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The Effect of Different Irrigation Frequency and Level on Yield and Quality Characteristics of Silage Sorghum

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ABSTRACT

This study was carried out to determine the effect of different irrigation frequency and levels on silage sorghum plant for yield and quality at the Bingöl University Agricultural Research and Application Field in 2022 using the Master BMR variety as plant material. Randomized complete blocks applying the split-plots experimental design with three replications was used; four irrigation levels (25%, 50%, 75% and 100%) and four irrigation frequencies (5, 10, 15 and 20 days) were considered as treatments. Percentage of moisture replacement was determined using total moisture loss from evapotranspiration (ET). Amount of water discharged by emitters were predetermined, hence, time was used to determine the exact amount. Properties related to green forage yield, dry matter yield, crude protein ratio, crude protein yield, acid detergent insoluble fibre, neutral detergent insoluble fibre, digestible dry matter, dry matter consumption and relative feed value were investigated. Statistically significant differences between all the examined features were observed. The highest green forage yield, dry matter yield and crude protein yield were obtained from 5-day frequency and 100% level. Highest crude protein ratio from 5-day frequency and 25% level, lowest acid detergent insoluble fibre rate and highest digestible dry matter rate from 20-day frequency and 25% level, highest dry matter intake and relative feed value with the lowest neutral detergent insoluble fibre rate were observed from 25% level with 10 and 20-day frequencies. In conclusion; it can be stated that, to obtain high yield from silage sorghum, it is necessary to irrigate at 5 days frequencies and 100% level. However, high-quality product can be obtained with a 10-day frequency and a 25% level with low yield.

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Introduction

Sorghum (*Sorghum bicolor* (L.) Moench), referred to as the crop of the future in animal nutrition, has had myriad of research conducted on it to determine its suitability as a replacement crop for maize/corn (McCary et al., 2020). De Morais Cardoso et al. (2017) identified sorghum as the fifth most cultivated cereal in the world after its domestication some 3000 years ago. Sorghum, with its multiple application, has been preferred due to its tolerance and adaptive capacity over a large geographical area on different continents (Hossain et al., 2022). On a marginal land, sorghum is relatively productive compared to the other popular cereals. Its complete replacement of maize is still limited due to several reasons mostly having to do with digestibility and nutrients availability (De Morais Cardoso et al., 2017; Hossain et al., 2022; McCary et al., 2020). Variety, developmental stage, nutritional content, feed processing among other factors have been identified to affect the suitability of sorghum as a replacement for maize in animal nutrition. If the digestibility and nutritional content of the sorghum crop are improved through genetic manipulations, cultural practices or postharvest treatments, sorghum could become a food security crop now and moving into the future amidst the increasing climatic impacts. As a response to eminent need, the Sudangrass-Sorghum hybrid was bred for its medium tillering, regrowth capacities, and nutritive values as an alternative to maize/corn in the production of silage and other forage resources (Bhat, 2019). The discovery of the BMR trait in Sorghum further improved its usability as a forage crop under water stress conditions. Over the past decades, studies assessing water use efficiency and climate tolerance have seen light in the potential of sorghum (Pennells et al., 2021; Hossain et al., 2022).

There exists a plethora of evidence to the fact that the climatic condition of the earth is changing (IPCC, 2014). Climate variability is real and the aspect of this variation which will significantly affect the agricultural industry is erratic precipitation patterns (Chadalavada et al., 2022). Reports of growing desertification and reduction of the amount and frequency of rainfall in various parts of the earth have been published by seasoned climate scientists (IPCC, 2007). Related to this observed impact of the changing climate and the fact that the situation will be getting worse, is the imperativeness to develop a system to salvage the food production process of the world. Animal feed is an important part of the food chain since more than 15% of human food is derived from animal sources (FAO, 2018). Thus, making it a lot more important to research into effective production process aimed at building climate adaptive capacity. Sorghum, as stated above, possesses the additional advantage suitable for climate stress production. According to the IPCC (2014) report, there will be significant variability in the global precipitation system, which brings to bare the need to develop efficient irrigation measures for crops with minimum demands, which may result in the optimal use of water resources. Genome sequencing for drought tolerance showed that Sorghum is superior to its counterpart cereal crops in terms of resistance to changes in climate variables (George et al., 2022). In a review report, Motsi et al. (2022) presented Sorghum as a crop with efficient use of water under stress condition, and thus could be used in building adaptive capacity especially for small holder farmers. Researchers working on deficit irrigation on sorghum have preferred the Drip Irrigation method to other forms of surface irrigation due to its preciseness in determining water-use efficiency (El-mageed et al., 2022; Aydinsakir et al., 2021; Garofalo & Rinaldi, 2013). The main objective of this study was to evaluate the yield characteristics of sorghum silage in response to frequency and levels (amount) of irrigation. The specific objectives were to: determine the most effect irrigation frequency for silage sorghum crop; determine the optimum irrigation level demand of silage sorghum crop; assess the quality of silage sorghum produced under irrigation.

Material and Method

This study was carried out in 2022 in Bingöl University Agricultural Research and Application Centre using Master BMR variety of Sorghum-Sudan grass hybrid as plant material. In general, the experimental soils have clay-loam texture, up to 53 % soil Field Capacity, neutral or near neutral in reaction (pH = 6.68), without salt (0.027 %), low and moderate levels of Calcium Carbonate (1.7 %), low organic matter (1.8 %), and most analysed soils were found to be deficient in terms of available phosphorus (5.5 $kgP_2O_2\ da^{-1}$) and sufficient in terms of available potassium (120 $K_2O\ da^{-1}$) as reported by (Ateş and Turan, 2015).

The research was carried out according to the Randomized Complete Block Design (RCBD) split-plot experimental design with 3 replications. In the experiment, 4 different irrigation frequencies (5-, 10-, 15- and 20-day intervals) were applied as main plots and 4 different irrigation levels (25%, 50%, 75% and 100%) were applied as sub plots as shown on (Figure 1). The experimental plots were planted in 4 rows by hand in rows of 5 m in length with 70 cm intervals and sowing was done by hand. In the trial, the width of the area was determined as 19 m x 56 m = 1064 m^2, and the block width was 5 m x 56 m = 280 m^2. Sowing was done at the rate of 4 kg of seeds per decare. Drip irrigation method was used for moisture replacement. Prior to sowing of the seeds, the field was marked to indicate the movement of irrigation lines. Afterwards, water was let through the emitters and the Rate of Discharge (Rd) was recorded for each line. Average Rate of Discharge (Rda) for each subplot was computed and subsequently used along with total losses due to Evapotranspiration (ETt) over the duration of the main-plot, to determine amount of moisture to be replaced depending on the irrigation levels based on time ($TIrr_{(x)}$) using the formulas below.

$$\mathrm{TIrr0.25} = \frac{0.25 \times \mathrm{ETt} \times \mathrm{A}}{\mathrm{Rda}} \tag{1}$$

$$\mathrm{TIrr0.50} = \frac{0.50 \times \mathrm{ETt} \times \mathrm{A}}{\mathrm{Rda}} \tag{2}$$

$$\mathrm{TIrr0.75} = \frac{0.75 \times \mathrm{ETt} \times \mathrm{A}}{\mathrm{Rda}} \tag{3}$$

$$\mathrm{TIrr1.00} = \frac{1.00 \times \mathrm{ETt} \times \mathrm{A}}{\mathrm{Rda}} \tag{4}$$

The obtained data were analysed with the help of the JMP statistical package program, and the differences and similarities were compared with the LSD test. Weed control was carried out with hoe during the growth periods of the plants in the trial plots. With the planting, 15-15-15 compound fertilizer was applied as base fertilizer at a rate of 10 kg per decare and 22 kg of Urea (46% N) per decare was applied as top dressing later in the season.

In the plots, after the edge effects were removed when the vegetative features mentioned below are at the harvest maturity period, observations and measurements were made on 10 randomly selected plants from each row in order to determine the yield characteristics, and according to the method specified by Steel & Torrie (1960) and Düzgüneş et al. (1983) as stated below. In addition, quality analyses were carried out on dried and ground herbage samples.

After removing the edge effect from each plot, the green parts of the plants harvested from the remaining area were weighed and the values obtained were converted to yield in kg per decares. 0.5 kg of the grass cut from each plot were taken as samples and dried in the drying cabinet at 70°C for 48 hours. They were then kept for 24 hours, weighed, and the dry matter weights were obtained. The obtained dried matter values were then converted to dry matter yield per decare. Nitrogen content of the grounded dried matter samples were determined using the Near Infrared Reflectance Spectroscopy (NIRS) as described by Corson et al. (1999). Crude protein yields per decare were found by multiplying crude protein ratios in dried matter by dried matter yields per decare.

Acid detergent insoluble fibre (ADF) ratios and Neutral detergent insoluble fibre (NDF) ratios were determined using the Near Infrared Reflectance Spectroscopy (NIRS) as described by Corson et al. (1999). Digestible dry matter was calculated using the formula: DDM = 88.9 - (0.779 × ADF %), Dry matter Intake was calculated using the formula: DMI = 120 / NDF% and Relative feed values were computed using the formula: RFV = (SKM × KMT) / 1.29 (Morrison et al., 2009).

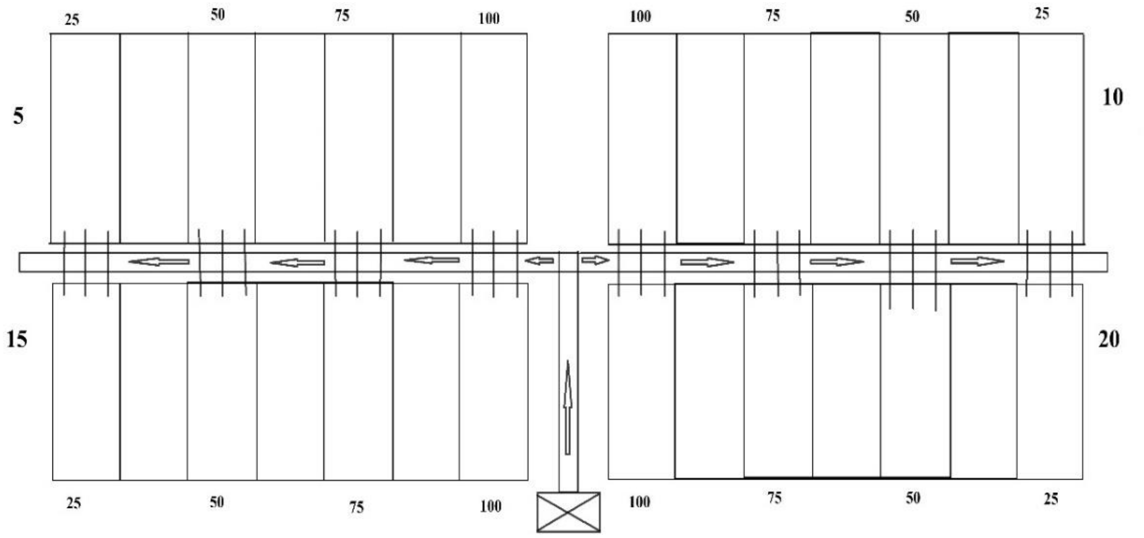

Figure 1. Design of the field experiment. Main plots serving as irrigation frequency and sub-plot serving as irrigation level. The arrow shows the movement of water

The experiment was set up in an RCBD split plot design with 3 replications. The obtained data were analysed with the help of the JMP statistical package program and the differences and similarities were compared with the Tukey test.

Results and Discussion

This aspect of the research presents the results of the field work in a summary and considering other previous studies. Questions raised from the objectives of the study were addressed within the context of the findings of the studies and as much as practically viable, the scientific foundations of the observations were highlighted.

Irrigation frequencies, levels and interactions between various irrigation levels and frequencies yielded significantly different outputs with regards to green herbage yield. Average treatment means were significantly different at $P \leq 0.01$. Highest green forage yield of 3062 kg/da was recoded with 5 days irrigation frequency as compared to the lowest 2281 kg/da for 20 days irrigation interval. For the irrigation levels, 100% irrigation level recorded the highest green herbage yield of 3112 kg/da compared to 2234 kg/da for 25% irrigation level (Table 1). With regards to the interaction between irrigation levels and frequencies, the highest green forage yield was recorded from 100% irrigation at 5 days interval. This was followed by 75% irrigation level at 5-day frequency and 100% irrigation level at 10-day frequency, which are not significantly different at $P \leq 0.01$. A maximum sorghum yield of 3860 kg/da was reported by El-Mageed et al. (2022) at full irrigation over the cropping season. This is more than 400 kg/da compared to what was observed at 100% irrigation with 5 days irrigation frequency. In another study, Atis et al. (2012) reported an average of 6087 kg/da. With lower irrigation level, an average of 2392 kg/da green forage yield was reported by Bhattarai et al. (2020). This report is similar to the average yield observed for 15 days irrigation frequency in this study. At 75% irrigation, the yield in this study surpasses that reported by Bhattarai et al. (2020). As irrigation level increases with increasing irrigation frequency, green forage yield is reported to increase. The evidence in this study agrees with this assertion, considering that observed yields increased significantly above 15 days irrigation frequency.

The results as shown on Table 1 indicated significant difference for dry matter yield in terms of irrigation level, irrigation frequency and the interactions between irrigation levels and frequencies at $P \leq 0.01$.

Just as recorded for green forage yield, 5 day irrigation frequency yielded the highest dry matter of 1067 kg/da with significant difference compared to the other frequencies, and the lowest yield of 821 kg/da was recorded with the 20 days irrigation frequency. With regards to levels of irrigation, 100% irrigation level yielded the highest dry matter yield of 1110 kg/da, which is significantly different from the other irrigation levels. Irrigating at 25% produced the lowest dry matter yield of 674 kg/da, in consistence with the observation in green forage yield. 50% and 75% irrigation levels followed a similar trend, falling between 25% and 100% irrigation levels with significant difference observed between them (Table 1). In terms of the interactions between treatment levels and frequencies, 100% irrigation level for 5 days, 10 days and 75% irrigation level at 5 days irrigation frequency are the highest with no significant difference at $P \leq 0.01$. The lowest dry matter yield was recorded for 25% irrigation level at 20 days irrigation frequency. With the exception of irrigation at 5 days frequency, all the 75% irrigation levels showed similarity in term of dry matter yield. Dry matter yield is a very important yield parameter especially for farmers. It is used to determine most nutrition quality. From the work of Kir and Şahan (2019), a maximum and minimum yield of 2896 kg/da and 878 kg/da, which are higher than the maximum and minimum values of this study (1183 and 448 kg/da respectively), were reported. Another report stated a varied dry matter yield of 2052 kg/da and 744 kg/da maximum and minimum respectively for no water stress and high stress level (Aydinsakir et al., 2021). At 50% ET irrigation, Garofalo and Rinaldi (2013) reported 1800 kg/da dry matter yield.

Table 1. Green forage and dry matter yields as affected by irrigation frequencies and levels

	Green Forage Yield**		Dry Matter Yield**	
	IrrFq (Days)*	IrrLv (% of ET)*	IrrFq (Days)*	IrrLv (% of ET)*
5 days/25%	3062 A	2234 D	1067 A	674 D
10 days /50%	2817 B	2542 C	920 B	878 C
15 days /75%	2454 C	2726 B	858 C	1005 B
20 days /100%	2281 D	3112 A	821 D	1110 A
CV	3.126		6.495	
LSD	69.2		49.6	

* F values for treatments are statistically significant at 1% (P≤0.01); ** F values for treatments interactions are statistically significant at 1% (P≤0.01); Values shown with the same letter(s) are statistically not different from each other according to LSD test within 1% (P≤0.01) error limits.

Table 2. Crude protein ratio and crude protein yield a affected by irrigation frequencies and levels

	Crude Protein Ratio**		Crude Protein Yield**	
	IrrFq (Days)*	IrrLv (% of ET)*	IrrFq (Days)*	IrrLv (% of ET)*
5 days/25%	7.83 A	7.45 A	83.97 A	49.02 D
10 days /50%	7.52 B	6.73 C	62.83 B	59.61 C
15 days /75%	6.76 C	7.40 A	57.51 C	74.71 B
20 days /100%	6.74 D	7.27 B	60.10 BC	81.06 A
CV	3.07		6.90	
LSD	0.18		3.81	

* F values for treatments are statistically significant at 1% (P≤0.01); ** F values for treatments interactions are statistically significant at 1% (P≤0.01); Values shown with the same letter(s) are statistically not different from each other according to LSD test within 1% (P≤0.01) error limits.

Table 3. Forage ADF and NDF as affected by irrigation frequencies and levels

	Acid Detergent Fibre (ADF) **		Neutral Detergent Fibre (NDF)	
	IrrFq (Days)*	IrrLv (% of ET)*	IrrFq (Days)*	IrrLv (% of ET)*
5 days/25%	37.96 A	33.18 C	66.95 A	61.26 C
10 days /50%	33.65 B	34.59 B	61.35 C	62.41 B
15 days /75%	33.94 B	35.32 A	63.17 B	64.57 A
20 days /100%	32.91 C	35.37 A	60.60 C	63.83 A
CV	2.18		2.10	
LSD	0.62		1.11	

* F values for treatments are statistically significant at 1% (P≤0.01); ** F values for treatments interactions are statistically significant at 1% (P≤0.01); Values shown with the same letter(s) are statistically not different from each other according to LSD test within 1% (P≤0.01) error limits.

the yield differences could be attributed to the differences in harvest time. At the booting stage, Lyons et al. (2019) reported 1110 kg/da dry matter yield similar to the yield recorded in this study at 100% irrigation level. Both irrigation level and frequency determine the stress level a crop is subjected to, thus, affect dry matter yield (Garofalo and Rinaldi, 2013; Aydinsakir et al., 2021). The result of this study agrees with that conclusion, observing that, with increasing frequency and level of irrigation, consistent and significant increment of dry matter yield has been recorded.

From Table 2, we observe that significant differences existed for crude protein ratios based on irrigation levels and irrigation frequencies. Furthermore, interaction between levels and frequencies of irrigation produced variation which are significant at P≤0.01.

No significant difference was observed for irrigation levels 25% and 75%. 50% irrigation level however showed a lower crude protein ratio which is significantly different from the other lower irrigation levels. With regards to irrigation frequencies, it can be observed from Table 2 that, 5 days irrigation frequency, recording 7.83% crude protein ratio, is the highest and significantly different from other treatments, followed by 10 days irrigation frequency (P≤0.01). Based on the interactions between levels and frequencies of irrigation, the highest observed crude protein ratio was observed with 25% irrigation level at 20 days frequency followed by 100% at 5 days irrigation frequency (P≤0.01). The lowest crude protein ratio was recorded with 50% irrigation level at 20 days irrigation frequency. Significant differences were recorded in almost all treatment combinations. Kir and Şahan (2019) reported in a cultivar trials, minimum and maximum crude protein ratios (CP) of 7.8 and 10.5%, respectively. The results of this study recorded 5.99 and 9.2% minimum and maximum CP, respectively. At the booting stage, Lyons et al. (2019) reported CP of 12.9 and 7.6% maximum and minimum CP similar to that reported by Kir & Şahan (2019). Moisture and heat stress have been reported to positive affect CP content; increasing stress increases CP content (Pupo et al., 2022). Result from this study however have different response between irrigation level and frequency. While irrigation level agrees with the previous studies, irrigation frequency from this study recorded the opposite. In effect, the result on irrigation frequency from this study agrees with the findings of Bean et al. (2013). The hypothesis behind the assertion of Pupo et al. (2022) is that, with increasing heat and water stress, photosynthetic apparatus tends to synthesize certain proteins to help in the survival of the plant. The BMR possessing varieties may respond differently (Reich, 2005; Sattler et al., 2010). Furthermore, though the differences are significant, what was observed, in terms of level and frequency of irrigation interaction, was about 3% between the highest and the lowest CP content.

As can be observed from Table 2, variations of significant levels have been recorded for crude protein yield for irrigation levels, irrigation frequencies and the interaction between levels and frequencies of irrigation at P≤0.01. The highest crude protein yield was recorded with 100% irrigation level, followed by 75%, 50% and 25% recording 81.06, 74.71, 59.61 and 49.02 kg/da, respectively, all showing significant differences at P≤0.01. No significant difference was observed between 15- and 20-days irrigation frequencies with regards to crude protein yield. The highest crude protein yield was observed with 5 days irrigation frequency followed by 10 days irrigation frequency with significant difference between them. 5 days irrigation frequency at 100% and 75% irrigation levels showed no significant difference, producing the highest crude protein yield with interaction between level and frequency of irrigation at P≤0.01 as can be observed on Table 2. The lowest observed crude protein yield for interaction between irrigation levels and frequencies is recorded with 25% level at 10-, 15- and 20-days irrigation frequencies. Crude protein yield (CPY) is affected positively by DM and CP (Kir and Şahan, 2019). It therefore follows that, increasing levels and frequencies as affected DM will affect CPY. Interestingly, though Gonulal (2020) used similar cultivars as done in this study, far less CPY was recorded in this study. Crude protein is very important in animal nutrition and forage quality and pricing. The highest yield in this study was 97.41 kg/da whereas that reported by Kir and Şahan (2019) and Gonulal (2020) are 280 kg/da and 253 kg/da, respectively. At the booting stage, higher CPY is expected (Ball et al., 2001) compared to the studies above. It thus follows that; some physiological factors are in play which are affected by the irrigation treatments.

Table 3 shows that significant variations were observed in ADF value at P≤0.01 for irrigation levels, frequencies and the interaction between levels and frequencies of irrigation. With regards to irrigation levels, the highest ADF value was observed with the 100% and 75% (35.37 and 35.32%, respectively) without any significant difference between them. The lowest ADF value was recorded by the 25% irrigation treatment which is significantly different compared to all other treatments at P≤0.01. At 5 days irrigation frequency, the highest ADF yield was recorded (37.96%); a value which is significantly different from the other irrigation frequencies at P≤0.01. The lowest observed ADF value was recorded with the 20 days irrigation frequency (32.91%). There exists no significant difference between the 10- and 15-days irrigation frequencies for ADF value at P≤0.01. Irrigating with the 100% level for at 5 days frequency yielded the highest ADF value which is significantly different compared to other treatment at P≤0.01. The three other irrigation levels at 5 days irrigation frequency were not significantly different from each other. At 25% irrigation level for 20 days interval, the lowest ADF value was recorded; a value which is significantly different from all other treatments with regard to ADF value at P≤0.01. At the booting stage, Lyons et al. (2019) reported a maximum ADF of 32.9% falls within 10 days frequency at 25% level and 20 days frequency at 100% level. In the work of Kir and Şahan (2019), a maximum of 37.5% similar to the value recorded in this study with 5 days frequency at 75% level. In an earlier study, Bean et al. (2013) reported 36.7% for non-BMR variety and 26.9% for a BMR variety. With increasing moisture stress, ADF values are expected to increase (Bean et al., 2013), however, the results of this study agrees with the theory which states that, robust growth leads to increase in ADF, which is a structural carbohydrate needed to support stem erection (Diepersloot et al., 2021). The work of Pupo et al. (2022) is in line with this observation. The stress factors in this study have not had any effect on ADF content. This observation can be attributed to the fact that, experimental plants under increasing stress have slow growth rate at the early stage, resulting in less demand for structural carbohydrates. Due to the fact that ADF is a complex of lignin (Bean et al., 2013), which is almost indigestible, lower levels of ADF is required for a higher quality feed to release higher energy levels.

Table 3 shows the NDF value variation for the treatments of irrigation levels, frequencies and their interaction. At P≤0.01, significant difference was recorded for irrigation levels and frequencies, such however cannot be said for the interaction between irrigation levels and frequencies at P≤0.01. At 75% and 100% irrigation levels, the highest NDF values were recorded. These values were significantly different from the other treatments at P≤0.01. The lowest NDF value was recorded with the 25% irrigation level; with 61.26% NDF, irrigating at 25% level is significantly different from the other higher treatments at P≤0.01. Irrigating at 5 days frequency yielded the highest NDF value of 66.95% which is significantly different from the other treatments. Interestingly, the mean NDF values for 10- and 20-days irrigation frequencies show no significant difference at P≤0.01. Irrigating at 15 days frequency yielded the second significantly higher mean value of NDF. NDF value of 57% was reported by Lyons et al. (2019) at the booting stage. This agrees with the report of Kir and Şahan (2019) when their highest reported NDF was 57.5%. These reports are similar to the lowest value recorded in this study. With normal sorghum varieties, increasing moisture stress increases NDF levels. In the BMR varieties however, less stress conditions led to increased NDF levels (Pupo et al., 2022). This conclusion agrees with the observations in this study. Increasing levels of irrigation increased NDF values. However, a mixed result was observed with regards to irrigation frequency in this study. Bulk of a forage fibre is NDF which consequently determines the amount of feed an animal can consume at a time (Bean et al., 2013). Higher NDF generally implies that less energy will be taken by the animal. This can be different with the BMR gene in play (Pupo et al., 2022). As a result, higher NDF values with the BMR variety does not directly result in poor quality feed.

Table 4 shows variations of digestible dry matter (DDM) ratio as affected by irrigation levels and frequencies and their interactions. The averages of DDM ratio are presented with their statistical differences as affected by irrigation levels, frequencies and their interactions. The highest DDM was recorded with 20 days irrigation frequency (63.26%) and the least was recorded with 5 days irrigation frequency (59.33%). 10- and 15-days irrigation frequencies exhibited no significant differences at P≤0.01. With regards to irrigation levels, 25% recorded the highest DDM followed by 50%. No statistical differences were recorded between 75% and 100%. DDMs of 63.06, 61.95, 61.39 and 61.34% were recorded in order of increasing irrigation levels. The interaction of 5 days irrigation frequency at 100% irrigation level yielded the lowest DDM value, which compared to the other interactions is significantly different. The highest DDM value is recorded with the 20 days irrigation frequency at 25% irrigation level. Higher DDMs were observed along lower irrigation levels as well as higher irrigation frequencies. At the highest stress level, this study recorded DDM (65.52%) content similar that reported by Kir and Şahan (2019), the lowest stress levels in this study recorded the lowest DDM (58.63%) which is slightly lower than that reported by Kir and Şahan (2019). These observations were expected following the increasing ADF content with decreasing stress of irrigation. It was established that, ADF is the main variable for determining DDM as presented in the function employed by Morrison et al. (2009). With increasing ADF content, DDM content reduces as ADF is inversely proportional to DDM. This assertion is counter the observation reported by Pupo et al. (2022). The difference in reported results may be attributed to the differences in method of calculating digestibility or digestible dry matter. Pupo et al. (2022) presented their data as a percentage of NDF30h whereas, in this study, the results are presented as a percentage of dry matter. Higher DDM is expected with the BMR trait. This is evident in this study compared with the results recorded by Bean et al. (2013) and Pupo et al. (2022) when the yield of other cultivars was reported.

The variance analysis of dry matter intake (DMI), as affected by irrigation levels and frequencies and their interactions, presented on Table 4 shows significant difference with irrigation levels and irrigation frequencies, however, no significant difference was observed with their interactions at P≤0.01. A decreasing can be observed as irrigation levels increases.

DMI of 1.963, 1.926, 1.861 and 1.886% were recorded in increasing order of irrigation levels. No significant differences were observed with 75% and 100% irrigation levels. Considering irrigation frequencies, the least DMI was recorded when 5 days intervals were applied. 10- and 20-days irrigation frequencies have no significant difference statistically. 15 days irrigation frequency averaged with the second DMI value which is statistically different from other treatments. An average of 2% DMI is expected of good quality forage (Government of South Australia, 2022). This helps to ensure that, the animal fed ration of such quality gains enough energy and nutrients to support maintenance and production. In a study, Aydin et al. (1999) reported 3.7 and 4.2% DMI for the BMR variety. This is higher than that reported in this study. Due to the fact that DMI is affected by NDF content, and that slow development of the plants in this experiment affected the NDF content with increasing moisture stress, the highest DMI was recorded by the treatment with the highest stress values (20 days frequency at 25% irrigation level). Pupo et al. (2022) reported DMI values similar to that reported by Aydin et al. (1999). The observed lower DMI values in this study compared to previous studies may be attributed to the higher values of NDF; as NDF content directly affects DMI according to the formula used by Morrison et al. (2009). Above 50% irrigation levels of this study, approximately 2% DMI was recorded, which agrees with the optimum values published by the Government of South Australia (2022). As such, forage crops produced under this study can be effectively used in the feeding of animals. The exception may be with dairy cattle which require higher DMI values due to their higher energy requirement.

On Table 4, the variance analysis is presented for relative feed value of the sorghum crop as influenced by irrigation levels and frequencies. Independently, irrigation levels and irrigation frequencies treatments varied significantly statistically at P≤0.01. No significant difference was however observed when the interactions between levels and frequencies of irrigation treatments were considered at P≤0.01. From Table 4.18, we observe that RFV increases with decreasing irrigation levels and frequencies. The highest RFV was recorded with 25% irrigation level (96.1), followed by 50% (92.56). Irrigating at 75% and 100% levels averaged in no significant difference at P≤0.01. On irrigation frequency, no significant difference was observed between 10- and 20-days frequencies, which produced the highest RFVs of 95.17 and 97.32 respectively. RFV is about the ultimate parameter used in the evaluation of forage quality. A 100% RFV is the in vitro analysis result of a full-bloom Alfalfa hay; an interaction of DMI and DDM of a given forage (Morrison et al., 2009). Results from this study fall within the third grade of hay quality scale as reported by Cherney and Parsons (2020), which results in it being a degree lower than what was reported by Ball et al. (2001) for forage of similar growth stage. The difference in RFV of this study compared to that reported by Ball et al. (2001) may be attributed to the differences in adaptation of the crops to seasons. Whereas sorghum is a warm season crop, grasses reported by Ball et al. (2001) are cool-season crops.

Table 4. Effects of irrigation frequency and levels on DDM, DMI and their resulting RFV

	Digestible Dry Matter (DDM) Ratio**		Dry Matter Intake (DMI) Ratio		Relative Feed Value (RFV)	
	IrrFq (Days)*	IrrLv (% of ET)*	IrrFq (Days)*	IrrLv (% of ET)*	IrrFq (Days)*	IrrLv (% of ET)*
5 days/25%	59.33 C	63.06 A	1.794 C	1.963 A	82.53 C	96.10 A
10 days /50%	62.68 B	61.95 B	1.958 A	1.926 B	95.17 A	92.56 B
15 days /75%	62.46 B	61.39 C	1.901 B	1.861 C	92.04 B	88.59 C
20 days /100%	63.26 A	61.34 C	1.983 A	1.886 C	97.32 A	89.80 C
CV	0.95		2.14		2.89	
LSD	0.49		0.03		2.22	

* F values for treatments are statistically significant at 1% (P≤0.01); ** F values for treatments interactions are statistically significant at 1% (P≤0.01); Values shown with the same letter(s) are statistically not different from each other according to LSD test within 1% (P≤0.01) error limits.

Furthermore, owning to the fact that ADF and NDF play significant role in determining RFV per the formula applied in its calculation (Morrison et al., 2009), and that this study recorded higher ADF and NDF values with decreasing moisture stress, lower RFV were expected for reducing moisture stress treatment. With the BMR trait, true RFV may be different from what was reported using in vitro methods due to the observation that, BMR varieties have higher digestible NDF as compared to non-BMR varieties (Cherney and Parsons, 2020). Wedig et al. (1987) in an earlier study reported an observation similar to this assertion. Hence, it can be said that forage produced from this study are all of good quality and differentiation for selection may be based on individual parameters rather than RFV.

Conclusion and Recommendation

This study was carried out to answer three fundamental questions; what the most effective irrigation frequency of silage sorghum is; what the optimum irrigation level is; and what the quality of silage sorghum produced under drip irrigation is. Ultimately, the work sort to evaluate the yield characteristics of sorghum silage in response to frequency and levels (amount) of irrigation based on loss due to ET as reported by the neighbouring meteorological station on daily bases. This is to help build adaptive capacity for the changing climate especially for regions of high expected impacts.

The highest yields, both green and dry matter content, were recorded by 100% irrigation level followed by 75% irrigation level on average, with differences of statistical significance. Juxtaposing green-herbage with dry matter content, relatively lower difference was observed. As such, though the highest yields were recorded by the 100% irrigation level, it can be concluded that, the optimum irrigation level demand for silage sorghum is at 75%. With regards to forage quality characteristics, irrigating at 75% recorded a significantly higher CP and similar average results as 100% for ADF, NDF and their derivatives. Generally, irrigation levels affected the yield and quality characteristics of sorghum plants. However, at the lowest stress level, relatively lower forage characteristics were recorded due to increase in ADF and NDF. Further studies may be needed to confirm the DDM at higher irrigation levels since the BMR cultivars are reported to have higher DNDF.

Irrigation has been observed to influence fibre characteristics, protein content and yield, and ultimately the value of forage. Lower irrigation levels resulted in higher forage characteristics based on the method used for computing quality parameters, but with very low yield parameter. Sorghum crop under slight moisture stress yielded a higher forage characteristic with a slight decrease in yield parameters. Interaction between irrigation frequencies and irrigation levels have consistently been observed to yield statistically different outcomes as affected by the treatments.

It is recommended that:

- Future studies in Southeast Anatolia conditions of Turkey including higher amounts of water and nitrogen fertilizer application be conducted to observe the performance of Sorghum under luxurious condition (up to 125% moisture replacement in 5 days). Protein yield per decare was highest under max irrigation (under 100% level and under 5-day intervals). This was probably due to more nitrogen scavenging by roots from deep soil horizons as water penetrated more with high irrigation levels and frequency.
- Sorghum should be subjected to some level of stress in the growth period to allow for build-up of protein content.
- Further studies should be conducted to ascertain the true digestibility of the BMR trait *in vivo*.

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