to 1.93% (Çetin 2000), with Asil (1.90%) following closely. Relative feed value, a composite index integrating both intake and digestibility, ranged from 83.28 (Compagne) to 95.34 (Asil), with Çetin 2000 (92.10) also performing well. Although no statistically significant differences were detected across varieties for these parameters, the data suggest that certain varieties like Asil and Çetin 2000 consistently performed better in multiple forage quality traits, whereas Compagne, despite its high biomass yield and fiber content, had lower values in intake and relative feed value. These findings emphasize the need to balance biomass yield with forage quality parameters when selecting barley cultivars for animal feeding purposes (Table 5).

**Table 5.** Means of neutral detergent fibre (NDF), acid detergent fibre (ADF), digestible dry matter (DDM), dry matter intake (DMI) and relative feed value (RFV)

| Barley variety | NDF (%) | ADF (%) | DDM (%) | DMI (%) | RFV |
|---|---|---|---|---|---|
| Compagne | 68.17 | 36.40 | 60.98 | 1.76 | 83.28 |
| Ibaiona | 67.97 | 35.43 | 61.38 | 1.77 | 84.11 |
| Arconda | 63.98 | 33.68 | 61.31 | 1.88 | 89.39 |
| Yalın | 66.77 | 36.58 | 61.48 | 1.79 | 85.65 |
| Çetin2000 | 62.30 | 32.31 | 61.67 | 1.93 | 92.10 |
| Asil | 62.85 | 32.05 | 64.42 | 1.90 | 95.34 |
| Aydan Hanım | 65.55 | 34.70 | 62.10 | 1.83 | 88.31 |
| Bozlak | 64.64 | 36.26 | 61.62 | 1.86 | 88.87 |
| Misket | 66.40 | 35.29 | 59.58 | 1.81 | 83.81 |
| Akar | 65.59 | 36.32 | 62.29 | 1.83 | 88.29 |
| Average | 65.43 | 34.91 | 61.69 | 1.84 | 87.92 |

## DISCUSSION

The results of this study revealed no statistically significant differences among the examined barley varieties in terms of green herbage yield, dry matter content, dry matter yield, and crude protein content. This suggests that under the specific Mediterranean ecological conditions of the study site, the tested genotypes perform similarly in biomass production and protein accumulation. Consistent biomass and protein contents across varieties may be indicative of their genetic closeness or adaptation to similar environmental factors such as temperature, soil type, and moisture availability, as supported by previous studies (Pswarayi et al., 2008). For forage producers, such uniformity ensures predictability in yield and protein quality, which are critical parameters for animal nutrition and farm management (Wilkinson, 2011). However, crude ash content differed significantly among varieties, ranging from 6.48% to 8.67%, pointing to variations in mineral nutrient uptake and accumulation. Crude ash is widely recognized as an important indicator of total mineral content in forage, reflecting essential macro- and microelements such as calcium, phosphorus, magnesium, potassium, and trace minerals vital for both plant physiology and animal nutrition (Marschner, 2012; McDonald et al., 2011). The significantly higher ash content observed in varieties like Ibaiona and Bozlak suggests that these genotypes may have a superior capacity to uptake or accumulate minerals from the soil, which could enhance their nutritive value. This aligns with findings from research by Marijanušić et al. (2017) and Capstaff and Miller (2018), who demonstrated that mineral content variability among forage cultivars affects livestock performance, influencing parameters like bone development, milk yield, and metabolic functions. The observed uniformity in crude protein but variability in mineral content emphasizes the need for a more comprehensive approach when selecting forage barley varieties. Traditional selection criteria have focused mainly on yield and crude protein due to their direct effects on animal performance (Van Soest, 1994). However, minerals play an equally crucial role, influencing not only animal health but also rumen microbial activity and forage digestibility (Arthington and Ranches, 2021). Therefore, incorporating mineral nutrient profiles into breeding programs could improve the overall forage quality and sustainability of livestock production systems, especially in Mediterranean regions where soil fertility and mineral availability can be limiting factors (Ben Salem and Smith, 2008). Moreover, the absence of significant differences in biomass and protein may also reflect the limited genetic diversity among the studied varieties or suggest that environmental factors had a homogenizing effect. Further research involving a wider range of genotypes and multi-location experiments would help elucidate genotype × environment interactions, which are critical for developing regionally adapted varieties with improved forage quality (Ceccarelli, 2015). In addition, mineral bioavailability, not just total mineral content, is essential for evaluating forage quality, as some minerals can be bound in forms less accessible to ruminants (Underwood and Suttle, 1999). Future studies employing mineral speciation analysis and animal feeding experiments would provide a deeper understanding of the functional nutritional differences among barley varieties.

In conclusion, while the barley varieties tested here showed broadly similar yield and crude protein levels, significant differences in mineral content highlight the importance of considering mineral nutrition in varietal selection. Selecting barley cultivars with enhanced mineral profiles can contribute to improved animal health and productivity and help optimize forage utilization in Mediterranean agroecosystems. The ten barley cultivars evaluated in this study exhibited similar trends across various parameters related to forage quality. No statistically significant differences were observed among cultivars for green herbage yield, dry matter content, dry matter yield, and crude protein content. This indicates that under the tested environmental conditions, genotypic differences in these traits were not prominent, and the genotype × environment interaction may have played a limited role (Naser et al., 2018). However, in forage production, variety selection should not be based solely on biomass yield but must also account for forage quality components. While Compagne, Aydan Hanım, and Misket were notable for their high green herbage and dry matter yields, cultivars such as Asil, Çetin 2000, and Akar stood out for digestibility and mineral content. These differences emphasize the need to select cultivars based on production goals: for instance, Compagne may be favoured in systems aiming for high biomass production, whereas Asil or Çetin 2000 could be prioritized for forage quality. The crude protein contents ranged from 11.9% to 14.0%, aligning well with previously reported ranges (Mahmud et al., 2020). The lack of significant differences among cultivars suggests genetic similarity in protein synthesis capacities under the same environmental conditions. Similarly, dry matter contents and yields did not significantly vary, supporting the idea that phenological development stages were comparable across cultivars (Moustafa et al., 2021). In contrast, crude ash content exhibited statistically significant differences. Particularly, Ibaiona showed the highest value (8.67%), followed by Bozlak (7.87%). As crude ash reflects the mineral content of the plant, these results are crucial since minerals are essential for metabolic activity, bone development, and overall animal health (Nair et al., 2016). Cultivars with higher mineral content may therefore enhance forage nutritional value.

Neutral Detergent Fiber (NDF) and Acid Detergent Fiber (ADF) levels (important indicators of digestibility and intake potential) ranged from 62.30% to 68.17% and 32.05% to 36.58%, respectively. These values are within the acceptable limits for ruminant nutrition and align with established guidelines (Mertens, 2017). Although no significant differences were found among cultivars, a trend was noted where Asil, with the lowest ADF (32.05%), had the highest digestible dry matter (DDM) value at 64.42%. High ADF is associated with reduced digestibility and energy availability (Minson, 2018), further highlighting the forage potential of Asil. The Dry Matter Intake (DMI) ranged from 1.76% to 1.93%, with Çetin 2000 and Asil achieving the highest values. DMI is critical as it determines the quantity of feed an animal can consume, directly influencing productivity, especially in dairy and beef systems (NRC, 2021). Notably, Compagne, despite its high yield, recorded the lowest DMI (1.76%), which may limit its effectiveness in high-performance systems. The Relative Feed Value (RFV), an index summarizing forage digestibility and intake potential, varied from 83.28 to 95.34. While all cultivars remained below the 100 thresholds typically considered indicative of "high-quality" forage (Linn and Martin, 2017), Asil and Çetin2000 demonstrated relatively superior RFV values, underscoring their potential for use in quality forage systems. In summary, while statistical differences in forage quality parameters among barley cultivars were mostly absent, several cultivars demonstrated superior performance in specific traits. Asil and Çetin 2000 emerged as strong candidates due to their favourable digestibility, intake potential, and relative feed value. Future studies should evaluate these cultivars across diverse environments and growing seasons, while also investigating their impact on animal performance to provide a more comprehensive understanding of their forage suitability.

## CONCLUSION

Based on the findings of this study, it is recommended that barley varieties be selected according to their intended use in forage production. Varieties such as Compagne and Aydan Hanım, which stood out with their high green herbage and dry matter yields, may be suitable for producers prioritizing biomass yield. In contrast, varieties like Asil and Çetin 2000, which demonstrated superior forage quality traits such as higher digestibility, lower ADF content, greater dry matter intake, and higher relative feed value, appear more appropriate for livestock operations that emphasize feed quality. Additionally, Ibaiona and Bozlak varieties showed higher crude ash content, indicating richer mineral composition, which may be beneficial for meeting the dietary mineral needs of specific animal groups. When using barley as a forage crop, it is essential to consider not only yield parameters but also key forage quality attributes. Therefore, characteristics such as fiber content, digestibility, and mineral composition should be incorporated into future forage breeding programs. Finally, since this research was conducted over a single growing season, it is advisable to support these findings with multi-year, multi-location experiments under varying climatic and soil conditions to enhance the generalizability and reliability of the recommendations.

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