DETERMINATION OF THE EFFECTS OF DIFFERENT WATER STRESSES ON SOME QUALITY CHARACTERISTICS OF SILAGE SORGHUM

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***Abstract*–This study was conducted to determine the effects of different water stresses on some quality characteristics of silage sorghum in Konya ecological conditions in 2017-2018 years. The study was conducted in randomized blocks design with three replications. In this study four different irrigation levels were applied (I_1: Full irrigation, I_2: 75 % of I_1, I_3: 50 % of I_1 and I_4: 25 % of I_1). According to the results of the first year (2017), the crude protein ratio (CP) varied between 8.0% (I_4)- 10.1 (I_1), acid detergent fibre (ADF) between 32.0 % (I_4)-35.6 (I_1), neutral detergent fibre (NDF) between 52.4% (I_4)-57.7 (I_1), ash content (Ash) between 6.9% (I_4)-7.6 (I_2), and cellulose ratio (CR) was 25.0% (I_4)-27.2 (I_1).**

In the second year, CP varied between 7.9% (I_4)-9.9% (I_1), ADF between 32.5% (I_4)-35.3 (I_1), NDF between 53.6% (I_4)-57.1 (I_1), CR between 25.3% (I_4)-26.9% (I_1) ash between 7.2% (I_3)-7.8 (I_1). It was determined that the rates of ADF, NDF, cellulose and ash were lower in water stress applications compared to full irrigation in the first year when precipitation and irrigation were less. In the study, it was determined that the ratios of ADF, NDF, ash ratio and cellulose ratio, which are desired to be low in animal nutrition, have lower values under water stress conditions and the sorghum plant gives good results in terms of quality values under water stress conditions.

***Keywords*— Climate change, drought, animal feeding, irrigation**

I. INTRODUCTION

The negative effects of climate change have become more evident especially on agricultural production in recent years and threaten a sustainable food supply with the increasing population.

Turkey has a complex climate structure. It has been stated that Turkey is one of the countries that will be most affected by a climate change that can be seen especially due to global warming. While arid and semi-arid regions such as Southeastern Anatolia and Central Anatolia are more threatened due to the risk of desertification, the semi-humid Aegean and Mediterranean regions that do not have sufficient water will be more affected by global climate change (Turan, 2018; Çetin, 2020).

In arid and semi-arid regions of the world, water is the main limiting factor for agricultural production due to the low or uneven distribution of annual precipitation (Afshar *et al*., 2014). If the current water use rate in the world continues with it is due to climate change and drought, it is estimated that 35% of the currently irrigated lands will not be irrigated in the future and the production amount will decrease (Haacker *et al*., 2016). In addition, irrigation and production costs increase with the pumping of water from deeper and deeper underground water use. It is necessary to apply more drought tolerant agricultural products and technologies for a sustainable agricultural production and to solve the problem of drought caused by water scarcity and lack of precipitation (Kapluhan, 2013).

It is anticipated that field crops will be the product group that will be most affected by the possible drought and decrease in water supply in the upcoming period and will pose a food security risk (Alghabari *et al*., 2016). Considering the current situation and forecasts, livestock enterprises are looking for alternative products in regions with insufficient water resources and low rainfall within the scope of adaptation to climate change. Researches aiming to meet the silage and other roughage needs with sorghum and similar plants that consume less water and are resistant to water stress are gaining importance. Sorghum, which has less water consumption than the corn plant used for similar purposes, is more resistant to many abiotic stress factors, especially water stress, and can be grown at low cost in marginal areas, is a plant that is resistant to water stress and has high water use efficiency (Li *et al*., 2010). Sorghum, which is used for many purposes (human food, animal breeding, bioethanol and cellulose production), is used intensively especially in animal breeding. Compared to similar plants used in animal breeding, sorghum can produce more biomass under water stress conditions and use water more effectively with its deep root structure, waxy stem structure, and vertical leaf structure. As in many plants, the environment, variety and agricultural practices have an impact on quality as well as yield in sorghum (Kökten *et al*., 2017). Water stress is an important abiotic stress factor that affects the biomass yield as well as the quality characteristics. The

https://doi.org/10.52292/j.laar.2023.1057

objective of this study is to determine some quality characteristics of silage sorghum under different water stress conditions and to determine the relations between irrigation level and properties in the conditions of the Konya basin which is in a semi-arid climate zone, the water resources tend to decrease every year and the precipitation regime is irregular, and also ranks first in Turkey in terms of animal existence.

II. MATERİALS AND METHODS

A. Description of experimental site

The study was carried out in the Konya-Karapınar Desertification and Erosion Research Center area for two years in 2017 and 2018. The study area has a continental semi-arid climate and an irregular precipitation regime with an annual precipitation of less than 300 mm. In the study years (2017 and 2018), the total precipitation was 249.6 and 286.7 mm, respectively, while the precipitation between May and August was between 64.8 and 69.2 mm. According to the long-term average, the total precipitation was 291.2 mm, while the amount of precipitation between May and August was 71.3 mm. Data about the soil of the study area is given in Table 1. According to this, the soil of the experiment site has low organic matter, high in lime and pH, has no salt problem and the top layer is sandy.

B. Plant material and cultivation processes

Early Sumac sorghum variety grown in the region was used in the study. After the first soil preparation was done with a plow, second tillage was applied before planting and the field was prepared for planting. Considering the soil analysis results, 90 kg of phosphorus and 30 kg of nitrogen were given per hectare. The remaining part of the nitrogen fertilizer was given with the drip irrigation system and completed at 150 kg ha^{-1}. It was sown in six rows on May 10 in 2017 and on May 13 in 2018 with 45 cm row spacing and 5 cm interrow spacing. The plot area is designed as 21.6 m^2 in total, 8 m long x 2.7 m wide. In the harvest, it was 10.8 m^2 after the edge effects were removed. Weed control was done mechanically and chemically.

C. Water stress treatments

In the experiment, irrigation water was applied as a drip irrigation system with pipes with a flow rate of 1.6 l/h and 20 cm dripper spacing, one lateral to each row. Soil moisture was monitored according to the gravimetric method at a depth of 0-90 cm.

Four irrigation levels applied in the experiment: I$_1$: Full irrigation application, it was calculated according to Equation 1, taking into account the consumption of 40% of the useful water at 0-90 cm effective root depth for full irrigation (Kara, 2011).

$$dn = (FC - AM) \times D / 100 \quad (1)$$

where dn is the net amount of irrigation water to be applied in each irrigation (mm), FC is the field capacity (as % of volume), AM is the available moisture at the effective root depth of sorghum (as % of volume) when 40% of the useful water capacity is consumed, and D is the effective root depth (mm).

Table 1. Some soil properties of the experimental site

Depth (cm)	Sandy (%)	Loam (%)	Clay (%)	Soil Texture	pH	Organic matter (%)
0-30	58.1	22.8	19.1	Sandy-Clay	7.8	.3
30-60	30.1	20.3	49.6	Clay	1	1.1
60-90	16.0	24.4	59.6	Clay	8.2	0.6

Table 2. Irrigation water amount, precipitation, change in soil water and evapotranspiration

Years	Irrigat. levels	Irrigat. water(mm)	Precipi-tation (mm)	*Change in soil water (mm)	Evapotran-spiration (mm)
2017	I$_1$	480	64.8	31.1	575.9
	I$_2$	368	64.8	44.9	477.7
	I$_3$	255	64.8	50.4	370.2
	I$_4$	143	64.8	60.2	268
2018	I$_1$	510	69.2	40	619.2
	I$_2$	390	69.2	46.8	506
	I$_3$	270	69.2	55.4	394.6
	I$_4$	150	69.2	75.6	294.8

***Change in soil water content**: It is a parameter used in the calculation of plant water consumption and expresses the difference in soil moisture between planting and harvesting time.

I$_2$: Irrigation was applied at the rate of 75% of the water applied to the subject I$_1$.
I$_3$: Irrigation was applied at the rate of 50% of the water applied to the subject I$_1$.
I$_4$: Irrigation was applied at the rate of 25% of the water applied to the subject I$_1$.

Before starting the irrigation applications, 30 mm of irrigation water was applied in the first year and 40 mm in the second year in order to bring the missing moisture to the field capacity for a homogeneous emergence and development. The amounts of irrigation water given to the research subjects are applied in Table 2.

D. Quality characteristics measurement

In this experiment, acid detergent fibre (ADF) neutral detergent fibre (NDF), crude cellulose and ash measurements were determined according to Celiktas *et al.* (2017) and crude protein analysis was determined according to Seydosoglu and Saruhan (2017).

Digestible dry matter (DDM), dry matter intake (DMI) and relative feed value (RFV) properties were calculated according to the following equations (Lithourgidis *et al.*, 2006).

$$\%DDM = 88.9 - (0.779 \times ADF)$$
$$\%DMI = 120 / NDF$$
$$RFV = (\%DDM) \times (\%DMI) \times (0.775)$$

E. Experimental design and statistical analysis

Irrigation subjects were randomly distributed to the blocks in the study, which was carried out in the randomized blocks design with three replications. The results obtained from the study were determined by the analysis of variance based on the procedure of JMP 11.1 and the differences among the irrigation treatments and groupings were analyzed according to LSD test. Evaluation of the relationships between characteristics was made by Biplot analysis.

III. RESULTS

In the experiment, while the differences between the irrigation levels for the 2018 data of the NDF characteristic

Table 3. Variance analysis table for the characteristic examined in the study (F Values)

Year/ Characteristic	Crude protein (%)	Cellulose (%)	ADF (%)	NDF (%)	Ash (%)	DMI (%)	DDM (%)	RFV (%)
2017	3.2**	2.52**	8.9**	16.11**	0.44**	0.33*	5.05**	136.2**
2018	2.7**	1.82**	5.1**	9.1**	0.28**	0.03*	9.9**	152.9**

**significant at P ≤ 0.01; *significant at P ≤ 0.05

Table 4. Some quality values obtained at different water stress.

	Protein (%)		ADF (%)		NDF (%)	
	2017**	2018**	2017**	2018**	2017**	2018*
I_1	10.1 ^{a}	9.9 ^{a}	35.6 ^{a}	35.3 ^{a}	57.7 ^{a}	57.1 ^{a}
I_2	9.7 ^{a}	9.4 ^{a}	32.1 ^{b}	33.7 ^{b}	55.0 ^{b}	56.5 ^{a}
I_3	8.2 ^{b}	8.3 ^{b}	32.4 ^{b}	32.6 ^{c}	53.4 ^{b}	54.1 ^{b}
I_4	8.0 ^{b}	7.9 ^{b}	32.0 ^{b}	32.5 ^{c}	52.4 ^{c}	53.6 ^{b}
Means	9.0	8.9	33.0	33.5	54.6	55.4
Std. dev.	0.98	0.89	1.76	1.23	2.27	1.87
CV(%)	4.1	3.5	1.8	1.1	1.7	1.8
LSD	0.7	0.62	1.2	0.8	1.9	2.0

**significant at P ≤ 0.01; *significant at P ≤ 0.05

Table 5. Some quality values obtained at different water stress

	Cellulose (%)		Ash (%)		RFV (%)	
	2017**	2018**	2017**	2018**	2017**	2018**
I_1	27.2 ^{a}	26.9 ^{a}	7.6 ^{a}	7.8 ^{a}	92.1 ^{c}	90.3 ^{c}
I_2	*25.7* ^{b}	26.5 ^{b}	7.5 ^{a}	7.6 ^{a}	100.8 ^{b}	104.6 ^{a}
I_3	25.6 ^{b}	25.9 ^{b}	7.0 ^{b}	7.3 ^{b}	106.6 ^{a}	101.6 ^{b}
I_4	25.0 ^{c}	25.3 ^{c}	6.9 ^{b}	7.2 ^{b}	106.1 ^{a}	104.8 ^{a}
Means	25.9	26.2	7.3	7.5	101.4	100.3
Std. dev.	0.84	0.72	0.37	0.29	6.8	7.1
CV %)	1.2	0.9	2.3	1.9	1.01	1.44
LSD	0.31	0.33	0.33	0.26	2.1	2.80

** significant at P ≤ 0.01

and the two-year data of the DMI feature were found statistically significant at the p<0.05 level. The 2017 results of NDF value with both year values of crude protein, ash, ADF, NDF, RFV, and cellulose were found statistically significant at p<0.01 level (Table 3).

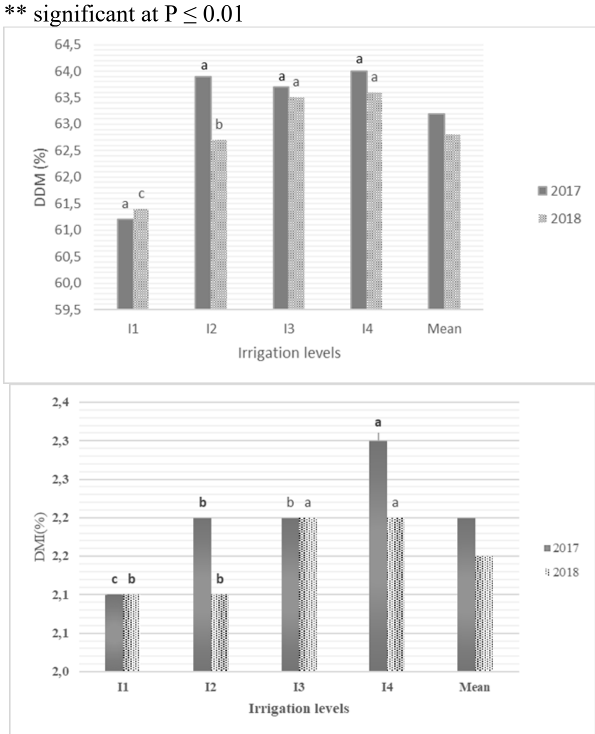
In terms of crude protein, the highest result in the first year was observed from I_1 subject (10.1%) while I_2 was also included in the same group (a), and the lowest result was obtained from subjects I_3 (8.2%) and I_4 (8.0%). In the second year, similar to the results of the first year, irrigation subjects of I_1 (9.9%) and I_2 (9.4%) showed the highest value while the lowest was from I_4 (7.9%) (Table 4).

In both years, the ratios of ADF and NDF reduced together with decreasing amount of irrigation water. The highest ADF value was obtained from I_1 subject as 35.6% and 35.3% in 2017 and 2018 and the lowest values were obtained from I_4 subject as 32% and 32.5%, respectively. The highest NDF value was determined as 57.7% (I_1) in 2017 and 57.1% (I_1) in 2018, and the lowest values were obtained from the I_4 subject (52.5% and 53.6%) in both years, as in the ADF ratio (Table 4).

Decreasing the amount of irrigation reduced ash and cellulose ratio while increasing the RFV value. In terms of ash, the highest and the lowest values resulted from I_1 (7.6%) and I_4 (6.9%) in 2017 respectively whereas similarly I_1 (7.8%) and I_4 (7.2%) in 2018. In terms of cellulose ratio, the highest values were obtained from the I_1 subject (27.2% and 26.9%) in both years, while the lowest values were obtained from the I_4 subject (25% and 25.3%). In terms of relative feed value (RFV), the lowest value was obtained from I_1 subjects (92.1% and 90.3%) in both years, while the highest value was obtained from I_3 (106.6%) subjects in 2017 and I_4 (104.8%) in 2018 (Table 5).

In the study, the lowest values in terms of DMI, which is one of the important parameters in terms of feed quality, were obtained from I_1 (2.1%) in both years, while the highest value was obtained from I_4 (2.3%) in 2017 and I_3 and I_4 (2.2%) in 2018.

DDM was also affected by the irrigation level, and the highest value was obtained from the I_4 subject (64% and 63.6%) and the lowest value was obtained from the I_1 subject (61.2% and 61.4%) in both years (Fig. 1).



2017 DDM Std. Deviation: 1.37 2018 DDM Std. Deviation:0.96
2017 DMI Std. Deviation: 0.08 2018 DMI Std. Deviation: 0.07

Figure 1. DMI (%) and DDM (%) values obtained in silage sorghum at different water stress.

Since the digestion level of ADF and NDF is very low in animal nutrition, it is a desirable parameter to have a low ratio in the ration and an increase in these values decreases the DMI and RFV (Kaplan *et al.*, 2015). Uzun *et al*. (2017) reported DMI in the range of 1.83-1.85, and RFV in the range of 82.56-85.7%, respectively, under full irrigation and water stress conditions.

The increase in insoluble fibers in plants having water stress is one of the physiological responses of plants to prevent moisture loss (Jahansouz *et al*., 2014), and an increase in the amount of ADF, NDF, crude cellulose, and ash was observed with the rise in the amount of irrigation. Similar results were reported by Uzun *et al*. (2017), Cotton *et al*. (2013). This is considered to be due to the reduction in the leaf/stem ratio with the increase in plant height under irrigated conditions (Pedersen *et al.*, 2005). Contrary to these views, Kiziloglu *et al.* (2009) observed that ADF and RFV parameters increased with water stress while Islam *et al*. (2012) showed that the amount of water did not affect ADF.

Cotton *et al*. (2013) stated that ADF rate as 36.5-31.5% and the ratio of NDF as 59.2-54.4%, respectively, in sorghum in full irrigated and water stress conditions. As a result of this experiment, it was observed that reduced irrigation decreased the rates of ADF and NDF.
There are different opinions about the effects of water stress on protein ratio. Keten (2020) and Khaton *et al*. (2016) reported that the protein value increased with increased irrigation water. Jahansouz *et al*. (2014), Uzun *et al*. (2017) and Liu *et al.* (2013) reported greater protein content in water stress. Islam *et al.* (2012) reported that water stress had no effect on protein in maize plant. Keten (2020) reported the protein ratio in sorghum as 9.6% under full irrigation conditions and 7.6% under water stress conditions.

While DDM calculated from the ADF value gave the lowest value for full irrigation, this value increased with water stress. Similarly, DMI calculated from NDF gave a higher result in water stress.

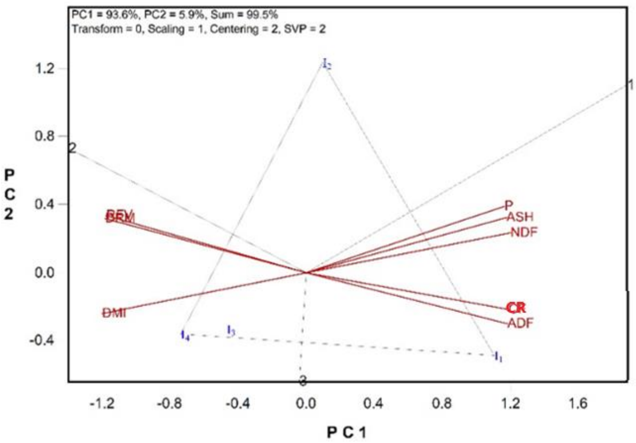
In terms of animal nutrition, it is desired to have high DDM and DMI properties, and these parameters were obtained high in I_3 and I_4 irrigation applications.

Relationship between irrigation levels and characteristics

Two-year averages of the Biplot graph, which was made to evaluate the relationship between the characteristics analyzed at different irrigation levels in sorghum, and the clustering and relationships created by the features at the irrigation levels visually, is given in Fig. 2. In the Biplot analysis, the main component 1 was 93.6% and the main component 2 was 5.95, and these two components were 99.5% in total (Fig. 2). This is a desired characteristic in Biplot graphics and this high value allows researchers to interpret more securely (Akcura, 2011). When the biplot graph given in Fig. 2 is examined, it consists of four parts, and in the first section where I_1 is diagonal, ADF, NDF, crude protein, ash, and crude cellulose characteristics are available, and the angle among them is narrow and the relationship is positive. In the Section II, where I4 is diagonal, a narrow-angle, and a positive relationship are seen among DDM, RFV, and DMI characteristic. Generally, diagonal applications are superior to other applications in terms of the feature or features in the same region. Besides, the characteristics that have positive and significant correlations with each other are narrower and these features are closer to each other (Akcura, 2011).

V. CONCLUSIONS

In this study, which was carried out for two years to determine the effects of different water stresses on some quality properties of silage sorghum, it was observed that all analyzed properties were affected by water stresses. It was concluded that the limited irrigation did not have a negative effect on the quality values of sorghum, and the irrigation program could be planned considering the biomass yield and irrigation costs. As a result, water stress decreased the ratio of ADF, NDF, and crude protein, cellulose, and ash, and increased the DMI, DDM, and RFV values.



P:Protein ratio,CR: Cellulose ratio, DDM: Digestible dry matter, DMI:Dry matter intake, RFV: Relative feed value, ADF: Acid detergent fibre, NDF: Neutral detergent fibre, ASH: Ash content

Figure 2. Biplot plot of the relationship between irrigation levels and properties.

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Received: April 26, 2022
Sent to Subject Editor: May 14, 2022
Accepted: September 10, 2022
Recommended by Subject Editor José Díaz de Tuesta