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Effects of Saline-Alkaline Soils on Forage Quality of Some Quinoa (*Chenopodium quinoa* Willd.) Varieties

Bazı Kinoa (*Chenopodium quinoa* Willd.) Çeşitlerinin Yem Kalitesine Tuzlu-Alkali Toprakların Etkileri

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Abstract: In this research, the forage quality performances of 7 different quinoa varieties in saline-alkaline soils were determined. The study was established using the factorial experimental design in random blocks with 3 replications for 2 years (2021-2022). Sandoval Mix (SM), Red Head (RH), Titicaca (T), Moqu Arrochilla (MA), French Vanilla (FV), Oro de Valle (OV), and Rainbow (R) varieties were used in the experiment. According to the research results, there was only a difference in the crude protein (CP) ratio over the years. Compared to the control soil, saline-alkaline soils had no effect on crude protein content, but caused significant changes in neutral detergent fibre (NDF), acid detergent fibre (ADF), dry matter intake (DMI), dry matter digastiblity (DMD), metabolized energy (ME), relative feed values (RFV) and digestible energy (DE). It was determined that there were significant differences in the forage quality of the quinoa varieties used in the study. According to the research results, Sandoval Mix, Red Head, French Vanilla and Oro de Valle quinoa varieties, which do not show a decrease in crude protein content, should be preferred in quinoa cultivation in saline-alkaline soils. On the other hand, quinoa cultivation should be carried out by taking into account that there will be an increase in NDF content and a decrease in DMI and RFV contents, which are important quality features of quinoa varieties in saline-alkaline soils.
Keywords: Saline, Crude Protein, NDF, ADF, RFV

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Öz: Bu araştırmada 7 farklı kinoa çeşidinin tuzlu-alkali topraklardaki yem kalite performasnları belirlenmiştir. Çalışma 2 yıl süreyle (2021-2022) tedadüf bloklarında faktöriyel deneme desenine göre 3 tekerrürlü olarak kurulmuştur. Denemede Sandoval Mix (SM), Red Head (RH), Titicaca (T), Moqu Arrochilla (MA), French Vanilla (FV), Oro de Valle (OV) ve Rainbow (R) çeşitleri kullanılmıştır. Araştırma sonuçlarına bakıldığında yıllara göre sadece ham protein (HP) oranında farklılık olmuştur. Kontrol toprağına göre, tuzlu-alkali toprakların ham protein oranı üzerine herhangi bir etkisi olmazken, nötr çözücülerde çözünemeyen lif (NDF), asit çözücülerde çözünmeyen lif (ADF), kuru madde tüketimi (KMT), kuru madde sindirilebilirliği (KMS), sindirilebilir enerji (SE), nispi yem değeri (NYD) ve metabolik enerji (ME) değerlerinde önemli değişimlere neden olmuştur. Araştırmada kullanılan kinoa çeşitlerinin besin değerlerinde önemli farklılıklar olduğu belirlenmiştir. Araştırma sonuçlarına göre, tuzlu-alkali topraklarda kinoa yetiştiriciliğinde ham protein oranında azalma göstermeyen Sandoval Mix, Red Head, French Vanilla ve Oro de Valle kinoa çeşitlerinin tercih edilmesi gerekmektedir. Diğer taraftan tuzlu-alkali topraklarda kinoa çeşitlerinin önemli kalite özelliklerinden NDF içeriğinde artış olacağı ve KMT ve NYD içeriklerinde ise azalış olacağı göz önüne alınarak kinoa yetiştiriciliğinin yapılması gerekmektedir.
Anahtar Kelimeler: Tuzluluk, Ham Protein, NDF, ADF, NYD

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INTRODUCTION

Extreme soil and climate conditions in the world are increasing day by day and limiting the number of products that can be grown in these areas. In addition, extreme climate and soil conditions (salinity, drought, erosion) significantly affect the forage and seed yields per unit area. Approximately 6% of the world's land and 20% of agricultural land are affected by salt (Munns and Tester, 2008). Saline areas are generally found in arid and semiarid areas (Masters et al., 2007). Ions such as Na+, Cl− and SO_4^{2-}, which increase in amount in saline soils, cause a decrease in water potential, ion toxicity in plants as a result of excess ion uptake, decrease in water uptake by plants and therefore slow down plant growth (Munns and Tester, 2008; Golos et al., 2016; Hussain et al., 2018). In saline areas, many crop plants cannot continue to develop and the yield per unit area is limited (Temel et al., 2015; Temel et al., 2016; Aras and Keskin, 2018).

In recent years, research has intensified to find alternative plants for the utilization of saline areas. One of the plants that can be grown in extreme soil conditions is quinoa. Quinoa is a species belonging to the *Chenopodium* genus, which contains approximately 250 species and mostly includes halophyte plants (Kadereit et al., 2005). Some quinoa species can continue their growth at an electrical conductivity salinity level of 600 mM NaCl (50 dS m^{-1}) (Biond et al., 2015). Seed germination in quinoa is not affected much up to 400 mM salinity level and continues to develop without significant yield reduction up to 10-20 dS m^{-1} electrical conductivity level (Pulvento et al., 2012; Jamali and Sharifan., 2018; Rezzouk et al., 2020; Keskin et al., 2023). On the other hand, quinoa is also resistant to adverse climatic conditions such as drought (Fuentes and Bhargava, 2011; Pulvento et al., 2012) and frost (Jacobsen et al., 2007; Rosa et al., 2009).

Quinoa is widely cultivated in South America and temperate regions as human food. Straw remaining during harvest for seed is evaluated as feed for animals (Blanco, 2015; Keskin and Önkür, 2019). Quinoa green parts are made into silage or fed directly to animals (Keskin and Duman, 2024; Keskin and Aksoy, 2024). Additionally, quinoa is rich in carotenoids, ascorbic acid, minerals and protein (Bhargava et al., 2007; Temel and Keskin, 2019a; Temel and Keskin, 2020). Thanks to its genetic diversity, quinoa has varieties that are adapted to different climate and soil conditions and that respond differently to extreme conditions (Morales et al., 2011; Tan and Temel, 2017).

Quinoa hay is used especially in the feeding of ruminant animals. Depending on the quinoa variety, around 4-8 tons ha^{-1} of dry matter can be obtained and 15-17% of the dry matter can consist of protein (Temel and Keskin, 2019a; Temel and Keskin, 2019b; Çağlayan and Kökten, 2021). No significant differences were observed in live weight gains between animals fed alfalfa hay and quinoa hay (Rubio and Rojas Lemus, 2007).

The aim of the present study was to determine some feed quality characteristics of hay belonging to different quinoa varieties grown in saline-alkaline soils and harvested at full bloom, which are important in animal nutrition.

MATERIAL AND METHOD

This research was carried out for 2 years (2021-2022) in the non-salt (control) and saline-alkaline trial areas of Iğdır University Agricultural Application and Research Center. In the research, Sandoval Mix, Red Head, Titicaca, Moqu Arrochilla, French Vanilla, Oro de Valle and Rainbow quinoa varieties with high yield capacity were used (Tan and Temel, 2017; Tan and Temel, 2018; Temel and Keskin, 2020).

The properties of the soils taken from the trial area are given in Table 1 (Richards, 1954; Ülgen and Yurtsever, 1974; FAO, 1990). When Table 1 is examined, it is seen that the pH of saline-alkaline soils is 9.8 and the EC value is 9.69 dS m^{-1}.

Some climate data for the year and long years in which the experiment was conducted are presented in Table 2. During the months of April, May and June when the experiment was conducted, the temperature varied between 17.0 °C and 26.8 °C and the relative humidity varied between 34.4% and 53.9%. The total rainfall for three months was 61 mm in 2021 and 106.6 mm in 2022. According to these data, 2021 was seen to be drier.

Table 1. Some properties of the trial soils.
Çizelge 1. Deneme topraklarının bazı özellikleri.

Analysis Name	Nonsaline soil		Saline soil	
	Value	Classification	Value	Classification
EC (dS m^{-1})	2.05	Nonsaline	9.69	Very saline
pH	8.41	Strong alkaline	9.80	Strong alkaline
Soil texture (Saturation %)	63.16	Clay loam	59.41	Clay loam
Organic Matter %	0.87	Very little	0.93	Very little

Table 2. Some climate data of the experimental area (Anonymous, 2022).
Çizelge 2. Deneysel alanın bazı iklim verileri (Anonim, 2022).

Months	Temperature (°C)		Precipitation (mm)		Relative humidity (%)	
	2021	2022	2021	2022	2021	2022
April	17.4	15.7	18.4	25.8	44.0	43.9
May	21.1	17.0	42.1	54.8	46.7	53.9
June	26.8	24.6	0.7	26.0	34.4	47.6
Ave/Total	21.7	19.1	61.2	106.6	41.7	48.4

In the experiment, seed sowing was done in the first week of April in both years. The trial plots were prepared as 8.75 m^2, 1.75 m wide and 5 m long. Seeds were sown at 35x10 cm intervals. Before planting, 80 kg ha^{-1} phosphorus (42% triple super phosphate) and 80 kg ha^{-1} nitrogen (21% ammonium sulphate) fertilizer was applied and mixed with the soil. Additionally, when the plant height reached 30 cm, an additional 50 kg ha^{-1} nitrogen fertilizer (21% ammonium sulphate) was given to each plot. When the useful water level in the soil reached 50%, irrigation was done with sprinkler irrigation systems. Forage harvests were made in the last week of June when full flowering occurred, leaving a 10 cm stubble height. After the harvested herbs were dried in the shade for a while, they were kept in a drying oven set at 70 °C for 48 hours and then ground with a grinding machine.

Crude protein ratios of ground hay were determined as nitrogen amounts according to the Kjeldahl method, and the crude protein percentage of the grass was determined by multiplying the determined nitrogen amounts by the coefficient of 6.25 (Baur and Ensminger, 1977). NDF and ADF ratios were determined with the Ankom fiber analyzer (Van Soest et al., 1991). DMD [88.9 - (0.779 x ADF)] (Oddy et al., 1983) and DMI (120 / NDF) (Sheaffer et al., 1995) ratios were determined by using NDF and ADF values. The amount of DE [0.27 + 0.0428 x (DMD)] was determined by using the DMD ratio (Fonnesbeck et al., 1984), and the amount of ME (0.821 x DE) was determined by using the DE ratio (Khalil et al., 1986). RFV value was determined by using DMD and DMI ratios (DMD x DMI / 1.29) (Sheaffer et al., 1995).

The data obtained in the experiment were subjected to variance analysis in the JMP 5.0.1 package program and the averages were grouped according to the LSD test.

RESULTS AND DISCUSSION

Some feed values of the harvested at full bloom are given in Table 3 and Table 4.

Crude Protein (CP)

Protein is essential for the growth and health of animals. Protein plays an important role in the formation of animal products (meat, milk). Meeting the energy needs of animals along with protein will contribute significantly to their growth, increased productivity and health (Kutlu et al., 2005; Kutlu and Özen, 2009). The crude protein content of quinoa grass has varied between years. It is estimated that the quinoa plant will grow better in 2022 (Table 2), when rainfall and air humidity are high, causing an increase in the crude protein ratio. Soil properties (control, saline-alkaline) had no effect on the crude protein content of quinoa plants. There were significant differences in crude protein ratios among the quinoa varieties used in the study. Crude protein content of Titicaca, Oro de Valle, Sandoval Mix, Red Head and Moqu Arrochilla quinoa varieties was higher than other varieties. The lowest crude protein content was observed in the French Vanilla variety (Table 3). Changes in crude protein ratios of quinoa varieties according to soil properties (types) are given in Figure 1. Compared to the control soil, there was an increase in crude protein content in Sandoval Mix, Red Head, French Vanilla and Oro de Valle varieties in saline-alkaline soils, while there was a decrease in crude protein content in Titicaca, Moqu Arrochilla and Rainbow varieties. When plant species and varieties are grown in saline environments, some studies reported a decrease in crude protein ratio (Elfeel and Bakhashwain, 2012; Temel et al., 2015; Kılıç et al., 2015; Hedayati-Fifoozabadi et al., 2020; Waldron et al., 2020; Şen et al., 2021), some studies reported an increase (Fowler et al., 1992; Heidari et al., 2023) and some studies reported no significant change (Suyama et al., 2007; Masters et al., 2010; Temel et al., 2016; Mahmoud and Sallam, 2017). It is thought that the genetic structure of the varieties and their different responses to salinity cause their crude protein contents to differ.

Table 3. CP, NDF, ADF and DMD of quinoa plant grown in saline-alkaline and non-saline soils.
Çizelge 3. Tuzlu-alkali ve tuzsuz topraklarda yetiştirilen kinoa bitkisinin HP, NDF, ADF ve KMS değerleri.

Years (Y)	CP (%)	NDF (%)	ADF (%)	DMD (%)
2021	17.5 b	32.3	19.6	73.7
2022	18.5 a	32.8	19.3	73.8
Soil type (S)				
Control	17.9	30.0 b	18.1 b	74.8 a
Salty-alkaline	18.1	35.1 a	20.8 a	72.7 b
Varieties (V)				
Sandoval Mix	18.2 a-c	35.0 a	20.6 a	72.8 b
Red Head	18.1 ab	32.4 b	19.8 a	73.5 b
Titicaca	19.3 a	30.2 c	16.6 b	76.0 a
Moqu Arrochilla	18.0 ab	32.0 b	19.4 a	73.8 b
French Vanilla	16.6 d	33.4 b	20.3 a	73.1 b
Oro de Valle	18.8 ab	33.3 b	19.6 a	73.6 b
Rainbow	17.0 cd	31.6 bc	19.9 a	73.4 b

The difference between the averages shown with the same letters is not significant.

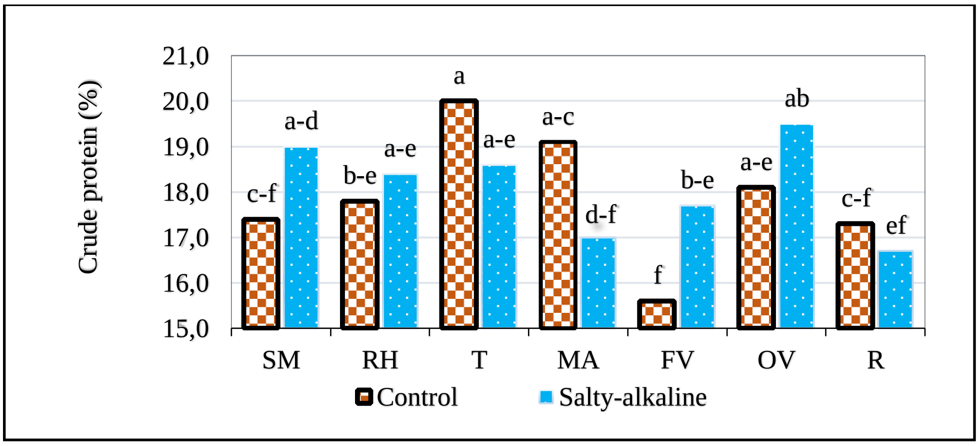

Figure 1. Changes in crude protein content of quinoa varieties according to soil properties.
Şekil 1. Toprak özelliklerine göre kinoa çeşitlerinin ham protein oranlarındaki değişimler.

Neutral Detergent Fibre (NDF)

The total of cellulose, hemicellulose, lignin and silicon contents in the structure of agricultural products is called NDF (Neutral detergent fiber). NDF gives an idea about the feed consumption of animals or the specific gravity of the feed (Kutlu et al., 2005). The NDF content of quinoa grass did not differ among the years. Soil properties (control, saline-alkaline) significantly affected the NDF content of quinoa plants. An increase in NDF ratio was observed in quinoa plants grown in saline-alkaline soils compared to the control soil. There were significant differences between the NDF rates of the quinoa varieties used in the study. While the NDF contents of the Titicaca and Rainbow varieties were lower, the NDF rate of the Sandoval Mix variety was higher than the other varieties (Table 3). Changes in NDF rates of quinoa varieties according to soil types (properties) are given in Figure 2. Compared to the control soil, there was an increase in NDF rates of all quinoa cultivars in saline-alkaline soils. In studies conducted with different plant species and varieties growing in saline environments, the NDF content of the plant increased in some studies (Masters et al., 2010; Elfeel and Bakhashwain, 2012; Temel et al., 2015; Kılıç et al., 2015; Hedayati-Firoozabadi et al., 2020; Waldron et al., 2020; Heidari et al., 2023), decreased in some studies (Fowler et al., 1992; Temel et al., 2016; Mahmoud and Sallam, 2017; Anderson et al., 2023) and no significant change was reported in some studies (Suyama et al., 2007). Extreme climate and soil conditions (salinity, drought, high temperature, low rainfall) cause an increase in plant cell walls and a decrease in carbohydrate content (Al-Dakheel et al., 2015). As a result, it causes an increase in NDF and ADF rates in the plant and thus a decrease in forage quality. In addition, the decrease in minerals taken by the plant from the soil causes the fiber content to increase (Blanco, 2015).

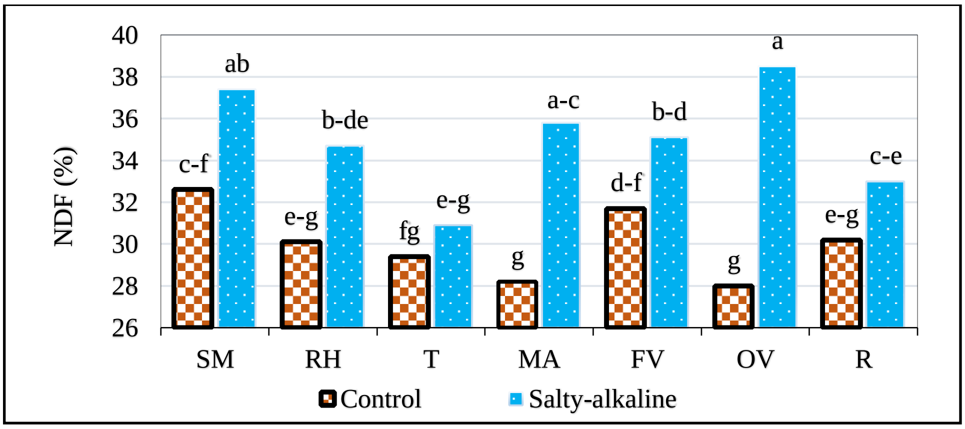

Figure 2. Changes in NDF rates of quinoa varieties according to soil properties.
Şekil 2. Toprak özelliklerine göre kinoa çeşitlerinin NDF oranlarındaki değişimler.

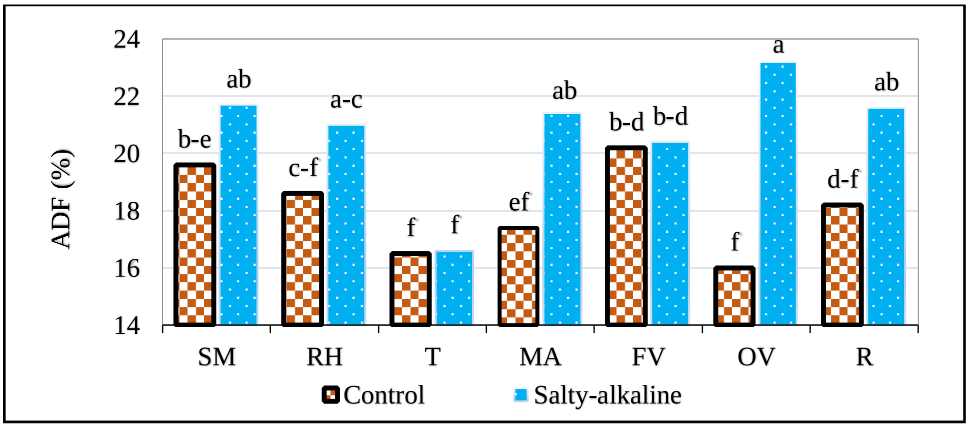

Figure 3. Changes in ADF rates of quinoa varieties according to soil properties.
Şekil 3. Toprak özelliklerine göre kinoa çeşitlerinin ADF oranlarındaki değişimler.

Acid Detergent Fibre (ADF)

The total of cellulose, lignin and silicon contents remaining after hemicellulose is removed from the NDF content in animal feeds is called ADF (Acid detergent fibre). ADF is an indicator of the digestion and energy intake capacities of feeds (Kutlu et al., 2005). The ADF ratio of quinoa grass did not differ between years. Soil properties (control, saline-alkaline) significantly affected the ADF ratio of the obtained hay. There was an increase in ADF rates in the grass of quinoa varieties grown in saline-alkaline soils compared to the control soil. There were significant differences in ADF ratios among the quinoa varieties used in the study. While the ADF rate was lowest in the Titicaca variety, the ADF rates of other quinoa varieties were high (Table 3). ADF rates of quinoa varieties in control and saline-alkaline soil are given in Figure 3. While there was an increase in ADF rates of Sandoval Mix, Moqu Arrochilla, Red Head, Rainbow and Oro de Valle cultivars in saline-alkaline soils compared to the control soil, there was no change in ADF rates of Titicaca and French Vanilla cultivars. In studies conducted with different plant species and varieties growing in saline environments, the ADF content of the plant has been reported to increase in some studies (Masters et al., 2010; Elfeel and Bakhashwain, 2012; Kılıç et al., 2015; Hedayati-Firoozabadi et al., 2020; Heidari et al., 2023) and to decrease in some studies (Fowler et al., 1992; Mahmoud and Sallam, 2017; Anderson et al., 2023).

Dry Matter Digestibility (DMD)

DMD (Dry matter digestibility) is an indicator of the rate at which feeds are digested by animals (Kutlu et al., 2005; Kutlu and Özen, 2009). The DMD rate of quinoa hay did not differ between years. Soil properties (control, saline-alkaline) significantly affected the DMD rate of quinoa plants. Compared to the control soil, a decrease in DMD rate was observed in the grass of quinoa varieties grown in saline-alkaline soils. There were significant differences in DMD rates among the quinoa varieties used in the study. The DMD rate of Titicaca quinoa variety was higher than other varieties (Table 3). DMD rates of quinoa varieties in control and saline-alkaline soil are given in Figure 4. While there was a decrease in DMD rates of Red Head, Sandoval Mix, Oro de Valle, Moqu Arrochilla and Rainbow cultivars in saline-alkaline soils compared to the control soil, there was no significant change in DMD rates of Titicaca and French Vanilla cultivars. In the research conducted with different plant species and varieties growing in salty environments, a decrease in the DMD content of the plant was reported (Kılıç et al., 2015). It is observed that the increase in ADF rates also causes an increase in DMD rates.

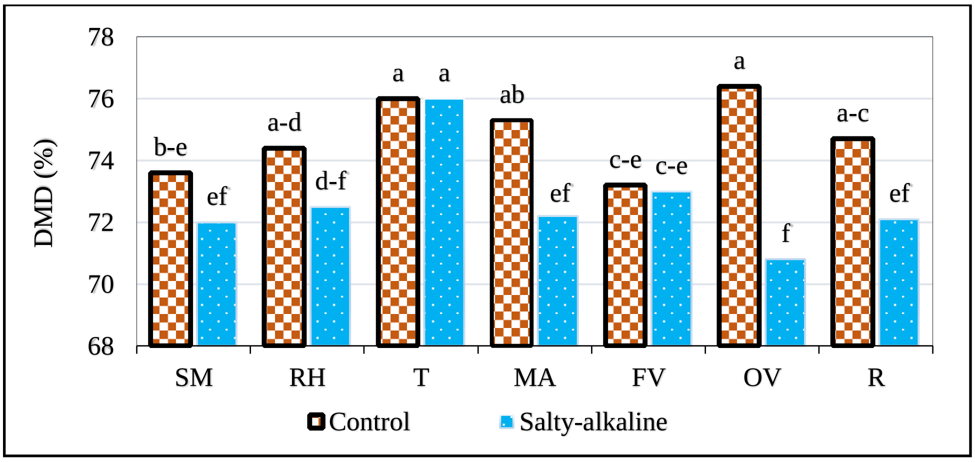

Figure 4. Changes in DMD rates of quinoa varieties according to soil properties.
Şekil 4. Toprak özelliklerine göre kinoa çeşitlerinin KMS oranlarındaki değişimler.

Dry Matter Intake (DMI)

DMI is an indicator of the rate at which animals can consume feed (Kutlu et al., 2005; Kutlu and Özen, 2009). The DMI ratio of quinoa grass did not differ between years. Soil properties (control, saline-alkaline) had a significant effect on the DMI ratio of quinoa plants. The DMI ratio of quinoa grass grown in saline-alkaline soils was lower than that of the control soil. There were significant differences between the DMI rates of the quinoa varieties used in the study. The DMI ratio of Titicaca quinoa variety was higher than other varieties (Table 4). DMI rates of quinoa varieties in control and saline-alkaline soil are given in Figure 5. Compared to the control soil, there was a decrease in DMI rates of all quinoa cultivars in saline-alkaline soils. In the research conducted with different plant species and varieties growing in salty environments, a decrease in the DMI content of the plant was reported (Kılıç et al., 2015). It is seen that the increase in NDF rates also causes an increase in the DMI rate.

Digestible Energy (DE)

Digestible energy is the energy obtained by subtracting the amount of energy excreted in feces from the total energy (Kutlu et al., 2005; Kutlu and Özen, 2009). The amount of DE in quinoa grass did not differ between years. Soil properties (control, saline-alkaline) had a significant effect on the DE content of quinoa plants. There was a decrease in the amount of DE in the grass of quinoa varieties grown in saline-alkaline soils compared to the control soil. There were significant differences in DE amounts among the quinoa varieties used in the study. The DE amount of Titicaca quinoa variety was higher than other varieties (Table 4). While there was a decrease in DE amounts in Sandoval Mix, Red Head, Oro de Valle, Moqu Arrochilla and Rainbow varieties in saline-alkaline soils compared to the control soil, there was no significant change in DE amounts in Titicaca and French Vanilla varieties (Figure 6).

Table 4. DMI, DE, ME and RFV contents of quinoa plant grown in saline-alkaline and non-saline soils.
Çizelge 4. Tuzlu-alkali ve tuzsuz topraklarda yetiştirilen kinoa bitkisinin DMI, DE, ME ve RFV içerikleri.

Years	DMI (%)	DE (Mcal kg^{-1})	ME (Mcal kg^{-1})	RFV
2021	3.77	3.42	2.81	215.4
2022	3.70	3.43	2.82	212.7
Soil property (S)				
Control	4.02 a	3.47 a	2.85 a	233.6 a
Salty-alkaline	3.45 b	3.38 b	2.78 b	194.5 b
Varieties (A)				
Sandoval Mix	3.44 c	3.38 b	2.78 c	194.8 c
Red Head	3.74 b	3.42 b	2.80 bc	212.9 b
Titicaca	4.00 a	3.52 a	2.88 a	235.7 a
Moqu Arrochilla	3.82 ab	3.43 b	2.83 b	218.8 b
French Vanilla	3.61 bc	3.41 b	2.79 bc	204.9 bc
Oro de Valle	3.72 b	3.42 b	2.82 bc	213.7 b
Rainbow	3.82 ab	3.39 b	2.80 bc	217.6 b

The difference between the averages shown with the same letters is not significant.

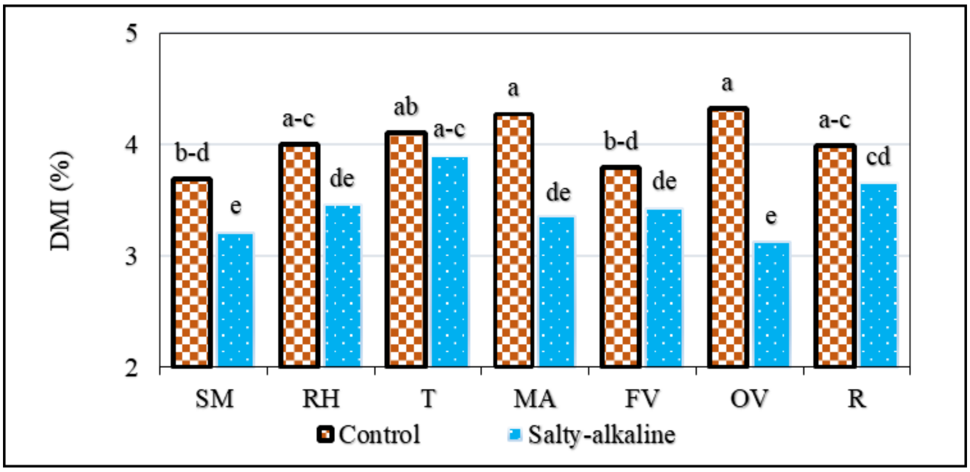

Figure 5. Changes in DMI rates of quinoa varieties according to soil properties.
Şekil 5. Toprak özelliklerine göre kinoa çeşitlerinin KMT oranlarındaki değişimler.

Metabolize Energy (ME)

Metabolic energy refers to the energy remaining after the energy excreted in urine and methane gas is subtracted from digestible energy (Kutlu et al., 2005; Kutlu and Özen, 2009). The amount of ME in quinoa grass did not differ between years. Soil properties (control, saline-alkaline) significantly affected the ME amount of quinoa plants. Compared to the control soil, a decrease in ME content was observed in quinoa varieties grown in saline-alkaline soils. There were significant differences in the ME amounts of the quinoa varieties used in the study. The ME amount of Titicaca quinoa variety was higher than other varieties (Table 4). While there was a decrease in ME amounts of Sandoval Mix, Oro de Valle, Red Head, Moqu Arrochilla and Rainbow varieties in saline-alkaline soils compared to the control soil, there was no significant change in ME amounts of Titicaca and French Vanilla varieties (Figure 7). In studies conducted with different plant species and varieties growing in saline environments, the ME content of the plant was reported to decrease in some studies (Masters et al., 2010; Waldron et al., 2020) and it did not cause a significant change in some studies (Suyama et al., 2007).

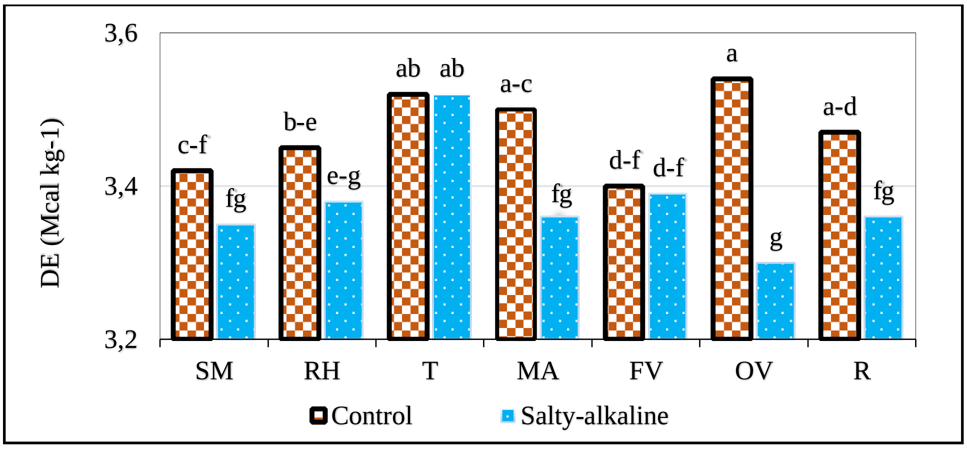

Figure 6. Changes in DE amount rates of quinoa varieties according to soil properties.
Şekil 6. Toprak özelliklerine göre kinoa çeşitlerinin SE miktarlarındaki değişimler.

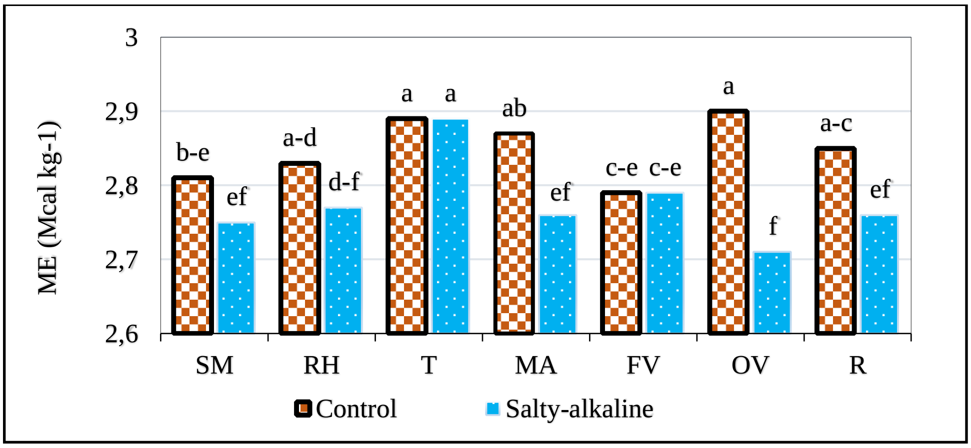

Figure 7. Changes in ME amount rates of quinoa varieties according to soil properties.
Şekil 7. Toprak özelliklerine göre kinoa çeşitlerinin ME miktarlarındaki değişimler.

Relative Feed Values (RFV)

The relative feed value calculated using NDF and ADF ratios is a measure of forage quality accepted as 100 for alfalfa plants (Rohweder et al., 1978; Ball et al., 1996; Morrison, 2003). An RFV value above 150 indicates that the grass is of first quality. If the RFV value is between 125-150, it is considered as the 2nd quality, if it is 103-124, it is considered as the 3rd quality, if it is 87-102, it is considered as the 4th quality, if it is 75-86, it is considered as the 5th quality, and if it is below 75, it is considered as the 6th quality (Rohweder et al., 1978). The RFV value of quinoa grass did not differ between years. Soil properties (control, saline-alkaline) significantly affected the RFV value of quinoa plants. It was observed that quinoa varieties grown in saline-alkaline soils caused a decrease in RFV contents compared to the control soil. There were significant differences between the RFV values of the quinoa varieties used in the study. The RFV value of Titicaca quinoa variety was higher than other varieties (Table 4). RFV rates of quinoa varieties in control and saline-alkaline soil are given in Figure 8.

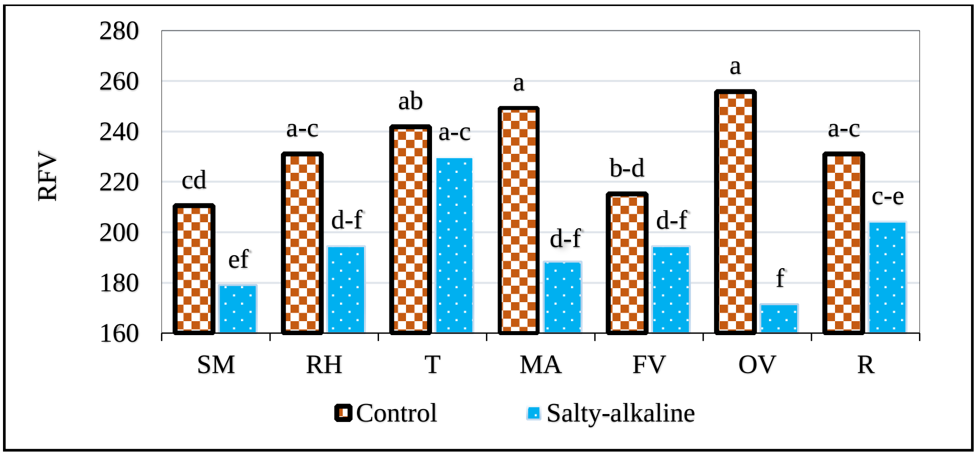

Figure 8. Changes in RFV value rates of quinoa varieties according to soil properties.
Şekil 8. Toprak özelliklerine göre kinoa çeşitlerinin NYD değerindeki değişimler.

Compared to the control soil, there was a decrease in RFV rates of all quinoa cultivars in saline-alkaline soils. In the research conducted with different plant species and varieties growing in saline environments, a decrease in the RFV content of the plant was reported (Kılıç et al., 2015). Quinoa grass has been found to have a Class 1 forage quality because its RFV value is higher than 150.

CONCLUSION

In the two-year study, the crude protein content of quinoa varieties varied from year to year, while there was no change in other feed quality characteristics. According to the average data, there was no significant change in the crude protein ratio of grass grown in saline-alkaline soil compared to the control soil, while other forage quality properties (NDF, ADF, DMD, DMI, DE, ME and RFV) showed significant differences. Accordingly, while there was an increase in the NDF and ADF ratios of the grass obtained in saline-alkaline soil, there was a decrease in the DMD, DMI, DE, ME and RFV contents. On the other hand, the forage quality properties of quinoa varieties CP, ADF, DMD, DE and ME were affected differently in saline-alkaline soils.

In saline-alkaline soils, there was an increase in the crude protein content of Sandoval Mix, Red Head, French Vanilla Oro de Valle varieties, while there was a decrease in the crude protein content of Titicaca, Moqu Arrochilla and Rainbow varieties. While there was an increase in ADF rates of Sandoval Mix, Red Head, Moqu Arrochilla, Oro de Valle and Rainbow cultivars in saline-alkaline soils, there was no change in ADF rates of Titicaca and French Vanilla cultivars. While there was a decrease in DMD rates of Sandoval Mix, Red Head, Moqu Arrochilla, Oro de Valle and Rainbow cultivars in saline-alkaline soils, there was no significant change in DMD rates of Titicaca and French Vanilla cultivars. While there was a decrease in DE amounts in Sandoval Mix, Red Head, Moqu Arrochilla, Oro de Valle and Rainbow varieties in saline-alkaline soils, there was no significant change in DE amounts in Titicaca and French Vanilla varieties. While there was a decrease in ME amounts in Sandoval Mix, Red Head, Moqu Arrochilla, Oro de Valle and Rainbow varieties in saline-alkaline soils, there was no significant change in ME amounts in Titicaca and French Vanilla varieties.

As a result, Sandoval Mix, Red Head, French Vanilla and Oro de Valle quinoa varieties, which do not show a decrease in crude protein content, should be preferred in quinoa cultivation in saline-alkaline soils. On the other hand, quinoa varieties should be cultivated by taking into account that there will be an increase in NDF content and a decrease in DMI and RFV contents in important quality properties.

CONFLICT OF INTEREST

There is no disagreement between the authors.

DECLARATION OF AUTHOR CONTRIBUTION

The authors contributed equally to each stage of the study.

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