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The Seasonal Variation of Forage's Chemical Composition of a Semi-Arid Rangeland According to Altitude and Aspects

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A B S T R A C T

This study was carried out on Kop Mountain, which is located at the intersection of Eastern Anatolia and the Eastern Black Sea in Turkey. Forage samples were taken from the semi-arid rangeland sites were analyzed for a status of the chemical composition according to altitude and aspect. In addition, the seasonal variation of the chemical composition was investigated by repeated analyzes in 3 different periods. In terms of aspect, the highest crude protein ratio (13.40%) occurred in the north, the lowest ratio (10.11%) occurred in the east, while the higher crude protein ratio (11.88%) was observed in the backslope in terms of altitude. The highest crude protein rate (15.15%) was found in May. The highest rate (53.67%) was found in the east and the lowest (45.86%) in the North in terms of NDF. NDF rates in May, July, and October were 48.27%, 47.11%, and 58.17%, respectively. The highest value (33.30%) was recorded in the west and the lowest value (27.66%) was recorded in the North in terms of ADF. ADF values observed in May, July, and October were determined as 26.98%, 30.93%, and 36.63%, respectively. According to the results of the research, it was determined that while the crude protein ratio decreased with the maturation of the plants, the elements forming the cell wall increased; and seasonal conditions changed and affected the forage quality.

1. Introduction

Rangelands and meadows are essential both as a feed source and sustainability of natural life. To derive benefits from rangelands in a manner that is compatible with long-term sustainability, it is important to ensure that they are used by following per under with the principles of forest management, that rangeland plant populations are safeguarded, and appropriate breeding activities are carried out using rangelands with the proper animal species and the number of animals, correct estimation of the grazing time, and selection of suitable breeding methods can become possible if all of the elements that impact the use of rangelands are taken into consideration. While grazing is the primary driver of rangelands, key elements such as altitude and aspect influence on rangeland vegetation. In a research (Gökkuş et al., 1993), the effects of altitude, slope, and aspect on sites of rangeland were assessed, and it was shown that as altitude increased, yield declined. The ratios of grasses, legumes, and other families were found to be different depending on the altitude in a study that was carried out by Çomaklı et al. (2012) on three rangelands located at 2000, 2500, and 3000 meters

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in altitude. Additionally, the canopy coverage rate was found to decrease as the altitude increased. Another factor affecting rangeland vegetation is seasonal variation. According to the study performed by Tarhan and Çaçan (2020) to discern the monthly variation and grazing season in rangelands based on the aspects, May was ascertained as the beginning of the grazing season for the rangelands in the Ormanardı village of the Bingol province, and May and June were the most productive months of the grazing season in terms of yield and quality as per the study results.

Eastern Anatolia region has the highest rangeland existence in Turkey. The country's total rangeland of 38% is located in this region (Anonymous, 2022). Kop Mountain, situated at the junction of Eastern Anatolia and the Eastern Black Sea, is part of the Eastern Black Sea Mountains. In the area situated near the intersection of the provinces of Bayburt, Erzurum, and Erzincan, mountain rangelands are used to raise livestock. In this research, variances in the chemical composition of forage samples from various altitudes and aspects of rangeland sites, seasonal variations in ADF, NDF, and Crude Protein ratios, and the consequences of these variations on forage quality were attempted to be identified.

2. Material and Method

The study was conducted by collecting samples from various portions of semi-arid rangeland sites of Kop Mountain, Turkey in 2019 and 2020, followed by laboratory analysis. Rangeland areas were determined to include 2 different altitudes and 4 different aspects.

The first altitude value chosen for the study was determined from the border of the agricultural land, while the second altitude value was chosen close to the summit. The first altitude value is called "footslope" and the second altitude value is called "backslope". It was discovered that the slopes of the research areas were similar. For this purpose, two different altitude measurements were taken into consideration at the footslope and backslope sites of Kop Mountain, with the aspect of the slopes (hillsides) serving as a starting point. Then, the four aspects of east, west, north, and south were identified. Rangeland sites at two distinct altitudes (1st altitude: 1871 -1985 m, 2nd altitude: 2372 - 2468 m) were chosen for each aspect, and the study was conducted in these eight rangeland sites.

The climate data for the research area were collected from the 12th Regional Directorate of Meteorology station in the district of Aşkale in Turkey, which is the closest station to the research area. Climate statistics show that the Aşkale meteorological station's annual average temperature for the 2013-2020 observation period was 7.6ºC, the average annual total precipitation was 386.95 mm, and the average annual relative humidity value was 64.7%. In the years 2019 and 2020, when the research was conducted, the average temperature was 7.4ºC in 2019, 7.9ºC in 2020, and relative humidity was 66.9% for 2019 and 61.6% for 2020. When the data is analyzed in terms of precipitation values, precipitation data for 2019 (373.1 mm) and 2020 (342.2 mm) were lower than the 2013-2020 average values.

In the laboratories of the Eastern Anatolian Agricultural Research Institute and the Faculty of Agriculture at Atatürk University, a total of 8 soil samples collected from the research area were examined. The results showed that soil had a neutral character (pH 6.74), organic matter content was 5.84% (rich), nitrogen rate was "high" (0.29%) and EC (salinity) rate was "slightly salty".

Three quadrats of 0.25 m^2 were harvested in May, July, and October to produce forage samples from the rangeland areas under study. When selecting the sampling locations on the rangeland, protected sampling areas were preferred. Forage samples were labeled and preserved in cloth bags after the procedures for sampling were carried out in three repetitions. The samples were gathered from two distinct altitudes and four distinct aspects, which are collectively referred to as Kop Mountain footslope and backslope sites. The forage samples that were predried in the greenhouse environment were dried at a temperature of 70ºC until they attained a constant weight. After drying, nitrogen ratios of the grounded forage samples were calculated by wet combustion using the Kjeldahl method to determine the crude protein ratio. The obtained total nitrogen ratios were multiplied by the advised 6.25 coefficient to calculate the forage plant's crude protein ratios (Adesogan et al., 2000), and crude protein ratios were calculated.

With the use of ANKOM Fiber technology, acid detergent fiber (ADF) analysis was performed on the plants obtained from rangeland areas to ascertain how much lignin and cellulose were present in their cell walls (Ankom, 2020). To lignin, cellulose, and hemicellulose amounts in the cell wall in forage samples, ANKOM Fiber technology was used for the neutral detergent fiber (NDF) analysis.

Following the analysis, the crude protein, NDF, and ADF values were analyzed according to the 4-factor (aspect x altitude x season x year) experimental design in randomized blocks with 3 repetitions (Yıldız and Bircan, 1994). After applying the arc-sin transform to the proportional data gathered from different rangeland sites, statistical analyses were conducted using SPSS (Version 20) software. The Duncan test was used to evaluate the statistically significant factor means based on the results of the variance analysis.

3. Results and Discussion

Table 1 shows the variance analysis results and the variation of crude protein, NDF, and ADF ratios in forage samples taken from rangeland sites according to the altitude, aspects, and season.

The evaluation of crude protein, NDF, and ADF values was provided below based on the information in Table 1.

Crude Protein (%)

The variance analysis of the crude protein ratio of the samples collected from the rangeland sites revealed non-significance regarding the research years (Table 1). Following the study years and combined analysis, the variation of aspect and seasonal crude protein ratio was shown to be very significant (p<0.01) While the values recorded in 2019 were insignificant based on altitude variable, the values recorded in 2020 and combined analysis were significant at 1% level.

Table 1. Variation of Crude Protein, NDF, and ADF Rates As Per Aspect, Altitude, and Season (%) and Variance Analysis Results of Crude Protein, NDF, and ADF Rates

	Crude Protein			NDF			ADF		
Aspect	**2019**	**2020**	**Combined Analysis**	**2019**	**2020**	**Combined Analysis**	**2019**	**2020**	**Combined Analysis**
East	10.46 C	9.74 C	10.11 C	54.59 A	52.74 B	53.67 A	35.29 a	30.45 A	32.87 A
West	12.05 B	10.24 C	11.15 B	49.53 BC	56.77 A	53.15 A	34.50 a	32.10 A	33.30 A
North	13.10 A	13.61 A	13.40 A	47.05 C	44.66 C	45.86 B	30.14 b	25.18 B	27.66 B
South	10.18 C	11.52 B	10.85 B	50.72 B	53.39 B	52.06 A	32.51 ab	31.95 A	32.23 A
Mean	**11.47**	**11.28**	**11.38**	**50.47**	**51.89**	**51.18**	**33.11 A**	**29.92 B**	**31.51**
Altitude									
Footslope	11.25	10.48 B	10.87 B	50.26	50.76	50.51	31.83 b	29.77	30.80
Backslope	11.69	12.07 A	11.88 A	50.68	53.02	51.85	34.39 a	30.07	32.23
Mean	**11.47**	**11.28**	**11.38**	**50.47**	**51.89**	**51.18**	**33.11 A**	**29.92 B**	**31.51**
Season									
May	15.39 A	14.90 A	15.15 A	46.78 B	49.76 B	48.27 B	26.43 C	27.53 B	26.98 C
July	12.22 B	12.17 B	12.20 B	45.81 B	48.41 B	47.11 B	34.38 B	27.48 B	30.93 B
October	6.80 C	6.76 C	6.78 C	58.83 A	57.50 A	58.17 A	38.52 A	34.74 A	36.63 A
Mean	**11.47**	**11.28**	**11.38**	**50.47**	**51.89**	**51.18**	**33.11 A**	**29.92 B**	**31.51**
Aspect	**	**	**	**	**	**	*	**	**
Altitude	ns	**	**	ns	ns	ns	*	ns	ns
Season	**	**	**	**	**	**	**	**	**
Aspect x Altitude	**	**	**	ns	ns	*	*	ns	ns
Aspect x Season	**	**	**	*	**	**	ns	*	ns
Altitude x Season	*	**	**	**	*	**	ns	*	*
Aspect x Altitude x Season	*	**	**	ns	**	**	ns	*	ns
Year	-	-	ns	-	-	ns	-	-	**
Year x Aspect	-	-	**	-	-	**	-	-	ns
Year x Altitude	-	-	**	-	-	ns	-	-	ns
Year x Season	-	-	ns	-	-	ns	-	-	**
Year x Aspect x Altitude	-	-	ns	-	-	ns	-	-	ns
Aspect x Season x Year	-	-	**	-	-	*	-	-	*
Altitude x Season x Year	-	-	ns	-	-	ns	-	-	ns
Year x Aspect x Season x Altitude	-	-	ns	-	-	ns	-	-	ns

*Mean scores marked with lowercase letters differ at 5%. **Mean scores marked with uppercase letters at 1%. ns: not significant

While aspect x altitude, aspect x season, year x aspect, year x altitude, and aspect x season x year interactions were very significant (p<0.01) in terms of both research years and combined analysis; year x season, year x aspect x altitude and altitude x season x year interactions were insignificant.

In 2019, the first year of the research, the north aspect had the greatest crude protein concentration (13.10%) while the south aspect had the lowest concentration (10.18%) (Table 1). Following the variance analysis findings of 2019, when the southern and eastern aspects statistically belonged to the same group, the crude protein ratios (p<0.01) were significantly different. In contrast to the results of the first year, the results for the year 2020 showed that the area in the north had the highest crude protein rate, with a value of 13.61%, while the area in the east had the lowest crude protein rate, with a value of 9.74%. According to the findings of the variance analysis conducted during the second year of the research, the east and west aspects were statistically classified as belonging to the same group, and the crude protein rate differences between the aspects were significant at the 1% level.

In contrast to the combined analysis of the 2020 values, which was determined to be statistically significant at the 1% level, the findings of the 2019 analysis were not statistically significant, based on results indicating the influence of the altitude factor on the crude protein ratio (Table 1). The crude protein ratio in the backslope (11.88%) was found to be higher than in the footslope sites (10.87%), despite the fact that the crude protein ratios were similar to one another in terms of altitude when the combined analysis was taken into account.

Table 1 shows the variation in crude protein ratios that occurred during the grazing season based on months. The data indicates that the highest crude protein rate (15.39%) for 2019 was recorded in May, while the lowest crude protein rate (6.80%) was recorded in October. In the second year of the study, the highest and lowest crude protein rates were observed in May (14.90%) and October (6.76%) respectively. Similar to the research years, the findings of the combined analysis showed that the highest crude protein ratio was observed in May and the lowest rate was in October. The season had a significant impact on the crude protein ratio (p<0.01) throughout all study years and combined analysis.

When evaluating the crude protein ratio's seasonal variation in terms of altitude and aspect, a significant difference was observed between the footslope and backslope sites of the north aspect. Additionally, it was discovered that the crude protein ratios in October differed more between aspects than altitude (Figure 1). This situation caused an aspect x altitude x season interaction.

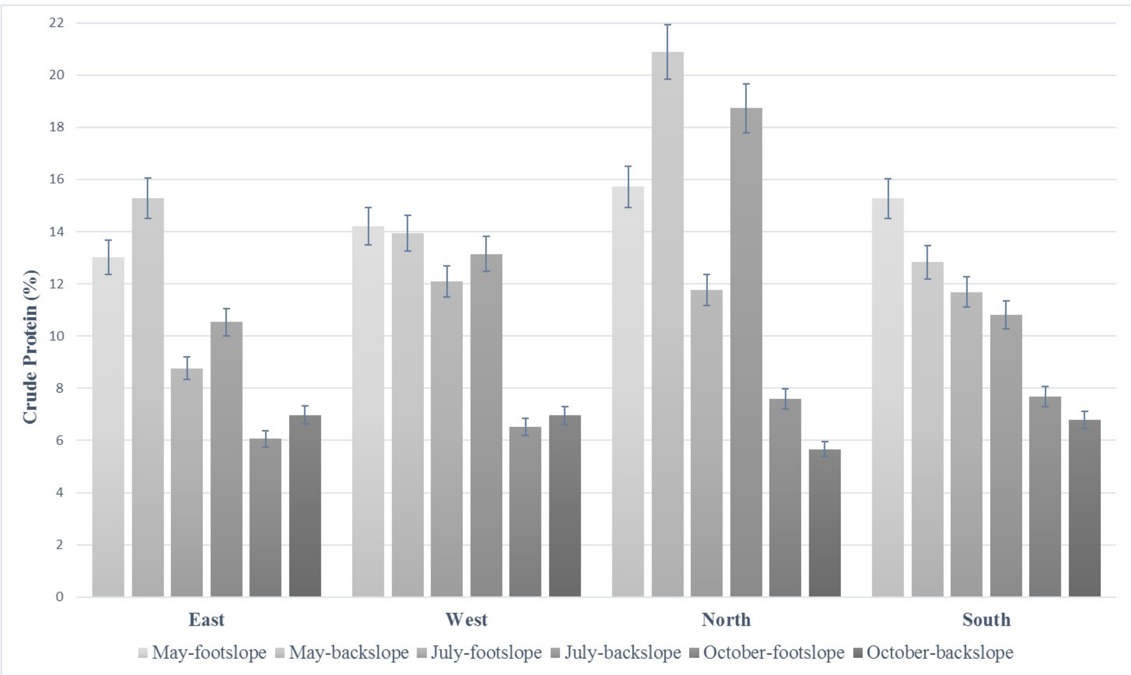

Figure 1. The aspect x altitude x season interaction of crude protein ratio according to the combined analysis

While The month of October showed similar results in terms of seasonal variations in the crude protein ratio as per the aspects in the experiment years, it was found that May and July showed more varied results in the research years (Figure 2). The effect of this situation caused a three-way interaction as aspect x season x year.

The crude protein ratio was highest in the north aspect (13.40%). It has been shown in several earlier studies that forage legumes had a higher ratio of crude protein (Andrae 2003; Shaver 2004; Rayburn et al., 2006; Rayburn 2020). This finding suggests that the high rate of legumes in the north may be responsible for the sites's reasonably high crude protein content. Additionally, the presence of more plentiful leafy and unmatured vegetation may have contributed to a greater crude protein ratio owing to the north's less restricting humidity factor (Holechek et al., 2004). Because plentiful leafy and green vegetation may have a greater protein content (Ball et al., 2001).

The variation in the crude protein ratio with respect to altitude determined insignificant based on the 2019 data; nevertheless, the results obtained in 2020 and the mean values revealed a very significant difference ($p<0.01$). In the combined analysis, the backslope site had a greater crude protein concentration than the footslope site. The higher ratio of crude protein in the backslope sites may be attributable to the increased soil moisture caused by the increased altitude. Because Dovel (1996) claimed that the variations in the crude protein ratios seen in forage samples were caused by changes in the vegetation and soil moisture as well as variations in the botanical composition.

Given the seasonal variation in the crude protein ratio, it can be seen that May, which marks the start of the grazing season, had the highest crude protein ratio. When maturation progressed as a result of the rise in temperature in July and October, the crude protein ratio gradually fell. In the study conducted by Ball et al. (2001), this phenomenon was attributed to the drop in the leaf-to-stem ratio that accompanies plant maturation, resulting in a fall in the protein ratio.

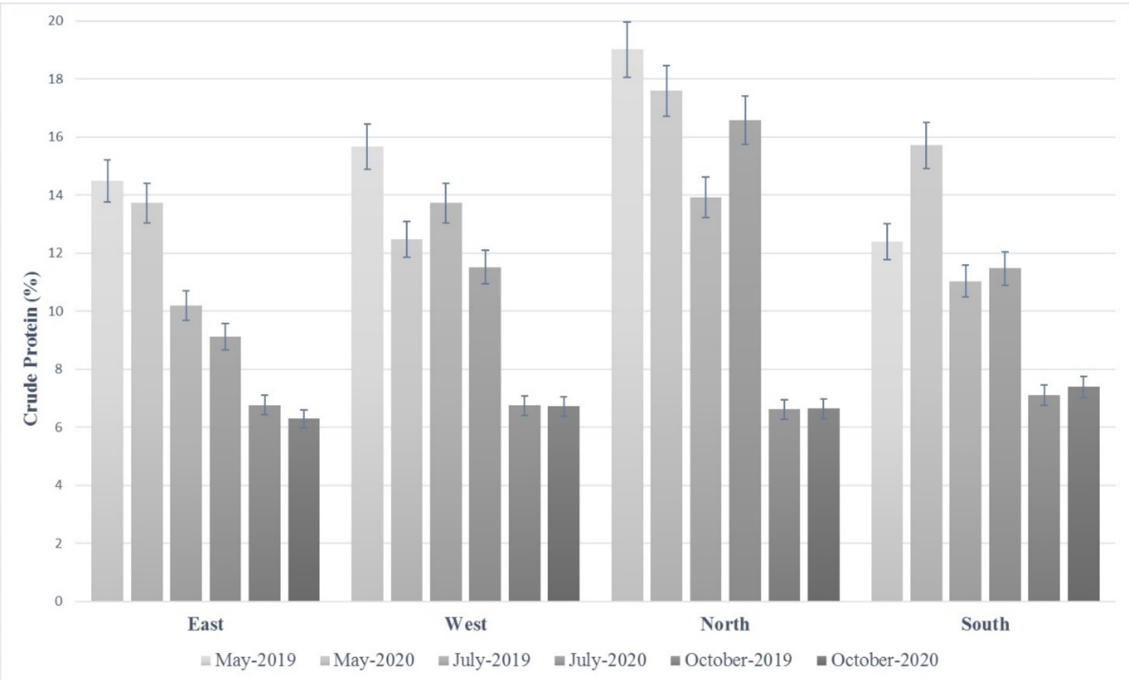

Figure 2. The aspect x season x year interaction of crude protein ratio according to the combined analysis

Neutral Detergent Fiber (NDF) rate (%)

The research years and altitude factor were determined to be insignificant, whereas the aspect and season were found to be significant at 1%, according to the variance analysis results of NDF rates obtained in rangeland parts (Table 1). According to the combined analysis, the aspect x altitude interaction was significant. While the aspect x season interaction was important for 2019, the combined analysis and 2020 results were concluded as significant at the level of 1%.

While the aspect x altitude x season interaction regarding NDF rates was insignificant in 2019, it showed a very significant difference in 2020 results and combined analysis. Aspect x season x year interaction was significant at the level of 5%. The altitude x season interactions based on the findings of the 2019 year and combined analysis of variance analysis and year x aspect interaction based on combined analysis were determined to be statistically significant at the 1% level. However, the aspect x season interaction has changed at the 5% significance level in 2019.

The change in NDF rates determined in the research areas according to the aspects was given in Table 1. As can be seen in the table, according to the variance analysis results of 2019, the highest NDF rate (54.59%) was detected in the east, and the lowest NDF rate (47.05%) was recorded in the north. No difference was found between the west, and the south and north aspect. In 2020, unlike the previous year, the west had the greatest NDF rate (56.77%), while the east and south were statistically in the same group, and the north had the lowest NDF rate (44.66%). According to the combined analysis, when the NDF change between the aspects was investigated, it was determined that the east, west, and south aspects were statistically in the same group, and the north aspect had the lowest NDF rate (45.86%) over the research years. Even though the influence of altitude on the NDF rate was determined to be insignificant, it was discovered that backslope sites had a higher NDF rate in both research years and the combined analysis (Table 1).

When examining the impact of seasonal variation on NDF rates (Table 1), it was established that May and July statistically belonged to the same group considering the results of the research years and combined analysis. Concerning 2019, 2020, and combined analysis findings, the highest NDF rate was recorded in October for all three time periods, at 58.83%, 57.50%, and 58.17%, respectively.

Assessing the seasonal variation of NDF rates in relation to aspect and altitude variables, it was found that there was a difference in NDF rates between the footslope and backslope sites by aspect and that October had a higher NDF value than the other two periods (Figure 3). The combined analysis that takes the effect of these factors into account showed that the aspect x altitude x season interaction has been very significant.

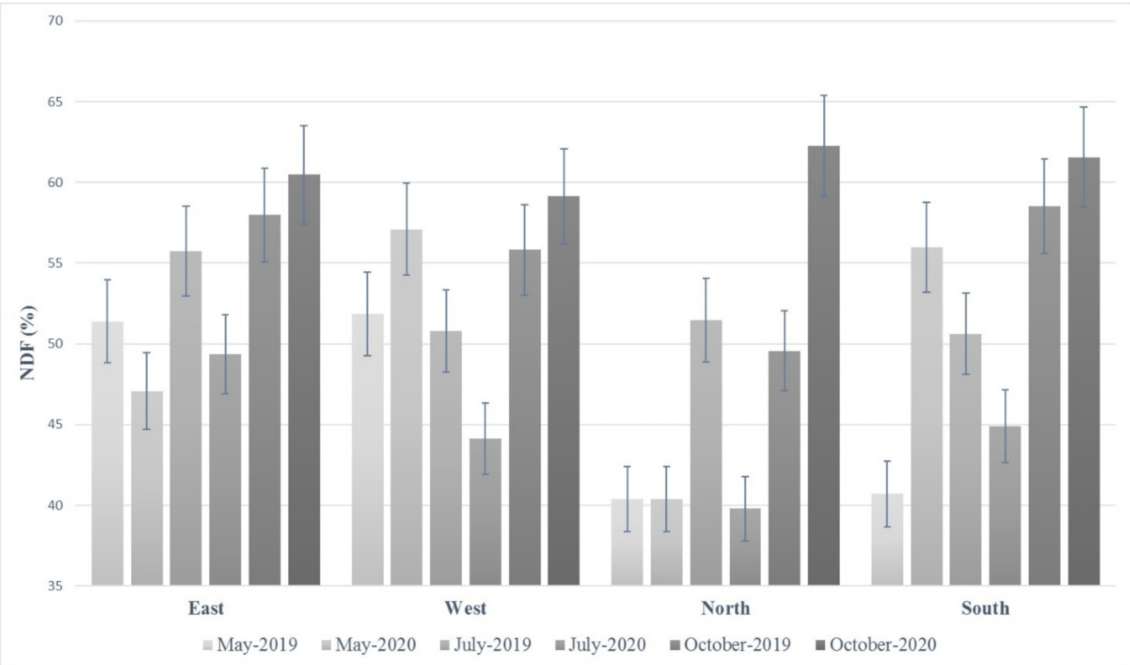

Figure 3. The aspect x altitude x season interaction of NDF rate according to the combined analysis

While a similar process was observed in October concerning seasonal variation of NDF rates as per the aspects during the experiment years, variability occurred in May and July (Figure 4). A three-way interaction of aspect x season x year has formed, particularly as a result of the elevated impact of these changes during the second year of the research.

NDF is a cell wall component consisting of cellulose, hemicellulose, and lignin (Rayburn 2020). The type of plant, growth stage, leaf-to-stem ratio, and different cultural methods in rangelands can all affect the NDF rate (Lacefield et al., 1999; Ball et al., 2001). The research's findings demonstrate that, in addition to these factors, the aspect also has an impact on the NDF rate. In fact, both in the research years and in the combined analysis, the NDF rate according to the aspects demonstrated a statistically significant difference (p0.01) (Table 1). The east aspect's high rate grass may be what caused the highest NDF rate to be found there. According to research of Reuss (2001) and Darambazar et al. (2003), grasses have a greater concentration of NDF than legumes. The north may have the lowest NDF rate owing to the lower illumination rate in this aspect and the higher leaf-stem ratio as a result of the plants' later maturity stage.

There is a significant relationship between maturation and the increase in NDF rate (Kamstra et al., 1968; Pieper et al., 1974). Plant maturation is impacted by seasonal variation as well as other factors. The NDF rate caused a difference according to seasonal change within the parameters of the study, and as a consequence, the NDF values found in the combined analysis between 2019 and 2020 were statistically significant at the level of 1%. The combined study reveals that May and July statistically belonged to the same group and that their respective NDF rates of 48.27% and 47.11% were close. The highest NDF rate was observed in October (58.17%). It is anticipated that the NDF rate will be lower in May and July owing to the onset of plant growth at the beginning of the grazing season and the high leaf-to-stem ratio. On the other hand, the response of legumes and grasses to changes in temperature and precipitation varies, as tap root legumes may increase their rates under dry conditions, but the growth of fibrous-root grasses rises with increased surface precipitation. The ratio of legumes to grass in rangelands may change as a consequence of this circumstance, and these variations result in a periodic change in the NDF rate. Given that the NDF rate is higher than in legumes, especially in grasses (Collins and Fritz, 2003; Deak et al., 2007; Tan et al., 2019), it leads to the fact that the NDF rate is affected by the proportional change of these two families. In addition, in rangeland sites exposed to grazing, the NDF rate may rise as a consequence of a reduction in the leaves, which are the portions favored by animals, hence, causing an increase in the stem ratio along with the fact that plants grow old meantime. Studies performed by Twidwell et al. (1988) and Ball et al. (2001) revealed that plant stems contain higher NDF than other components. This situation also explains why the highest NDF rate was seen in October.

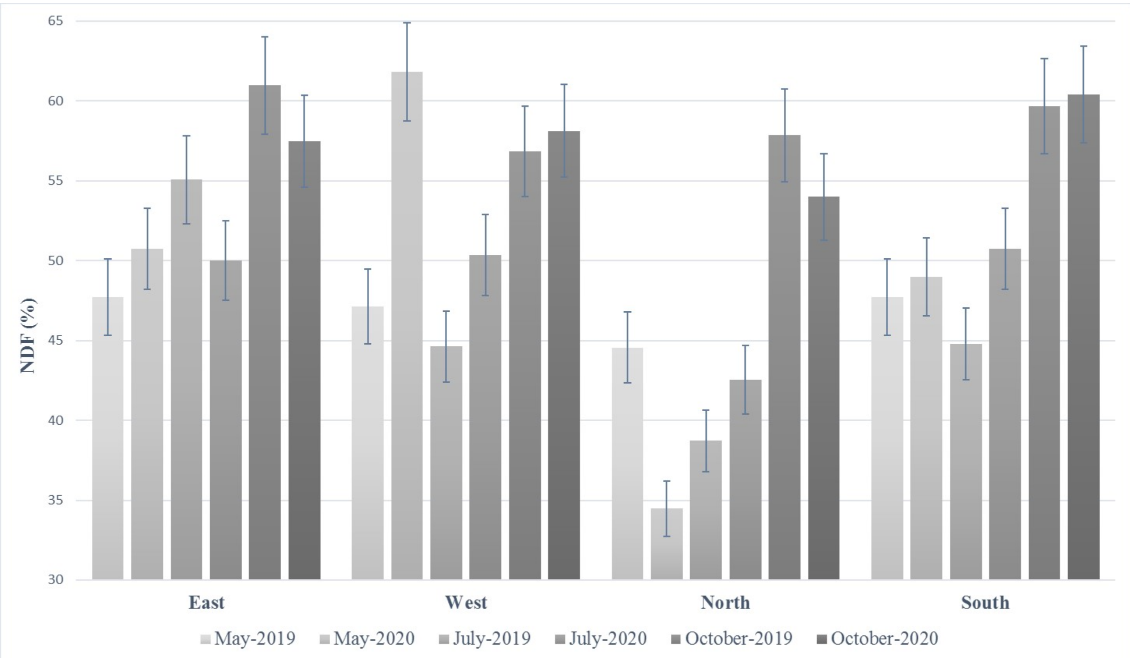

Figure 4. The aspect x season x year interaction of NDF rate according to the combined analysis

Acid detergent fiber (ADF) rate (%)

Examining the variance analysis findings for the rangeland sites that were the topic of the study (Table 1), it was discovered that the ADF rates are statistically very significant ($p<0.01$) when taking the research years and season variables into consideration. Furthermore, it was determined that the results of 2019 were 5% significant in terms of aspect, and lastly, it was determined that the combined analysis data and 2020 results were very significant. Altitude-wise, it was found that the combined analysis and findings for 2020 did not statistically vary from those of 2019 and that only the results from 2019 were significant at the level of 5%. According to the variance analysis findings of 2019, the interaction between aspect and altitude was significant; however, as indicated by the results of 2020, the interactions between aspect and season, altitude and season, and aspect x altitude x season were significant. As per the results of the combined analysis, while the interactions of altitude x season, and aspect x season x year were significant, it was found that the interaction of year x season showed a statistically significant difference.

In 2019, the first year of the research, the East had the highest ADF rate (35.29%), while the North had the lowest ADF rate (30.14%); statistically, the East and West were in the same group. Unlike the first year, the highest ADF rate in 2020 was determined in the West with a value of 32.10%. In the second year of the study, when the east, west, and south were statistically grouped, the north had the lowest ADF rate with a value of 25.18%. According to the combined analysis, the west, east, and south were statistically in the same group when it came to their ADF rates, with the west having the highest ADF rate (33.30%) and the north aspect having the lowest ADF rate (27.66%).

Only in 2019 was there a statistically significant difference in the ADF rate as per the altitude, in comparison to the previous years, and the ADF rate was higher on the backslope (34.39%) in comparison to the foot slope (31.83%). The combined analysis with 2020 revealed that the backslope sites had a greater rate of ADF, albeit this finding was not statistically significant (Table 1).

The effect of seasonal variation on the ADF rate was given in Table 1. According to the study years and mean values, it is evident from the table that the seasonal variation in the ADF rate is statistically significant at the 1% level. It was determined that the highest ADF rates for 2019 and 2020 were both recorded in October with values of 38.52% and 34.74%, respectively; while the lowest ADF rates were observed in May 2019 (26.43%) and in July 2020 (27.48%). The ADF rates were 36.63% in October, 30.93% in July, and 26.98% in May based on the combined analysis of the years. Significant variations between the features in terms of the change in ADF rates by months developed over the experiment years, particularly in the second year of the research. The three-way interaction as aspect x season x year was significant in the north because the ADF rate differed from the other aspects in terms of seasonal variation (Figure 5).

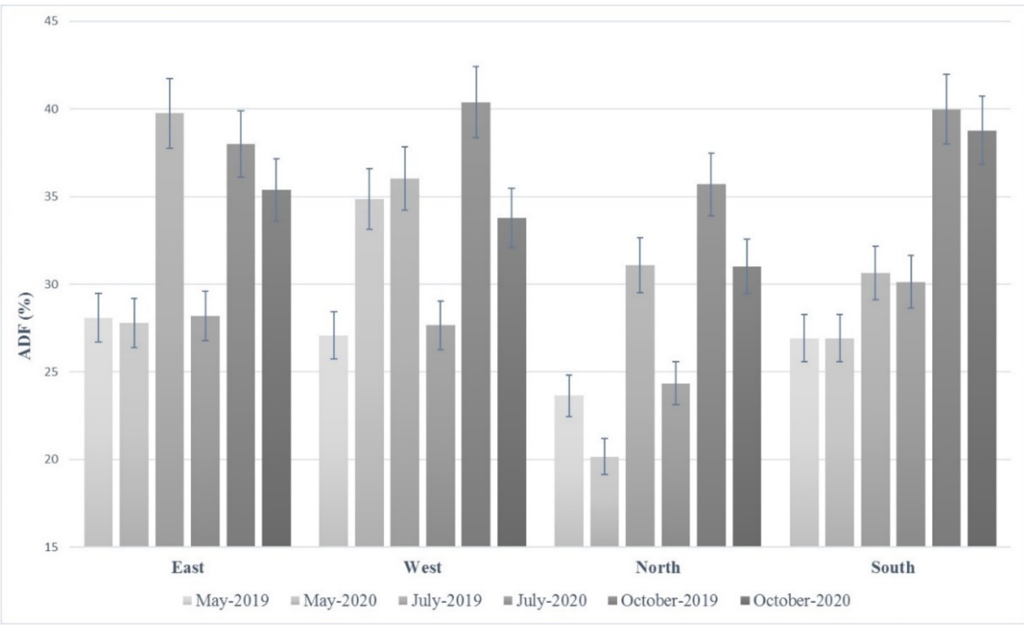

Figure 5. The aspect x season x year interaction of ADF rate according to the combined analysis

While the ADF rate was 33.11% in the first year of the study, it was 29.92% in the second year, varying statistically by 1% between the years of the research. This may be attributed to varying precipitation levels between research years. Rangeland forage ADF rate is an essential measure of the digestible nutrient rate (Rayburn, 2020), and there is a significant negative relationship between the digestibility rate and ADF rate (Barney, 2009). When looking at the combined analysis results, the change in the ADF rate by aspect was very significant ($p<0.01$), and the west (33.30%) had the highest ADF rate among the aspects. The reason for the highest rate of ADF might be because the vegetation matured sooner owing to the west's high rate of illumination. Because the leaf-stem ratio in plants decreases with maturation, ADF increases with the fiber ratio (Martiniello et al., 1997; Andrae 2003). The lowest ADF rate (27.66%) among the aspects was determined in the north. These plants grow later as a consequence of the temperature difference and low illumination rate of the north aspect, and as a result, the higher leaf-stem ratio has played a significant role in this outcome.

In terms of altitude, backslope sites had a higher ADF rate (34.39%) in 2019 than foot slope sites (31.83%). Due to partial grazing on rangelands and the effect of regrowth of vegetation in the footslope as they are being closer to the settlements, this may have led to lower ADF values.

The seasonal variation of the ADF showed very significant difference ($p<0.01$) both in the research years and in the combined analysis. According to the combined analysis, the highest ADF rate (36.63%) and the lowest ADF rate (26.98%) were discovered in October and May, respectively. Due to the low stem ratio in plants that are still at the start of the development phase in May, it is anticipated that the ADF rate will be low. So, ADF and other components of the cell wall are becoming more abundant in plants as they mature (Linn and Martin 1999; Kaya et al., 2004; Avcı et al., 2006). Variations in the climate also lead to changes in the vegetation, which have an impact on the seasonal variations in forage quality (Mountousis et al., 2008; Teka et al., 2012; Koç et al., 2014). This led to the conclusion that the rate of ADF increased at an accelerating rate between July and October, with October having the highest rate.

4. Conclusion

All rangeland sites that were the subject of the study had a crude protein ratio of above 7%, with the north being the aspect where this ratio was the highest. The lowest value of the crude protein ratio, which was obtained in October (6.78%), was shown to have declined since the start of the grazing season. The west had the highest ADF rate (33.30%) and the east had the highest NDF value (53.67%), both of which are significant variables influencing forage quality. In terms of seasonal variation, the ADF rate has increased linearly since May and reached the highest value in October. In NDF, there was only a small change in May and July, but a major increase was seen in October. The study's findings show that although the crude protein ratio drops as plants mature while the number of elements that constitute the cell wall increases, hence, the change in seasonal circumstances has an impact on the quality of the forage. In light of these findings, it has been determined that including the footslope sites in the grazing program in line with the management principles is crucial for the future of Kop Mountain semi-arid rangelands. And it was determined that doing both research and application studies for rangeland improvement would be beneficial.

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