Effect of Dynamic Irrigation Program on Corn Silage Quality

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Abstract: This research was conducted to determine the effects of dynamic irrigation program on corn silage quality. Different irrigation intervals (3, 6 and 9 days) and irrigation water levels (0.75, 1.00 and 1.25 times) were applied in the study. At the end of the research, the differences created by the dynamic irrigation program in silage quality parameters crude protein, crude ash, dry matter, ADF, NDF) were found to be significant (5% significance level). Crude protein ratios varied between 6.09-8.25%, crude ash ratios between 3.41-5.96%, dry matter ratios between 26.06-34.65%, Acid Detergent Fiber (ADF) ratios between 20.10-25.13% and Neutral Detergent Fiber (NDF) ratios between 33.66-38.09%. In corn production under similar conditions (climate, soil and variety), it was thought that it would be beneficial to apply 1.25 times the value of 6-day cumulative evapotranspiration (ETo) corrected with the crop coefficient (Kc) in Balıkesir-Manyas climate and clay-loam soil conditions in order to reach high values in crude protein, which is the main silage quality parameter.

Keywords: Silage quality, Protein, ADF, NDF

Dinamik Sulama Programının Mısır Silaj Kalitesine Etkisi

Öz: *Bu araştırma, dinamik sulama programının mısır silaj kalitesine olan etkilerini belirlemek amacıyla yapılmıştır. Çalışmada farklı sulama aralığı (3, 6 ve 9 gün) ve sulama suyu seviyeleri (0.75, 1.00 ve 1.25 katı) uygulanmıştır. Araştırma sonunda silaj kalite parametrelerinde, dinamik sulama programının oluşturduğu farklılıklar istatistiksel olarak önemli (%5 önem düzeyinde) bulunmuştur. Silaj kalite parametrelerinden ham protein oranı %6.09-8.25, ham kül oranı %3.41-5.96, kuru madde oranı %26.06-34.65, Asit Deterjanda Çözünmeyen Lif (ADF) oranı %20.10-25,13 ve Nötral Deterjanda Çözünmeyen Lif (NDF) oranı %33.66-38.09 arasında değişim göstermiştir. Benzer koşullardaki (iklim, toprak ve çeşit) mısır üretiminde, silaj kalite parametrelerinin başında gelen ham proteinde yüksek değere ulaşmak için Balıkesir-Manyas iklim ve killi tın toprak koşullarında 6 günlük birikimli evapotranspirasyon (ET0) değerinin bitki katsayısı (Kc) ile düzeltilmiş değerinin 1.25 katının uygulanmasının yararlı olacağı düşünülmektedir.*

Anahtar Kelimeler: *Silaj kalitesi, Protein, ADF, NDF.*

INTRODUCTION

In agricultural production, which is one of the sectors that use the most water, it is necessary to select high-efficiency irrigation systems and optimize irrigation water. Among the options that producers can use to optimize water use, selection of the most easily accessible plant species tolerant to water stress and irrigation systems with high water use efficiency are the easiest alternatives. If producers prefer the drip irrigation method, they will have taken an important step towards optimizing both the irrigation water used and the energy cost used in production. It is emphasized that the deficit irrigation strategy can significantly minimize yield loss and increase water use efficiency when applied correctly at critical growth stages (Ali and Talukder, 2008; Kranz et al., 2008; Zhang et al., 2019a; Sullivan et al., 2023).

The yield and quality characteristics of silage corn are important parameters for evaluating feed value and determining the performance of livestock (Liu et al., 2018; Shi et al., 2012). Sustainable feed production also provides sustainable livestock. From this perspective, optimization of water in silage corn production naturally contributes to sustainable feed and livestock farming. Feed efficiency determines the amount of dry matter that animals can use, and feed quality can affect animal growth and livestock products by affecting feed digestibility and energy intake (Coleman and Moore, 2003; Khan et al., 2012; Richman et al., 2015). To evaluate feed quality, researchers have developed quality parameters such as crude protein (CP), ether extract (EE), crude ash (Ash), acid detergent fiber (ADF), neutral detergent fiber (NDF) and nitrogen-free extract (NFE) (Carr et al., 2004; Grant et al., 2014; Zhang et al., 2018; Zhao et al., 2022). The Relative Feed Value (RFV) is a number found on a hay or pasture analysis. It is an end result of forage species, environmental conditions, water and fertilizer, and when a forage grower harvested the product. On a Dairy One/Equi-Analytical analysis it's at the very, VERY bottom of the page. What you need to know about RFV is that it's a calculation (Kasra, 2014). It's not extracted from the forage sample. It is calculated using

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Digestible Dry Matter as a function of Acid Detergent Fiber (ADF%) and Dry Matter Intake Potential as a function of Neutral Detergent Fiber (NDF%)- All of which are measurements of structural carbohydrates and, ultimately, the digestibility of the forage in question. The RFV is a rough estimate of how the forage will behave in your horse; will it make your animal gain weight, lose weight, or stay the same? It summarizes the fiber values (i.e. cellulose, hemicellulose and lignin) which dictate the health and happiness of your animal's microbiome. For this reason, the FDV value, which is one of the most important elements of feed quality, is also an important parameter in silage quality. In silage corn, forage yield and quality are greatly affected by sowing density (Marsalis et al., 2010), fertilization (Aydın and Uzun, 2005), harvest time (Bumb et al., 2016), irrigation (Karyoti et al., 2018; Zhang et al., 2019) and weed and pest control (Bailey et al., 2015). Inadequate/faulty irrigation often causes serious losses in yield and quality, while also increasing production costs. This leads to a decrease/reduction in the expected income from production. In optimizing irrigation water in agricultural production, different deficit irrigation strategies can be used to maximize production and profit. These strategies may include changing irrigation schedules, concentrating irrigation on critical crop growth stages, reducing irrigation rates, terminating irrigation early, or increasing irrigation efficiency in various ways, some of which provide economic benefits (Manning, 20018). In optimizing irrigation water, it may be more beneficial to focus on the quality parameters of the final product rather than the raw yield. Focusing on the desired product may be more beneficial in optimizing resources.

Since corn has a fast growth characteristic, it requires the implementation of a good irrigation program in its cultivation. Water deficit occurring at any time during the corn plant's growth period generally causes losses in grain yield. The amount of yield reduction depends on the plant's growth period and the length and severity of stress occurring during this period, as well as the plant variety's resistance to water stress (Lorens, 1987; Dağdelen et al., 2010). Different methods and tools are used in irrigation planning. Developing technology allows for the accurate instantaneous determination of irrigation times and irrigation water amounts for plants. In recent years, ETo values are calculated with different methods using measured climate parameters and are used in irrigation programming as irrigation water amount after being corrected with plant coefficients. Irrigation programming done in this way can be called dynamic irrigation programming. In this study, the reference ET0 values calculated with FAO Penman Monteith method from daily climate parameters measured at the meteorological station in the production area were corrected with the Kc of the corn plant (shown with ETc symbol after correction process) and the obtained values were applied as irrigation water at different rates (0.75, 1.00 and 1.25 times). The effect of the applications on the silage quality of corn grown as a second crop was investigated. In other words, the changes in the silage quality of the second-crop corn caused by the planned dynamic irrigation program with the specified features were investigated.

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MATERIAL and METHODS

Materials

The study was carried out on the land of a producer engaged in extensive agriculture in Manyas, Balıkesir (Figure 1). The study area is located at 40º 02’ latitudes and 27º 51’ longitudes. The altitude is 52 m.

Figure 1. Study area

Irrigation Water and Soil Properties

Irrigation water was supplied from an underground water well and its properties are given in Table 1. The electrical conductivity value of the irrigation water was calculated as 782 µmhos/cm, pH as 7.25 and SAR as 0.44 and its class was determined as SA3A1. There is no limitation in terms of corn production in terms of irrigation water properties.

The results of the analyses performed on soil samples taken from the plots (up to 120 cm depth) are given in Table 2. While the soils have a loamy texture at 0-30 cm depth, they showed a clayey texture towards the lower layers. The organic matter content is 21.23% in the surface soil (0-30 cm), decreasing with increasing depth. The reason for the high organic matter rate is that the field previously has been used for paddy farming for 15 years. In addition, there is no drainage inadequacy, groundwater and soil salinity problem in the field.

Table 1. Analysis results of irrigation water in the experimental area

EC µmhos/cm	pH	Cations (me/l)				Anions (me/l)				Na (%)	SAR	Class
		Na	K	Ca	Mg	CO_3	HO_3	Cl	SO_4			
782	7.25	0.94	0.06	5.8	3.1	-	2.8	1.5	5.6	0.09	0.44	$SA3A_1$

Table 2. Some physical and chemical properties of the soil samples

Depths	0-30	30-60	60-90	90-120	Aver
	cm				
Sand (%)	38.33	32.83	35.54	36.48	35.80
Clay (%)	22.19	29.07	27.76	30.46	27.37
Silt (%)	39.49	38.1	36.71	33.07	36.84
Texture	Loamy	Clay-Loam	Clay-Loam	Clay-Loam	Clay-Loam
Dew (%)	70	65	58	55	62
pH	7.35	7.59	7.52	7.39	7.46
EC (dS/m)	0.98	0.84	0.87	0.84	0.88
Lime (%)	3	3	3	3	3.00
Organic Matter (%)	21.23	18.99	13.12	12.99	16.58
P (kg/da)	0.318	0.147	0.149	0.128	0.19
K (kg/da)	68	28	27	24	36.75
Field Capacity (p/w)	41.13	39.84	38.30	35.73	38.75
Wilting Point (p/w)	17	17.3	19.81	19.38	18.37
Volume Weight (g/cm^3)	1.2	1.19	1.16	1.18	1.18

Climate of the Research Area

The parameters measured by the automatic climate station located near the research area are presented in Table 3 as 10-day averages. Reference evapotranspiration values were calculated using these values.

Table 3. Climatic parameters measured during the production period

Tarih	T_{mean} (°C)	P (mm)	U_2 (m/s)	Ra (W/m^2)	RH (%)	ET_0 (mm)
1-9 July	25.27	0.00	1.22	303.78	65.11	5.50
10-19 July	25.07	0.00	0.82	292.95	67.62	5.06
20-31 July	25.29	0.00	1.25	284.61	65.19	5.20
1-9 August	26.81	0.04	1.14	250.68	73.07	4.73
10-19 August	23.97	0.02	1.22	220.25	69.92	4.07
20-31 August	24.39	0.00	1.06	215.25	71.82	3.84
1-9 September	23.44	0.00	0.95	201.04	67.98	3.55
10-19 September	22.22	1.66	0.71	173.08	65.60	2.84
20-30 September	15.74	0.46	0.44	142.15	77.84	1.91

Crop

The corn variety used in the study was the Hido corn variety belonging to May Seed Co. The variety is included in the FAO 7000 maturation group. It has an average development period of 100-110 days. Under ideal conditions, silage contains 9% crude protein and around 30% starch. Sowing density is recommended as 70 cm between rows and 13 cm between seeds. Soil selectivity is quite low (Anonymous, 2019).

Cultural Practices

Composite 15-15-15 fertilizer was applied as base fertilizer during planting. Fertilization was done as 30 kg of pure nitrogen per decare in total. The remaining nitrogen amount from base fertilization was divided into three equal parts in the form of urea and applied with a drip irrigation system. Hoeing was done in three different time periods to combat weeds throughout the study and insecticide applications were made as needed for pest control.

Method

Experimental Design and Irrigation Applications

Experiments were conducted in randomized blocks - split plots experimental design with 3 replications as shown below. In the study, 3 different irrigation intervals (3, 6 and 9 days) and 3 different levels (0.75, 1.00 and 1.25 times) of evapotranspiration (ETc) values calculated by correcting ETo with Kc calculated by FAO Penman Monteith method were applied. Kc values were taken from the "Plant Water Consumption of Irrigated Plants in Turkiye" guide. The Kc values used in the calculations are 1st period: 0.23, 3rd period: 1.21 and 4th period: 0.52, respectively, according to their periods. In the first irrigation, the current soil moisture determined from the soil sample taken from the field was increased to field capacity. The next irrigation was applied approximately 3 weeks later. Thematic irrigations were started when the plants had 3-4 leaves.

Experimental treatments were arranged as follows:

SA3-0.75 Treatment with 0.75 times of the ETc value applied every 3 days

SA3-1.00 Treatment with 1.00 times of the ETc value applied every 3 days

SA3-1.25 Treatment with 1.25 times of the ETc value applied every 3 days

SA65-0.75 Treatment with 0.75 times of the ETc value applied every 6 days

SA6-1.00 Treatment with 1.00 times of the ETc value applied every 6 days

SA9-0.125 Treatment with 1.25 times of the ETc value applied every 6 days

SA9-0.75 Treatment with 0.75 times of the ETc value applied every 9 days

SA9-1.00 Treatment with 1.00 times of the ETc value applied every 9 days

SA9-1.25 Treatment with 1.25 times of the ETc value applied every 9 days

Silage Quality Analysis

After the corn plant was brought to the laboratory environment, it was crushed with a corn grinder and vacuumed in a vacuum machine and kept in the dark for 60 days. At the end of the period, the vacuum packages were opened and the samples were analyzed in 3 repetitions after being homogenized.

Crude Protein Ratio: The samples were analyzed with the kjeldahl method in the kjeldahl device and the results were expressed as % (Waddell, 1956).

Crude Ash Ratio: For the determination of crude ash, 1 g of the samples were weighed in a porcelain crucible and then ashed at 550 °C for 8 hours in a muffle furnace and calculated as % (Molina and Poole, 2004).

Dry Matter Ratio: After the fresh weights of the silage samples were determined, their moisture content was removed in the oven at 75 °C for 72 hours and their dry weights were also determined. The weighing results were calculated as % dry matter ratios using the formula below (Acar and Yıldırım, 2001).

$$\%\text{Dry Matter} = \frac{\text{Final Weighing} - \text{Tare}}{\text{Sample Weighing} - \text{Tara}} * 100$$

%Moisture = 100 – %Dry Matter

Acid Detergent Fiber Ratio: To determine the Acid Detergent Insoluble Fiber (ADF) ratio, the samples were passed through a 1 mm diameter sieve and analyzed in the 200 Fiber Analyzer Ankom device (Van-Soest, 1963).

Neutral Detergent Fiber Ratio: To determine the Neutral Detergent Insoluble Fiber (NDF) ratio, the samples were passed through a 1 mm diameter sieve and analyzed in the 200 Fiber Analyzer Ankom device (Van-Soest, 1967).

Relative Feed Value (RFV): RFV has been a long-standing metric for assessing and comparing the quality of hays and silages. This index is derived from two key components: it evaluates the digestible dry matter (DDM) based on Acid Detergent Fiber (ADF), and estimates the potential dry matter (DM) intake as a percentage of body weight (BW) using Neutral Detergent Fiber (NDF). The final RFV is computed by multiplying the DDM by the dry matter intake (DMI expressed as a percentage of BW), and then dividing the result by 1.29, as described by Moore and Undersander (2002) in their publication.

DDM = Digestible Dry Matter = 88.9 - (0.779 x % ADF)

DMI = Dry Matter Intake (% of BW) = 120 / (% NDF)

RFV = (DDM x DMI) / 1.29.

Table 4. Relative Feed Value and Degree of Quality (Moore and Undersander 2002)

Quality Standards	RFV
Prime (Prime)	>151
1 (Premium)	150-125
2 (Good)	124-103
3 (Fair)	102-87
4 (Poor)	86-75
5 (Reject)	<74

Statistical Analysis

The values obtained from the study were analysed in the JMP statistics program. The significant parameters in the variance analysis results were compared with the t-test. In addition, the graphs were prepared in the MS Office-Excel program.

RESULTS and DISCUSSION

Crude Protein Ratio

When evaluated in general, a reduction in irrigation interval and irrigation water amount or an excessive amount of application caused a decrease in protein ratio. The differences in silage crude protein content caused by the applications were determined to be significant at 1% significance level (Table 5). Crude protein ratios varied between 6.09-8.25% (Figure 2). The highest crude protein ratio was obtained as 8.25% in SA6-1.25, followed by SA6-1.00 with 8.18%. The lowest average crude protein ratio was determined as 6.09% in SA3-0.75. The research results are consistent with other studies. Akdeniz et al. (2004) obtained similar results under ecological conditions of Van province (5.52-8.17%), Karayiğit (2005) in Kahramanmaraş province ecological conditions (5.78-6.41%) and Kabakçı (2014) in Iğdır ecological conditions (4.8-7.0%).

Table 5. Effect of irrigation intervals and amounts on corn silage quality parameter

Treatment	Irrigation Water Amounts (mm)	ETa (mm)	Crude Protein Ratio (%)	Crude Ash Ratio (%)	Dry Matter Ratio (%)	ADF (%)	NDF (%)	Relative Feed Value
SA3-0.75	293.7	320	6.09^{e}	5.96^{a}	26.06^{b}	23.71^{c}	36.75^{c}	224
SA3-1.00	391.6	419	6.36^{de}	4.63^{b}	31.20^{a}	23.29^{d}	37.32^{b}	215
SA3-1.25	489.5	520	6.34^{de}	3.41^{c}	31.77^{a}	21.33^{e}	35.34^{e}	234
SA6-0.75	293.7	350	7.87^{b}	3.67^{bc}	34.65^{a}	20.1^{g}	33.66^{h}	245
SA6-1.00	391.6	466	8.18^{a}	3.98^{bc}	32.96^{a}	20.61^{f}	34.70^{f}	233
SA6-1.25	489.5	570	8.25^{a}	3.52^{bc}	31.71^{a}	24.6^{b}	36.83^{c}	221
SA9-0.75	293.7	365	6.85^{c}	4.48^{bc}	31.91^{a}	21.62^{e}	34.43^{g}	235
SA9-1.00	391.6	475	6.40^{d}	4.17^{bc}	33.40^{a}	25.13^{a}	38.09^{a}	215
SA9-1.25	489.5	582	6.15^{de}	3.67^{bc}	31.79^{a}	20.39^{fg}	36.45^{d}	223

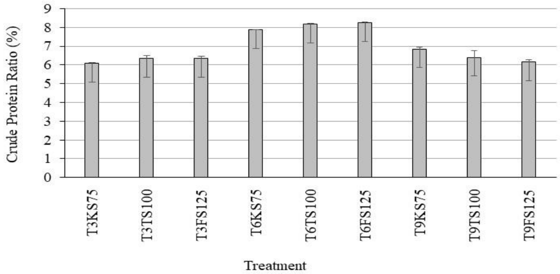

Figure 2. Change in crude protein contents of the treatments

Crude Ash Ratio

When evaluated in general, increasing irrigation water amounts caused a decrease in the crude ash ratios. The results of statistical analysis regarding the changes in silage crude ash ratios caused by irrigation water levels and irrigation intervals are shown in Table 5. As a result of the observations, the average crude ash ratios varied between 3.41-5.96% (Figure 3). The highest average crude ash ratio was obtained as 4.67% in the SA3 irrigation interval, followed by 4.1% in the SA9 irrigation interval. The lowest average crude ash ratio was determined as 3.73% in the SA6 irrigation interval. The highest average crude ash ratio was determined in KS75 irrigation water levels, while the lowest average crude ash ratio was determined in FS125 irrigation water levels. The obtained results are consistent with the results obtained in the study conducted by Erdal et al. (2009) in Antalya province ecological conditions (4.18-6.91%) and in the study conducted by Okan (2015) in Diyarbakır ecological conditions (3.25-8.14%).

Dry Matter Ratio

When evaluated in general, increasing irrigation water amounts caused a decrease in Dry Matter (DM) ratios. Average Dry Matter (DM) ratios in the study varied between 26.06-34.65% (Figure 4). Statistical analysis results regarding changes in silage dry matter ratios caused by irrigation water levels and irrigation intervals are shown in Table 4. DM ratios measured in the study varied between 26.06-34.65% (Figure 4).

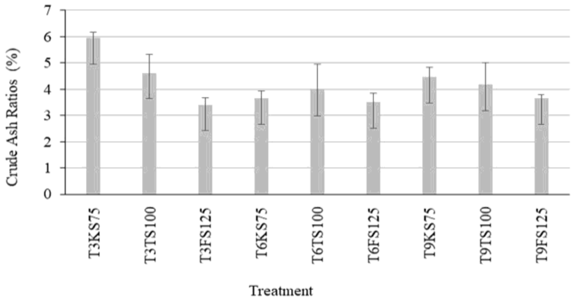

Figure 3. Change in crude ash ratios of the treatments

While the highest average dry matter ratio was obtained as 34.65% in SA6-0.75 treatment, this was followed by SA9-1.00 treatment with 33.40%. The lowest average dry matter ratio was determined as 26.06% in SA3-0.75 treatment. The results obtained are similar to the results obtained by İptaş and Avcıoğlu (1997) in the ecological conditions of Tokat province (18.5-26.3%), by Sade et al. (2002) in the ecological conditions of Konya province (29.25-38.24%) and by Geren et al. (2003) in the ecological conditions of İzmir province (21.16-26.18%).

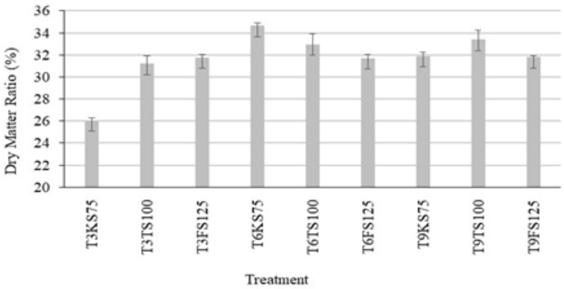

Figure 4. Change in dry matter ratios of the treatments

Acid Detergent Insoluble Fiber

Average Acid Detergent Insoluble Fiber (ADF) values in the study varied between 20.10-25.13% (Figure 5). In general, it can be said that increasing irrigation water amounts caused a decrease in the ADF content of corn silage. The statistical comparison results of irrigation water levels and irrigation intervals regarding the ADF content of silage are given in Table 4. The highest ADF value was 25.13% in SA9-1.00 and the lowest average ADF rate was determined as 20.1% in SA6-0.75. The results obtained from the study are consistent with the results obtained by Okan (2015) in Diyarbakır province ecological conditions (21-29.9%), and Öz et al., (2012) in Samsun-Çarşamba conditions (20.38-30.76%).

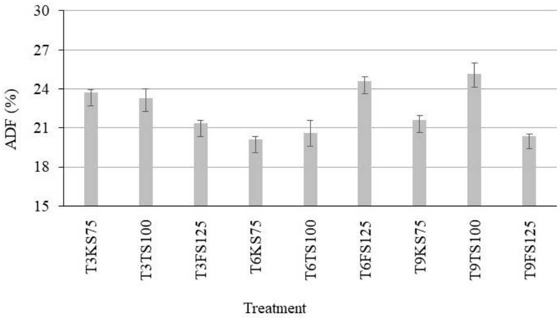

Figure 5. Change in ADF content of the treatments

Neutral Detergent Insoluble Fiber

In the study, the average Neutral Detergent Insoluble Fiber (NDF) values varied between 33.66-38.09% (Figure 6). The statistical comparison results of irrigation water levels and irrigation intervals regarding the change in the NDF content of silage are given in Table 4. According to the t-test results of the average values of the subjects, the highest average NDF value was obtained from the SA9-1.00 treatment (38.09%), while the lowest average NDF rate was obtained from the SA6-0.75 treatment (33.66%). The results obtained were found to be slightly lower than the results obtained by Cengiz et al. (2011) in Sakarya conditions (41.7-47.9%), Öz et al. (2012) in Samsun-Çarşamba conditions (43.07-57.66%) and Güney et al. (2010) in Erzurum conditions (44.98-56.98%). The reason for this is thought to be the difference in vegetation and harvest periods and also the variety difference.

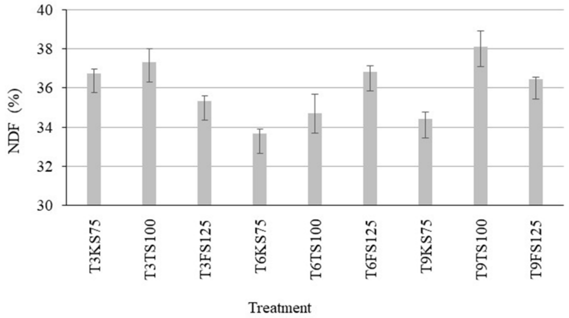

Figure 6. Change in NDF contents of the treatments

Relative Feed Value

One of the parameters taken into consideration in determining the forage quality is the RVF value. The RFV values of the subjects varied between 169-202 (Figure 7 and Table 4). The highest RFV value was obtained from the T6KS75 subject and the lowest values were obtained from the T3TS100 and T9TS100 subjects. Dunham (1998) examined the RFVs of some forage crops at different growth stages and reported that the RFV value of corn silage (well-eared one) increased up to 133 (first-class quality). Kasra (2014) calculated the RFV values between 74-121 in the study he conducted in Kahramanmaraş conditions and in different regions and varieties. It is thought that the reason for the high values obtained in the study is the high ADF content and low NDF content.

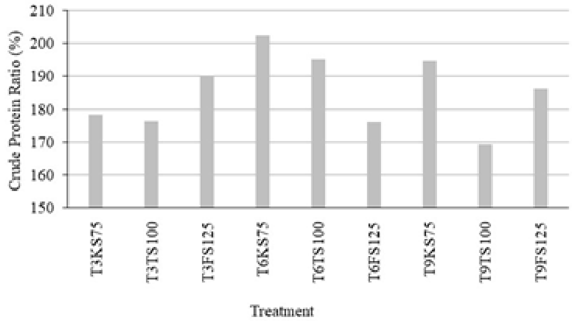

Figure 7. Change in RFV values of the treatments

CONCLUSION

Irrigation interval and irrigation water amount significantly affected the silage quality of corn. In general, 6-day irrigation interval (SA6) provided the highest crude protein rates. The highest crude protein rate was determined in 6-day irrigation interval and in full water (1.00) requirement (8.18%) and excess water (1.25) applications (8.25%). Low ADF and NDF values generally mean better digestibility. The lowest ADF (20.10%) and NDF (33.66%) values were obtained in SA6-0.75 application in the study. Frequent irrigation led to higher ash content. The highest crude ash content was observed in SA3-0.75 application (5.96%). In the case of dynamic irrigation program application in the production of 2nd crop silage corn in Manyas district of Balıkesir province, it was shown that 6-day irrigation interval generally provided the best silage quality. SA6-1.00 and SA6-1.25 treatments stand out with their high protein content and acceptable ADF/NDF values. As a result, in corn silage production, 6-day irrigation interval and full water requirement (1.00) and excess water (1.25) applications yielded the best results in terms of protein content and digestibility. However, considering water saving, SA6-1.00 application (391.6 mm irrigation water) can be considered as the optimum option. This application provided high protein content, reasonable dry matter content and good ADF/NDF values. In corn production under similar conditions (climate, soil and variety), it was thought that it would be beneficial to apply 125% of the cumulative ETc value every 6 days to ensure high silage quality.

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