RESEARCH ARTICLE

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Comparison of physical and quality characteristics of silage maize and silage sorghum under deficit irrigation conditions

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Abstract
Silage sorghum has the feature of being an alternative to silage maize in many ways. Considering this feature, the nutritional contents and physical properties of silage maize and silage sorghum were examined. The aim of this study was to compare the physiological and quality characteristics of silage maize and silage sorghum under different irrigation treatments (M100-S100, M80-S80, M60-S60, M40-S40, and M20-S20). This study examined the physiological characteristics (chlorophyll content, plant height, stem diameter, and number of leaves) and quality characteristics (acid detergent fiber (ADF), neutral detergent fiber (NDF), and protein content (HP)) of second-crop silage maize and silage sorghum. Chlorophyll contents were measured before and after irrigation. These measurements showed that irrigation had no effect on the chlorophyll content in both plants in the middle of the growth period, and chlorophyll contents decreased towards the harvest. There was no significant difference between silage maize and silage sorghum plant height values. In the mean values for both years in which the plants were examined, stem diameter values and numbers of leaves were higher in sorghum compared to maize ($p<0.05$). There was no significant difference between maize and sorghum in terms of their protein contents (8.47% and 8.25%, respectively), acid detergent fiber (ADF), or neutral detergent fiber (NDF) values. In this case, it was seen that sorghum can be an alternative to maize in terms of nutritional quality. The protein contents of both plants decreased from the 100% irrigated treatment to the 20% irrigated treatment ($p<0.01$). This study will provide valuable information to feed producers and researchers in terms of comparing the physiological and quality characteristics of silage maize and silage sorghum under deficit irrigation conditions.

Keywords: Water, Protein content, Chlorophyll content, Acid detergent fiber

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INTRODUCTION

Considering the scarcity of water resources, water must be used economically (Fereres and Soriano, 2007). The management of water resources is one of the most important problems to be solved in the 21st century (Kuscu, 2010). In particular, using modern technologies in irrigation water management is the most important parameter to be considered for the achievement of maximal plant production (Panda et al., 2003). Deficit irrigation is one of the most useful methods applied in this context. The purpose of deficit irrigation is to increase plant production while using less water. For this reason, the development of deficit irrigation programs is important (Igbadun et al., 2008). In general, water can be saved by expanding deficit irrigation programs and determining the deficit irrigation program suitable for each plant (Oktem, 2008; Kuscu, 2010).

It is crucially important to increase food production sufficiently to feed the growing population of the world and manage limited water resources for agricultural use worldwide (Asrey et al., 2018). According to Chai et al. (2014), although deficit irrigation is one of the solutions for water saving in agriculture, it may be insufficient alone for food production. In addition to deficit irrigation, alternative plants that have similar characteristics to each other need to be grown. Animal feed, which is an important input in the livestock sector, is provided from plants such as silage maize, silage sorghum, sudangrass, alfalfa, vetch, and sainfoin in Turkey. Maize is a widely used plant in silage making, followed by sorghum-sudangrass hybrids and other sorghum species (Geren and Kavut, 2009). Silage maize is grown in irrigation conditions because it has high levels of seasonal crop water consumption (Mustek and Dusek, 1980). This situation causes a problem for fodder supply. Sorghum species have great potential in terms of proving an alternative to maize both in arid and irrigated agricultural areas (Arslan, 2016).

Chlorophyll content can be used in the evaluation of plant water stress and cold tolerance, as well as the detection of ozone damage (Rose and Haase, 2002; Perks et al., 2004; Demirel et al., 2010). Carol et al. (2017) determined the crop water stress index of maize by implementing complete and deficit irrigation methods in Utah conditions. While 700 mm of water was sufficient for irrigation, they used 480 mm water in their deficit irrigation program. They found the chlorophyll content of the well-irrigated treatment as 36.2, while that of the deficit irrigated treatment was 34. In the study conducted by Yamamoto et al. (2002), chlorophyll contents varied between 15 and 60 during the 54-day plant growing season after plantation. Jangpromma et al. (2010) cultivated sorghum varieties in arid conditions (no irrigation) in Thailand and evaluated their chlorophyll contents. Accordingly, the chlorophyll content values of the varieties differed between 21.58 and 39.55. Cetin (2017) emphasized that there are multiple factors that affect the chlorophyll content of a plant; therefore, it is necessary to increase the number of studies about chlorophyll contents.

The diameter of the stem of a plant has the highest impact on its yield. Grain and silage plant height, stem diameter, and number of leaves are the features to be considered when choosing maize varieties (Torun, 1999). El-Samnoudi et al. (2019) applied different irrigation treatments to the sorghum plant grown in Egyptian conditions. They named the treatment where all of the water that evaporated from the evaporation vessel was met I100, the treatment where 85% of it was met I85, and the treatment where 70% of it was met I70. They reported that plant height and stem diameter values decreased from the I100 treatment to I70 treatment groups. They reported that the plant height values varied between 148.8 cm and 132.65 cm, and the stem diameter values varied between 2.01 cm and 1.7 cm. Keskin et al. (2018) evaluated the quality characteristics of sorghum cultivars under irrigated conditions. They reported that plant height values were between 197.1 cm and 299.4 cm, and numbers of leaves varied between 9.5 and 12.5. Uzun et al. (2017) investigated the responses of silage maize and sorghum in wet and dry conditions (in natural precipitation conditions) in Turkey. They used 2 Maize (Rx-893, Karadeniz Yıldızı) and 7 sorghum (Jumbo, Grazer, Hayday, El Rey, Gozde, Rox E., Suma) varieties. The authors reported that the varieties grown under irrigated conditions had higher feeding quality and yield compared to those grown under rainfed conditions. While the heights of the maize varieties grown in irrigated conditions were in the range of 191.2-197.3 cm, those of sorghum varieties ranged between 330.7 cm and 189 cm.

In animal nutrition, especially in ruminant rations, acid detergent fiber (ADF) has started to be used as an energy indicator. ADF, which is included in the structural carbohydrates of plants, consists of cellulose and lignin (Tekce and Gul; 2014). Neutral detergent fiber (NDF) is effective on carbohydrates that make up a large part of ruminant rations, the milk fat of ruminants, milk components, the acetic acid/propionic acid ratio in the rumen, dry matter consumption, microflora, and microfauna in the rumen (Ferreira and Mertens, 2007; Hansey et al., 2007). An increase in the amount of irrigation water applied to silage maize (0-480 mm) increased the dry matter yield from 9.3 to 23.8 t/ha and NDF values from 524 to 555 g/kg, but crude protein decreased from 78 to 52 g/kg, and water-soluble carbohydrates decreased from 88 to 31 g/kg (Islam et al., 2012). Sorghum protein content was reported as 10.14% in irrigated conditions and 14.86% in dry conditions in Kansas. Dry conditions increased the protein content of sorghum (Liu et al., 2013). Sorghum is the world's fifth most important cereal crop. It is a drought-tolerant plant. It has a higher protein content compared to maize, but its content of digestible protein is lower (Dowling et al., 2002).

Although there are previous studies on silage maize and sorghum, no studies were found to compare chlorophyll contents based on irrigation schedules. The number of articles where certain physiological and quality parameters were compared under an irrigation program is low. The aim of this study is to measure and compare the physiological and quality characteristics of silage maize and sorghum under a deficit irrigation program. Because the chlorophyll contents of these two plants were not compared before, this study will fill a gap in the relevant literature. The comparison of physiological and quality characteristics based on irrigation schedules will also help other studies conducted on this subject. The results of this study will be beneficial for many plant producers and researchers.

MATERIALS AND METHODS

Site, Soil, Climate, and Agricultural Operations

This study was carried out on the soils of Kahramanmaraş Eastern Mediterranean Transition Zone Agricultural Research Institute and Kahramanmaraş Sütçü İmam University Laboratories. It was conducted in the second crop growing seasons in 2018 and 2019. In the growing periods of the plants (June-September), the long-term average lowest temperature was measured in September at 18.3°C, and the highest temperature was in August at 36.0°C. In the years when this study was conducted, the lowest temperature was measured at 9.0°C in September 2019, and the highest temperature was measured at 43.4°C in June 2019. The average temperature values during the growing period of the plants varied between 24.9°C and 29.3°C in the first year and between 26.0°C and 29.3°C in the second year.

The physical properties of the soils are shown in Table 1. Soil pH values were slightly alkaline and would not cause a problem in terms of agricultural production. It was found that the electrical conductivity values of the soil were not at a level that would cause a salinity-related issue. The amount of organic matter was found to be low for both years. The lime-related parameters showed the soil to be "highly calcareous" in both years of the study. The concentration of phosphate was found to be "low" in both years. While the potassium values of the examined soil in 2018 were found to be "sufficient", they were found to be "excessive" in 2019 (Table 2).

In the study, while the silage maize (Zea mays L.) plant was selected as the Colonia variety, which is a variety that can be used as a second crop and is adapted to the region, the Es Foehn cultivar was used as silage sorghum (Sorghum bicolor). Silage sorghum and silage maize plants were planted in the third week of July for both years. The horizontal and vertical distances between the rows were 70 cm and 15 cm, respectively. The study was planned with a randomized complete block factorial design with three replications. After the soil was plowed, 8 kg of fertilizer with nitrogen and phosphor contents was applied to the soil before planting. As the plants started to develop, nitrogen-containing fertilizer was applied to the soil at a rate of 10 kg per decare. The nitrogen-containing fertilizer was applied via fertigation. The length and width of each plot were 8 m and 3.5 m respectively. The total working area was 1590 m^2, and the distance between the plots was 2 meters while the distance between the blocks was 3 meters. To determine the irrigation time and amount, soil moisture was measured by the gravimetric method. The moisture content of the soil samples taken from a depth of 90 cm was measured according to the dry weight percentage calculation method. Irrigation was started when the usable water holding capacity of the soil was consumed by 50% (Dagdelen and Gurbuz, 2008). Considering these values, it was seen that the irrigation interval changed between 5 and 7 days. Soil moisture values were taken from all irrigation treatments, but irrigation was made only based on the soil moisture statuses of the M100-S100 treatments. Irrigation was started around the morning hours. The M100-S100 treatment involved meeting the entire water requirement of the plant (control treatment), while the treatment named M80-S80 corresponded to a 20% reduction in the water applied to the plant compared to the control treatment, M60-S60 corresponded to a 40% reduction, M40-S40 corresponded to a 60% reduction, and M20-S20 corresponded to an 80% reduction. The irrigation program was started on 8 July in 2018 and on 23 July in 2019. Irrigation was completed 10 days before harvesting. The irrigation program was applied using a drip irrigation system.

Table 1. Physical properties of the soil in the study area

Years	Depth	Field Capacity		Wilting point		Bulk Density	Soil Texture
		Pw (%)	mm	Pw (%)	mm	g cm^{-3}	
2018	0-30	29.35	110.06	19.80	74.25	1.25	CL
	30-60	28.25	106.79	19.60	74.08	1.26	CL
	60-90	19.65	71.33	13.95	50.63	1.21	SCL
2019	0-30	21.45	105.53	12.19	59.97	1.64	SiL
	30-60	23.35	107.88	14.28	65.97	1.54	SiL
	60-90	23.54	114.40	13.03	63.32	1.62	SL

Table 2. Chemical properties of the soil in the study area

Years	Soil depth (cm)	pH	EC (dS/m)	Organic matter (%)	P_2O_5 (kg da^{-1})	K_2O (kg da^{-1})	Lime (%)
2018	0-30	7.92	0.018	1.51	5.22	59.18	21.22
2019	0-30	7.80	0.023	1.03	3.66	62.00	19.85

Chlorophyll Content, Physiological, and Quality Measurements

Chlorophyll content

During plant development, measurements were taken before and after each irrigation step with a SPAD-502 chlorophyll meter (Minolta Co, Tokyo, Japan) device from 5 leaves of all treatment groups. The SPAD 502 chlorophyll meter is a small, handy device that measures light transmittance at red (650 nm, chlorophyll absorption) and near-infrared (960 nm) wavelengths, thus making it possible to take measurements without harming the plant (Minolta 1989, Ling et al., 2011). While measuring chlorophyll content, the device was held in such a way that it would not cast a shadow on the leaf, and readings were taken from 5 plants in each plot. The measurements were made from the area between the leaf edges and the leaf veins of the plants between 11:00 and 14:00. These measurements were made 1 day before and 1 day after irrigation.

Physiological measurements

Plant height (cm), stem diameter (mm), and numbers of leaves were measured by using an average of 10 plants from each plot at irrigation times throughout the growing season. Plant height was measured with a steel measuring tape from the ground level to the uppermost point of the plant. Stem diameter was measured by using an electronic caliper. The number of leaves was determined by counting the leaves on the stem.

Quality parameters

To measure ADF and NDF after the harvest, the dried samples were ground in a mill with a sieve allowing particles to pass at a diameter of 1 mm. Samples weighing approximately 0.5 g were placed in filter bags, and each bag was closed with glue and then weighed afterward. The empty weight (blind) of the filter bags was also measured. A mixture to be used for ADF analyses and a mixture to be used for NDF analyses were prepared. The prepared samples were placed in an ANKOM 200 Fiber Analyzer. The prepared ADF mixture (NDF with similar preparation steps) was poured on the samples placed in the device, and the device was operated. The samples were boiled at 100°C for approximately 90 minutes. When the 90-minute boiling period was over, the samples were mixed with hot water twice for 10 minutes. After the samples were removed from the device, they were kept in acetone. Afterward, the samples were kept in a fume hood to allow the acetone to evaporate. The samples, with acetone evaporated, were dried in an oven at 80ºC until they reached a constant weight. After they were removed from the oven, they were put into a desiccator to bring them to room temperature. The samples at the room temperature were weighed and measured according to Equation 1 (Van Soest, 1963).

$$\%ADF, \%NDF = \frac{[W3-(W1xC1)x100]}{W2} \quad \text{Eq. 1}$$

In the equation,

W1: Tare of bags

W2: Sample weight

W3: Weight of "sample + bag" after drying

C1: Blind weight (weight/tare of the empty bag after drying)

To measure protein contents, after the harvest, the dried samples were ground in a mill with a sieve allowing particles to pass at a diameter of 1 mm. 0.2 g of the ground samples was taken and put into Kjeldahl tubes. The empty weight (blind) of the filter bags was also measured. 25 ml of sulfuric acid and a catalyst (potassium sulfate) tablet were added to the samples. Afterward, the tubes were kept at a high temperature for 5 hours in the wet burning unit. 25 ml of boric acid was prepared. After wet burning, the tubes and boric acid were placed in the Gerhart brand distillation unit. After the desired color change (green-blue) was observed in the flask containing boric acid, it was titrated with hydrochloric acid. The amount of hydrochloric acid that was consumed was recorded when the color turned pink. The amount of crude protein (AOAC, 1990) was determined using the Kjeldahl method according to Equation 2.

$$\%Nitrogen = \frac{(V1-V0)xNx0.014}{m} x100 \quad \text{Eq. 2}$$

In equality,

V1 = Amount of HCl solution spent in titration, ml

V0 = Amount of HCl solution spent in titration for the blank sample, ml

N = Normality of the HCl solution used in titration, 0.1 N

0.014 = Mil-equivalent weight of nitrogen; m: Amount of food sample taken, g or ml

Protein= %Nitrogen x 6.25

Statistical Analysis

The data that were collected in the study were analyzed according to the factorial experimental design in random blocks. An analysis of variance (ANOVA) was conducted to determine the levels of differences between the groups of data. The investigated plant height, stem diameter, number of leaves, ADF, NDF, and protein content were analyzed using a standard ANOVA test using the general linear model (SAS Institute, 1996). The significance of the differences was tested by the "F" test (Gomez and Gomez 1984). When differences were found in the ANOVA, Duncan's Test (grouping) was applied to determine the source of the significant differences.

RESULTS AND DISCUSSION

Chlorophyll Content

Seven irrigation steps were applied to the plants in 2018, and 8 were applied in 2019. Figure 1 shows the chlorophyll contents of the silage maize and sorghum before and after irrigation in 2018 and 2019. In 2018, the chlorophyll content of the silage maize increased in all treatments from the vegetative period to the milk stage, and then, it decreased after the milk stage. While the highest chlorophyll content was 56.93 in M100 in the 4th irrigation, the lowest was 39.73 in M20 in the 7th irrigation. Other measurements varied between these values. No significant difference was found between before and after irrigation in terms of chlorophyll content. It was shown that irrigation did not change the chlorophyll content in the medium term. Thus, it was also understood that irrigation did not change the chlorophyll content in the short term. Chlorophyll content tended to be high in the non-water-stressed treatments while it decreased in the water-stressed treatments. The chlorophyll content of maize increased in the M100 and M80 treatments until harvesting, while it decreased from the milk stage to harvesting in the M60, M40, and M20 treatments and reached the lowest value at harvest in 2019. While the highest chlorophyll content value was 47.53 for M60 in the 1st irrigation, the lowest was 26.70 for M20 in the 8th irrigation. In the evaluation of both years together, it was seen that the progression of measurement times did not affect the chlorophyll contents significantly in a short time (1 to 2 days). The chlorophyll content of maize increased in all treatments from the vegetative period to the harvest in 2018.

The highest chlorophyll content of the silage sorghum was 57.57 for S100 in the 7th irrigation, and the lowest was 37.23 for S100 in the 1st irrigation in 2018. The S100 treatment had a higher chlorophyll content than the other treatments. Other measurements varied between these values. It was determined that irrigation did not significantly change the chlorophyll contents of the sorghum plants in the short term, as in the case of maize. The chlorophyll contents showed a high trend in the treatments that were not under water stress and decreased in the treatments which were subjected to water stress. The content of chlorophyll in sorghum increased until the 4th irrigation, and then, it decreased from this point to the harvest and reached lowest point at harvest in 2019. While the highest chlorophyll content was 40.23 for S100 in the 4th irrigation, the lowest was 29.93 for S20 in the 8th irrigation. The S100 treatment had a higher chlorophyll content than the other treatments. The values of the other treatments varied between these values in 2019. Considering the results in both years, no significant differences were observed between the chlorophyll contents of silage maize and silage sorghum. Both plants showed similar trends as a response to water stress.

Many researchers have reported that chlorophyll contents decrease along with increasing stress (Demirtas and Kırnak, 2009; Pouyafard et al., 2016). Moreover, Yolcu (2014) reported that as irrigated treatments have more soil moisture, the nitrogen in the soil is transmitted to the leave, and it has an increasing effect on the chlorophyll content there. Kabay and Şensoy (2016) observed that when plants were negatively affected by any adverse environmental condition, there was a decrease in the chlorophyll contents, yield, and quality of these plants. Several researchers have found different results regarding the chlorophyll contents of silage maize and sorghum. The chlorophyll content of maize has been found in the range of 36.44 to 70.78 by other researchers (Hokmalipour and Darbandi 2011; Tunali 2012; Kappes et al., 2013; Kappes et al., 2014; Yolcu 2014; Carol et al., 2017; Galindo et al., 2019). The chlorophyll content of sorghum has been reported in the range of 40 to 52.54 (Kassahun et al., 2010; Vinodhana and Ganesamurthy 2010; Kaplan and Kara 2014; Mahama 2014; Abunyewa et al., 2016; Kumari et al., 2016; Sory et al. 2017; Kiran et al. 2018).

Physiological Characteristics

The average plant height was taken in the harvest period. The results of the ANOVA on the physiological characteristics of the silage maize and sorghum plants are shown in Table 3. There was no significant difference between the maize and sorghum plants in 2018, in 2019, and in terms of the average of the two years (Table 4). No significant difference was found in the plant heights of maize and sorghum between the values of the two years. According to the average of two years, the highest plant height was obtained from the 100% irrigated treatments. The lowest plant height was obtained from the 40% and 20% irrigated treatments. Deficit irrigation reduced plant height values in both plants. Ashraf et al. (2016) found plant height values of 157 to 203.7 cm in maize, while Galindo et al. (2019) found values of 215 cm to 255 cm. El-Samnoudi et al. (2019) found plant height values to be 132.65 cm to 148.8 cm in sorghum, while Kaplan et al. (2019) found plant height values of 203 cm to 255.35 cm.

The results of the ANOVA on the stem diameters of the silage maize and sorghum plants are shown in Table 5, and the results of the Duncan's test groups formed according to the ANOVA results are given in Table 6. While the mean stem diameter of maize was 22.34 mm, that of sorghum was 20.48 mm in 2018. No significant difference was found between the stem diameters of maize and sorghum in 2019. The mean stem diameter of maize was 21.62 mm, and that of sorghum was 19.87 mm as the average of two years (Table 4). It is known that having a large stem diameter is an important factor for the achievement of high yield. Cruz et al. (2008) reported

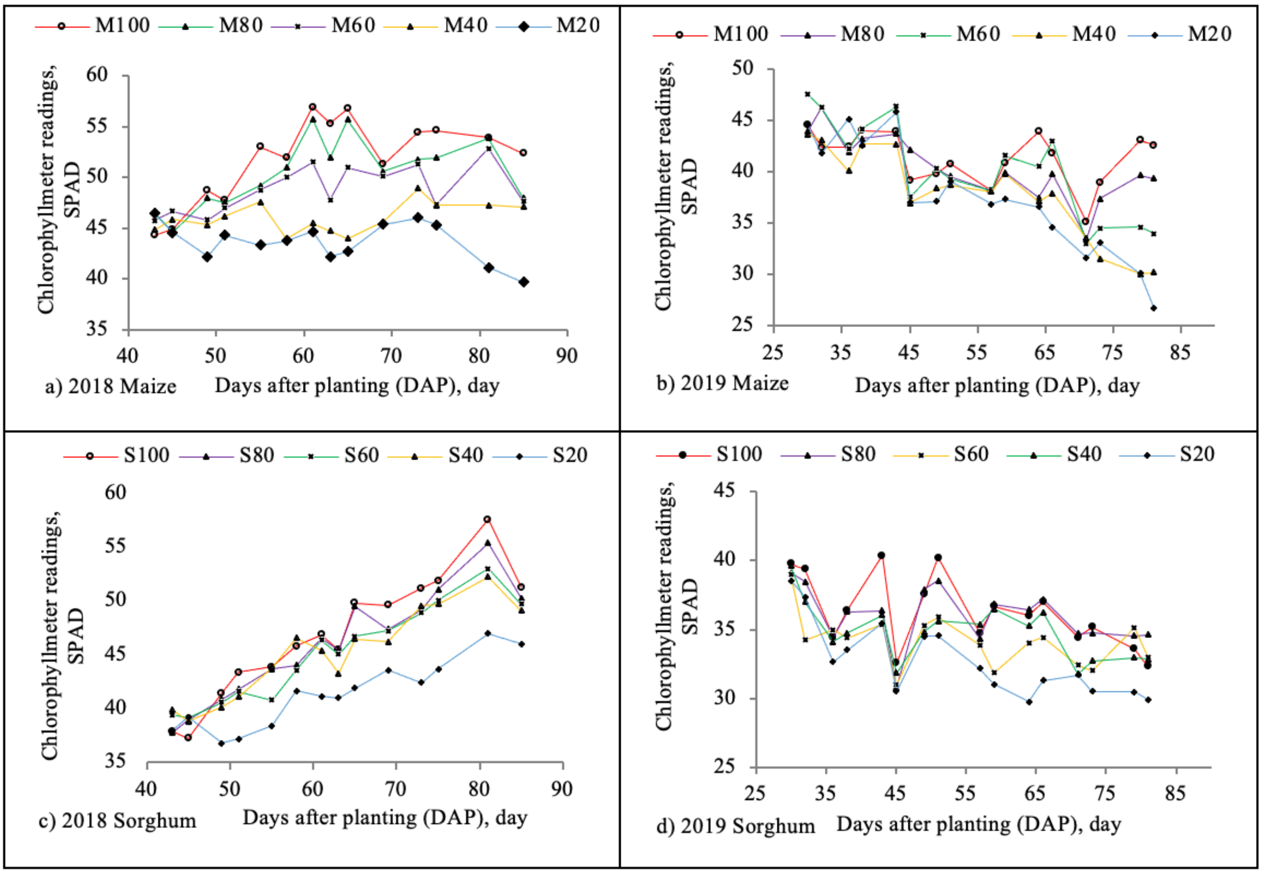

Figure 1. Plots of chlorophyll content values in silage maize and silage sorghum

Table 3. ANOVA results of height values of silage maize and sorghum at irrigation levels

Source of variation	Degrees of freedom	Mean square	F
Year	1	844.35	4.86*
Species	1	394.95	2.27
Irrigation levels	4	3024.58	17.42**
Year*Species	1	293.04	1.69
Year*Species	4	26.04	0.15
Species*Irrigation levels	4	587.82	3.39*
Year*Species*Irrigation levels	4	57.31	0.33
Error	36	173.64	

Table 4. Plant heights of silage maize and silage sorghum

Irrigation levels	2018			2019			Average of 2 years		
	Maize	Sorghum	Avg	Maize	Sorghum	Avg	Maize	Sorghum	Avg
100%	218.37	240.05	229.21a	222.67	246.33	234.49a	220.52	243.19	231.85a**
80%	212.94	228.58	220.76a	217.89	231.44	224.66a	215.41	230.01	222.71ab
60%	209.68	219.33	214.50a	222.44	222.22	222.33ab	216.06	220.77	218.41b
40%	194.16	199.37	196.76b	214.67	201.22	207.94bc	204.41	200.29	202.35c
20%	190.13	185.71	187.91b	207.22	187.22	197.22c	198.67	186.46	192.57c
Avg	205.05a	214.60a	209.83b	216.97a	217.68a*	217.33a	211.01a	216.14a	

that the larger the stem diameter, the greater the plant's capacity to store photo-assimilates that contribute to grain filling. In this case, it was understood that more yield could be obtained from the maize plant compared to the sorghum plant. While the highest stem diameters were 22.74 mm and 22.24 mm in the 100% and 80%

irrigated treatments, respectively, the lowest stem diameter was 19.61 mm in the 20% irrigated treatments in 2018. No significant difference was found among the irrigation treatments in 2019. According to these results, it was understood that in the 100% irrigated treatments, the stem diameters values were the greatest. Deficit irrigation caused a decrease in the stem diameters of the plants. The stem diameters of sorghum were previously found to be in the range of 16.07-20.1 mm by some researchers (Snider 2012; El-Samnoudi et al., 2019).

The results of the ANOVA on the number of leaves of the silage maize and sorghum plants are shown in Table 7, and the results of the Duncan's test groups formed according to the ANOVA results are given in Table 8. The maize plants had greater numbers of leaves compared to the sorghum plants. There was no significant difference in the numbers leaves between the maize and sorghum plants in 2018. The number of maize leaves was found to be 12.33/plant, while the number of sorghum leaves was found to be 11.71/plant in 2019. Orak and İptaş (1999) and Sade et al. (2002) stated that the number, weight, and ratio of leaves are important parameters for silage plants. Vartanlı and Emeklier (2007) reported that photo-assimilation increased along with an increase in the number of leaves. Yield has a positive association with photo-assimilation. According to these results, it was understood that the 100% irrigated treatments had the highest numbers of leaves, and deficit irrigation caused a decrease in the number of leaves.

Quality Features

The results of the ANOVA on the ADF values of the silage maize and sorghum plants are shown in Table 9, and the results of the Duncan's test groups formed according to the ANOVA results are given in Table 10. The ADF value of maize was 24.49%, and the ADF value of sorghum was 27.13% in 2018. ADF is expected to be low for the easier digestion of feed (Van Soest 1994; Yavuz 2005). Therefore, it was thought that maize feed could be digested more easily than sorghum feed. Maize and sorghum were found in the same group in terms of their ADF values in 2019 and based on the average of two years. While the ADF of maize was found as 25.72%, that of sorghum was 25.17% in 2019. In the average values of both years, the ADF of maize was 25.17%, while it was 26.15% in sorghum.

The was no significant difference among the irrigation treatments in 2018, in 2019, and considering the two-year average values. ADF values varied between 24.52% and 26.85% in 2018, while they varied between 24.40 and 26.27% in 2019. As the average of both years, these values varied between 24.46% and 26.35%. When the values were examined in total, the lowest ADF values were found in the 100% irrigation treatment. It was understood that the 100% irrigated treatments were more easily digestible. Seif et al. (2016) reported that ADF values increased in maize under low irrigation conditions and found maize ADF values of 22.1% to 29.5%. Teixeira (2014) reported sorghum ADF values of 21.98%-23.64%. The results of this study coincided with the results reported by the aforementioned researchers.

The results of the ANOVA on the NDF values of the silage maize and sorghum plants are shown in Table 11, and the results of the Duncan's test groups formed according to the ANOVA results are given in Table 12. In 2018, the NDF values of maize and sorghum were 50.03% and 53.68%, respectively. In 2018, these values for maize and sorghum were respectively 52.46% and 49.77%. A low NDF value is desired in animal nutrition since the structures that make up NDF cannot be digested by intestinal enzymes (Saki et al., 2010). In other words, feeds with high NDF values slow down the digestion in animals and cause a feeling of satiety. Therefore, NDF reduces the amount of feed consumed by the animal (Van Soest, 1994; Yavuz 2005). Maize and sorghum were in the same group in terms of their average NDF values of the two years. Nocek and Russell (1988) reported that NDF must be between 32.3% and 68.3% for silage maize to be suitable for animal feeding. In this study, NDF values were found higher in the deficit irrigation treatments. This situation showed that deficit irrigation reduces the digestibility of feed. Likewise, Seif et al. (2016) reported that NDF increased in maize under water stress conditions.

The results of the ANOVA on the protein content values of the silage maize and sorghum plants are shown in

Table 5. ANOVA results of stem diameters of silage maize and sorghum at irrigation levels

Source of variation	Degrees of freedom	Mean square	F
Year	1	26.77	2.55
Species	1	45.72	4.36*
Irrigation levels	4	25.82	2.46*
Year*Species	1	0.18	0.02*
Year*Species	4	0.69	0.07
Species*Irrigation levels	4	0.25	0.02
Year*Species*Irrigation levels	4	2.28	0.22
Error	36	10.47	

*, **: Significant at p<0.05 and p<0.01 levels, respectively

Table 6. Stem diameter of silage maize and silage sorghum

Irrigation levels	2018			2019			Average of 2 years		
	Maize	Sorghum	Avg	Maize	Sorghum	Avg	Maize	Sorghum	Avg
100%	22.98	22.51	22.74[a]	23.18	21.02	22.10[a]	23.08	21.77	22.42[a]
80%	22.97	21.52	22.24[a]	22.47	20.00	21.23[a]	22.72	20.76	21.73[a]
60%	22.53	21.11	21.82[ab]	21.06	19.34	20.19[a]	21.79	20.22	21.00[ab]
40%	22.13	19.18	20.65[bc]	19.39	18.41	18.89[a]	20.76	18.79	19.77[ab]
20%	21.11	18.12	19.61[c]	18.40	17.55	17.97[a]	19.76	17.83	18.79[b]
Avg	22.34[a]	20.48[b]	21.41[a]	20.89[a]	19.26[a]	20.08[a]	21.62[a]	19.87[b]	

Table 7. ANOVA results of numbers of leaves of silage maize and sorghum at irrigation levels

Source of variation	Degrees of freedom	Mean square	F
Year	1	1.35	2.40
Species	1	2.54	4.52*
Irrigation levels	4	9.71	17.27**
Year*Species	1	0.66	1.18
Year*Species	4	1.36	2.42
Species*Irrigation levels	4	0.32	0.58
Year*Species*Irrigation levels	4	0.33	0.59
Error	36	0.56	

*, **: Significant at p<0.05 and p<0.01 levels, respectively

Table 8. Numbers of leaves in silage maize and silage sorghum

Irrigation levels	2018			2019			Average of 2 years		
	Maize	Sorghum	Avg	Maize	Sorghum	Avg	Maize	Sorghum	Avg
100%	13.78	13.44	13.61[a]	13.44	12.22	12.83[a]	13.61	12.83	13.22[a]
80%	13.22	13.22	13.22[a]	12.78	11.89	12.33[ab]	13.00	12.56	12.77[ab]
60%	12.33	12.89	12.61[a]	12.11	11.78	11.94[bc]	12.22	12.33	12.27[b]
40%	11.78	11.22	11.50[b]	12.00	11.44	11.72[bc]	11.89	11.33	11.61[c]
20%	11.00	10.33	10.66[b]	11.33	11.22	11.27[c]	11.17	10.78	10.97[d]
Avg	12.42[a]	12.22[a]	12.32[a]	12.33[a]	11.71[b]	12.02[a]	12.37[a]	11.96[b]	

Table 9. ANOVA results of ADF values of silage maize and sorghum at irrigation levels

Source of variation	Degrees of freedom	Mean square	F
Year	1	1.98	0.29
Species	1	16.44	2.40
Irrigation levels	4	6.87	1.00
Year*Species	1	38.35	5.60*
Year*Species	4	1.49	0.22
Species*Irrigation levels	4	6.60	0.96
Year*Species*Irrigation levels	4	1.98	0.31
Error	36	6.85	

*, **: Significant at p<0.05 and p<0.01 levels, respectively

Table 10. ADF levels of silage maize and silage sorghum

Irrigation levels	2018			2019			Average of 2 years		
	Maize	Sorghum	Avg	Maize	Sorghum	Avg	Maize	Sorghum	Avg
100%	22.87	26.18	24.52[a]	23.62	25.18	24.40[a]	23.25	25.68	24.46[a]
80%	23.44	28.12	25.77[a]	26.13	26.42	26.27[a]	24.78	27.27	26.02[a]
60%	24.98	27.07	26.02[a]	27.48	24.56	26.01[a]	26.23	25.81	26.02[a]
40%	24.32	27.47	25.89[a]	25.01	24.43	24.72[a]	24.67	25.95	25.30[a]
20%	26.86	26.86	26.85[a]	26.41	25.29	25.85[a]	26.63	26.08	26.35[a]
Avg	24.49[b]	27.13[a]	25.81[a]	25.72[a]	25.17[a]	25.45[a]	25.11[a]	26.15[a]	

Table 11. ANOVA results of NDF values of silage maize and sorghum at irrigation levels

Source of variation	Degrees of freedom	Mean square	F
Year	1	8.32	0.56
Species	1	3.51	0.23
Irrigation levels	4	17.85	1.19
Year*Species	1	150.63	10.05**
Year*Species	4	10.06	0.67
Species*Irrigation levels	4	9.41	0.63
Year*Species*Irrigation levels	4	2.23	0.15
Error	36	14.98	

*, **: Significant at p<0.05 and p<0.01 levels, respectively

Table 12. NDF levels of silage maize and silage sorghum

Irrigation levels	2018			2019			Average of 2 years		
	Maize	Sorghum	Avg	Maize	Sorghum	Avg	Maize	Sorghum	Avg
100%	46.81	51.85	49.32[a]	50.50	49.73	50.11[a]	48.65	50.79	49.72[a]
80%	49.08	54.38	51.73[a]	52.59	51.51	52.05[a]	50.84	52.94	51.89[a]
60%	49.74	53.84	51.78[a]	54.39	49.49	51.94[a]	52.06	51.66	51.86[a]
40%	50.24	52.97	51.60[a]	51.10	49.61	50.35[a]	50.67	51.29	50.98[a]
20%	54.31	55.41	54.85[a]	53.72	48.54	51.13[a]	54.01	51.97	52.99[a]
Avg	50.03[b]	53.68[a]	51.86[a]	52.46[a]	49.77[b]	51.11[a]	51.24[a]	51.73[a]	

Table 13. ANOVA results of protein contents of silage maize and sorghum at irrigation levels

Source of variation	Degrees of freedom	Mean square	F
Year	1	1.43	2.38
Species	1	0.71	1.18
Irrigation levels	4	4.76	7.90**
Year*Species	1	2.87	4.77*
Year*Species	4	0.20	0.34
Species*Irrigation levels	4	0.63	1.05
Year*Species*Irrigation levels	4	0.76	1.26
Error	36	0.60	

*, **: Significant at p<0.05 and p<0.01 levels, respectively

Table 14. Protein contents of silage maize and silage sorghum

Irrigation levels	2018			2019			Average of 2 years		
	Maize	Sorghum	Avg	Maize	Sorghum	Avg	Maize	Sorghum	Avg
100%	8.19	9.78	8.98[a]	9.95	9.34	9.46[a]	9.07	9.56	9.31[a]
80%	8.35	8.81	8.57[ab]	8.97	8.10	8.53[b]	8.66	8.45	8.55[b]
60%	8.10	8.11	8.10[ab]	8.82	8.25	8.53[b]	8.46	8.18	8.32[bc]
40%	8.10	7.53	7.81[bc]	8.02	8.00	8.00[b]	8.06	7.76	7.91[bc]
20%	7.75	7.36	7.55[c]	8.46	7.25	7.85[b]	8.11	7.30	7.70[c]
Avg	8.09[a]	8.31[a]	8.51[a]	8.84[a]	8.18[b]	8.20[a]	8.47[a]	8.25[a]	

Table 13, and the results of the Duncan's test groups formed according to the ANOVA results are given in Table 14. While the protein content of maize was 8.09%, that of sorghum was 8.31% in 2018. The highest protein content was 8.84% for maize, while it was 8.18% for sorghum in 2019. Maize and sorghum were in the same group in terms of their protein contents considering the average of the two years. Regarding the average values of the two years, while the protein content of maize was 8.47%, that of sorghum was 8.25%. Mison (1990) reported that the minimum protein content should be 7% for the maintenance of the microbes in the rumen of animals. According to these results, it was understood that the protein contents of the plants examined in this study were at a suitable level. While the highest protein content was 9.31% in the 100% irrigated treatment, the lowest protein content was 7.70% in the 20% irrigated treatment based on the average values of the two years. According to these results, it was determined that water stress caused a decrease in protein contents. Simsek et al. (2011) concluded that increasing the amount of irrigation increased the protein content of the plant. Mahama and Doka (2019) found high protein contents in their full irrigation treatment. Many researchers have found different results regarding the protein contents of maize and sorghum. Kizilsimsek et al. (2016) reported protein contents of maize as 6.37% to 8.48%. Singh (2018) showed the protein content of sorghum to vary from 3.68% to 6.71%. Hajibabaei and Azizi (2012) emphasized that protein content is affected by many interactions like environmental, agricultural, and genetic factors. Additionally, these factors reduce the protein content of maize in cases of drought and soil moisture deficiency.

CONCLUSION

The chlorophyll contents of the plants did not show a significant decrease or increase from before to after irrigation since the measurement intervals of chlorophyll content were short. This showed that irrigation did not change the chlorophyll content of plants in a short time. It was observed that the highest values were in the 100% irrigation treatments for both plants during the plant growing period. The chlorophyll contents decreased in the period from vegetative development to the harvest, especially in the treatments that were irrigated at a rate of 60% or lower. No significant difference was found in plant height values between maize and sorghum. The stem diameter of the maize plant was higher than that of the sorghum plant. Since stem diameter is a feature related to yield, it may be more economical to grow maize at an irrigation rate of 60%. As the water stress increased, the number of leaves tended to decrease. In this study, it was observed that physiological parameters (plant height, stem diameter, and number of leaves) regressed relatively at water stress levels over 60%.

Many interactions such as variety, environment, and agricultural factors affect silage feed quality (ADF, NDF, protein content). Low ADF, low NDF, and high protein content are decisive criteria for feed quality. According to the average of two years, the irrigation treatments did not change the ADF values of maize and sorghum, and ADF values were not significantly different between maize and sorghum. A similar situation was observed for NDF. There was no significant difference in protein content between maize and sorghum. An increase of 20% or more in the deficit of irrigation caused a decrease in protein content. When the silage maize and sorghum were evaluated in terms of feed quality, there was no significant difference between them. In this case, it was seen that sorghum can be an alternative to maize in terms of nutritional quality. Similarly, there was not much difference between the physiological characteristics of the plants. Consequently, silage sorghum can be grown as an alternative to maize for silage feed. If irrigation resources are limited, sorghum is more resistant to adverse environmental conditions than maize. Therefore, sorghum can be grown and used as fodder in arid and semiarid regions. If sorghum cultivation is made prevalent in these regions, one of the greatest problems in animal husbandry can be resolved.

COMPLIANCE WITH ETHICAL STANDARDS

Peer-review

Externally peer-reviewed.

Declaration of interests

The authors declare that they have no competing, actual, potential or perceived conflict of interest.

Author contribution

Mualla KETEN GOKKUS: Conceptualization; data curation; investigation; methodology; formal analysis; visualization; writing –original draft; writing review and editing.

Hasan DEGIRMENCI: Data curation; Supervision; writing – original draft; writing review and editing.

Ethics Committee Approval

Ethics committee approval is not required. This article does not contain any studies with human participants or animals performed by any of the authors.

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