Interactive effect of irrigation regimes and sowing dates on morpho-physiological response, fodder yield and quality and antinutrient HCN of multi-cut sorghum in the semi-arid region

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Abstract

A two-year field experiment (2016/2017) with three moisture regimes (60 CPE (cumulative pan evaporation), 120 CPE, and no irrigation) and six sowing dates in three replications was conducted to investigate the effect of diffe-rent moisture regimes and sowing dates on multi-cut hybrid fodder sorghum in the semi-arid region. Early sowing and irrigation at 60 CPE had resulted in improved morpho-physiological responses with better fodder quality in terms of higher crude protein, *invitro* dry matter digestibility, and lower crude fiber in both seasons. Early sowing resulted in an increase of green fodder yield (GFY) from 638.7 to 805.4 q/ha in 2016 and from 643.7 to 780.9 q/ha in 2017. Irrigation at 60 CPE showed 46% and 41% increase in GFY over no irrigation. In all three cuts, HCN content was significantly higher in the crop with no irrigation and also in late sown crop (at 2nd and 3rd cuts).HCN decreased drastically by 41% (2016) and 36% (2017) in the crop irrigated at 60 CPE (at 1st cut). Findings suggest that,late sowing of the sorghum affects the fodder yield and quality due to effect on growth parameters and therefore, the adverse effects of decreased precipitation as the result of change in weather conditions can be diminished particularly by sowing early and irrigating at 60 CPE.

Abbreviations

CPE-Cumulative pan evaporation
CF-Crude fiber
CP-Crude protein
DAP-Days after planting
DAS-Days after sowing
d.f.-degree of freedom
DFY-Dry fodder yield
GFY-Green fodder yield
HCN-Hydrogen cyanide
IVDMD-*invitro* dry matter digestibility
LAI-Leaf area index
L:S-leaf to stem ratio
NFE-Nitrogen free extract
N-Nitrogen
RH-Relative humidity
pH-potential of hydrogen (is a scale used to specify the acidity or basicity of an aqueous solution).
WSC-Water soluble carbohydrates

Introduction

Sorghum (*Sorghum bicolor* L. Moench) is a multi-use crop grown for food, feed, and nowadays for bioenergy.Forage sorghum can be used for grazing, as fresh fodder, converted into hay, or for making silage (Pedersen and Fritz, 2000). Sorghum fodder contain about 15% dry matter, 3270 kcal/kg metabolizable energy for poultry, 9.5% crude protein, 2.6 % ether extract, 27 % crude fiber, 9.8% ash and 56.6 % nitrogen-free extract (NFE) (Maunder, 2002). Sorghum grows very fast in warm weather and provides sufficient feed during the lean period in mid-summer. Sorghum grows very well in warm weather and fertile soil, whereas, growth of sorghum is retarded in cool weather and waterlogged soils. Sorghum can be cultivated in numerous environments due to its wider adaptation property and this makes sorghum an important fodder crop in less and irregular rainfall areas (Bibi *et al.*, 2012). When soil moisture is not sufficient, the sorghum plant does not wilt but becomes dormant. Once moisture conditions improve, growth starts again. Compared to other cereals, drought, soil toxicity, and temperature extremes tolerance of sorghum is high.The decline in yield and growth of the plant when exposed to drought or any abiotic stress is a common outcome observed due to limited photosynthesis, photosynthetic assimilates, and energy to the plant. Plants must use this limited supply of nutrients to gain a maximum advantage under stress. Under drought stress conditions, plants should increase the uptake of water, which is usually more available in deep soil (Xiong *et al.*, 2006).

Drought stress effects could be seen in almost all plant developmental stages. The decrease in the availability of water also affects crop production at plant's different growth stages with a general decrease in coleoptile length, higher root to shoot ratio, and longer roots (Khayatnezhad *et al.*, 2010). Water deficit stress has been reported to leave significantly adverse effects on green and dry fodder yield in sorghum (Jabereldar *et al.*, 2017) which might be attributed to decreases in crop growth (Payero *et al.*, 2006), leaf area index (LAI) (NeSmith and Ritchie, 1992) and plant height (Traore *et al.*, 2000). Anti-nutritional factors are the plant components that have the potential to adversely affect farm productivity (Mello, 2000). Leaves and other plant parts used in feeding possess these anti-nutritional components. The quantity of HCN in sorghum varies with cultivar and the growth conditions but diminishes with age. HCN toxicity increased when normal growth is disrupted by any stress. Drought is probably the most common cause of HCN in sorghum (Vough and Cassel, 2000).

Moreover, forage productivity of sorghum along with the type of genotype depends on various other factors that include the timing of outset cutting, interval of cuttings, climatic conditions, the stubble height and frequency of cutting, planting date, mineral nutrition in the soil, plant density,etc (Ramanjaneyulu *et al.*, 2018). The sowing date affects the crop yield and is considered as another factor that plays a role in yield assessment in areas with short growing seasons (Ozturk *et al.*, 2017). Sowing date is probably the most subject to variation because of the very great difference in weather at planting time between season and within the range of climates. Wrong sowing dates can cause critical stages of plant growth and development to coincide with environmental stress that can potentially damage, limit, or terminate plant growth and development (Mokhtarpour, 2011). The proper management of sowing dates influences the crop growth and development and it also shapes the interactions between the growth and stress period with improvement in crop water and nitrogen use efficiencies (Abd El-Lattief, 2011). The interactive effect of sowing time and moisture regimes on forage sorghum productivity and forage quality aspects are still quite unexplored.Therefore, keeping these considerations in view, the present study was formulated to investigate whether sowing date affects growth performance, forage productivity and quality along with hydrocyanic acid antinutrient of sorghum grown under different irrigation regimes in the semi-arid region of Northwest India.

Material and methods

Experimental location, climatic data and soil features

The present study was carried out at Forage Research Farm, Department of Plant Breeding and Genetics, Punjab Agricultural University, Ludhiana during *kharif* seasons of 2016 and 2017. Ludhiana, situated at 30°54'N latitude and 75°48'E longitude with an altitude of 247 meters above the mean sea level, is placed in the central plain region of Punjab under Trans-Gangetic agro-climatic zone of India. It represents sub-tropical and semi-arid climate. The data regarding temperature (maximum, minimum and mean), relative humidity, rainfall, and evaporation for the different cutting are given in Supplementary Table S1.

The soil of the experimental field was loamy sand in texture throughout from 0-30 cm. The average bulk density for the field was 1.59. The experimental fields were low in organic carbon and available nitrogen with medium available phosphorus and potassium status. The soil pH and electrical conductivity values were within the normal range. The physico-mechanical and chemical properties of soil are presented in Supplementary Table S2.

Experimental set-up and crop management

The Sorgum-Sudan Grass Hybrid - Punjab Sudex Chari 4 (PSC-4) was sown in 18 treatment combinations and laid out in a split plot design with three replications. Three moisture regimes (irrigation at 60 CPE (Cumulative Pan Evaporation), irrigation at 120 CPE and no irrigation) were in main plots and six sowing dates (10^{th} April, 20^{th} April, 30^{th} April, 10^{th} May, 20^{th} May and 30^{th} May) were in sub plots. A heavy pre-sowing irrigation (10 cm) was applied to the all treatments by dividing the field in smaller plots with ridges and bunds so as to ensure even distribution of moisture in soil profile in whole of the field and its adequate availability at the time of planting. Plots were given pre sowing irrigation 4 days prior to the respective sowing date and after harvest of each cut. Subsequent irrigations were applied when cumulative pan evaporation (CPE) reached (60 or 120). The details of which are given in Supplementary Table S3. The depth of each irrigation was 7.5 cm and was measured with the help of Parshall flume

(Parshall, 1950).

Sowing was done on scheduled time when field was at field capacity. Sowing was done in rows 30 cm apart with uniform seed rate of 37.5kg per ha in all treatments. Before sowing, seeds were treated with thiomethoxam @ 2ml per kg in both the experiment during both the years for protection against attack of shoot fly to get good plant stand. The uniform basal dose of 20 kg P_2O_5 ha^{-1}in the form of DAP and 100 kg N ha^{-1} in the form of urea (46% N) was applied at the time of sowing and after every cut another dose of nitrogen (100 kg N ha^{-1}) in the form of urea was applied.

Sampling and observations

First cutting was done at 60 days after sowing during both the years. Subsequent cuttings were taken at an interval of 40 days and was harvested thrice (1st, 2nd and 3rd cut) manually. Also, all harvests were clipped manually by mower at a uniform stubble height of approximately 10 cm above the ground.

Morpho-physiological parameters

The plants were carried to laboratory to record the following morpho-physiological responses before drying it in oven.

*Plant height:*Plant height of ten tagged plants in each plot was measured from ground level up to the base of the last fully opened leaf at 30, 45 DAS and at each harvest and expressed as average height.

*Leaf –stem ratio:*The samples were taken at each harvest. The leaves and stem were separated and separate weight of leaves and stem was measured immediately. Leaf-stem ratio was calculated by using the formula:

$$\text{Leaf-stem ratio} = \frac{\text{weight of leaves (green)}}{\text{weight of stem (green)}}$$

*Leaf area index:*Leaf area index (LAI) at each harvest was recorded by using the Sun Scan Canopy Analyzer, Model: Sun Scan type SS1, Manufactured by Delta-T Devices, Cambridge- England.

*Number of tillers per meter row length:*The numbers of tillers was counted from one meter row length in each plot at the time of each cutting.

Fodder yield parameters

Green fodder yield:The crop was harvested for green fodder and yield was recorded at 60 days after sowing (DAS) for 1st cut and at 40 days interval thereafter. The harvested green fodder was weighed plot wise using hanging scale electronic balance and was converted into q ha^{-1}.

*Dry fodder yield:*Dry matter yield was recorded at each cutting. Fresh weight (250 g) of plant samples was taken at the time of cutting and dried in sun and then in the oven at 60 ± 2° C to a constant weight. The dried samples were weighed and expressed as dry matter in q ha^{-1}.

Fodder quality attributes

The difference between fresh and dry weights of representative samples from each plot at 30, 45 DAS and at each harvest were utilized to calculate the moisture percentage by using following formula:

$$\text{Leaf-stem ratio} = \frac{\text{Fresh weight}}{\text{Dry weight}}$$

After the harvest, the plant samples were first sun dried and then dried in hot air oven completely to obtain a constant weight. The dried samples were finely meshed by grounding with Willy grinder and are used for the quality parameters estimation. The mineral matter and crude fiber were estimated by the method as described by A.O.A.C (1990). Among quality traits crude protein (CP), hydrocyanic acid (HCN), *in-vitro* dry matter digestibility (IVDMD) and water-soluble carbohydrates were estimated by the method proposed by Kjeldhal's method (AOAC 1990), Hogg and Ahlgren (1942), Telly and Terry (1963) and Dubois *et al.* (1956), respectively.

Statistical analysis

Data were analyzed using the analysis of variance (ANOVA) and general linear model (GLM) procedure of SAS (SAS 9.3) means of treatment were compared using FPLSD at 5 % levels of significance. The split up of degrees of freedom (d.f.) for different sources of variation in the two experiments are given in Supplementary Table S4.

Results and discussion

Morpho-physiological responses

The plant height and leaf area index (LAI) decreased with a decrease in water availability from 60 CPE to no irrigation and at all three cuts during both seasons (Tables1 and 2). The increase in plant height at 1st cut, when irrigated at 60 CPE, was 16.2% and 81.1% over 120 CPE and no irrigation respectively in 2016. In 2017, the highest plant height was obtained with irrigating crop at 60 CPE which was 21cm (18.8%) and 58.4 cm (78.9%) higher than the crop irrigated at 120 and with no irrigation. Irrigation regimes significantly affected LAI at every stage of the crop during both years except for 2nd cut in 2016. At 1st cut, crop irrigated at 60 CPE recorded 10.8% and 19.4% more LAI compared to crop irrigated at 120 CPE in respective years. The highest L:S ratio and number of tillers were observed in no ir-

Table 1 - Effect of sowing time and irrigation regimes on periodic plant height (cm) of fodder sorghum (DAS-Days after sowing; CPE-Cumulative pan evaporation)

TREATMENTS	30 DAS		45 DAS		60 DAS (1st cut)		100 DAS (2nd cut)		140 DAS (3rd cut)	
	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017
Main plot (Irrigation regimes)										
60 CPE	46.8	40.9	96.5	85.5	147.2	132.4	125.0	100.2	111.2	91.7
120 CPE	32.6	31.6	75.2	71.3	126.7	111.4	113.0	90.4	87.6	84.1
No irrigation	25.0	21.9	65.5	48.3	81.1	74.0	111.6	78.3	78.9	72.0
CD (p=0.05)	3.3	4.0	6.2	5.1	19.4	13.6	10.9	9.1	10.8	11.7
Sub plot (Sowing Dates)										
10th April	21.4	22.0	48.6	47.8	87.9	78.6	134.6	120.3	116.7	97.8
20th April	25.0	23.0	54.9	49.8	97.0	81.3	136.8	120.8	106.8	93.9
30th April	25.4	25.3	62.8	52.4	112.0	93.8	119.1	90.4	98.4	80.1
10th May	32.1	30.1	86.6	71.8	131.0	120.8	111.9	78.0	82.6	74.6
20th May	40.7	36.2	104.2	86.7	138.3	122.7	97.7	67.8	80.0	75.4
30th May	64.1	52.1	117.5	101.8	143.9	138.6	99.1	60.6	70.9	73.8
CD (p=0.05)	3.1	3.0	8.2	6.6	11.9	11.4	11.1	12.1	13.0	11.2
Interaction (I*D)	5.5	NS	14.2	11.4	20.7	19.8	NS	NS	NS	NS

rigation plots during both the years at all stages which was significantly higher over the crop irrigated at 60 and 120 CPE. A perusal of data revealed that tillers per meter row length were not affected by irrigation regimes at 1st cut whereas, significant variation in the number of tillers was obtained during the 2nd and 3rd cut in both years of study. At 1st cut, the highest L:S ratio of 0.50 during 2016 and 0.51 during 2017 were obtained where no irrigation was applied which was 66.7% and 38.8 % higher in 2016 and 59.4% and 37.8% higher in 2017 overirrigation at 60 and 120 CPE, respectively. The corresponding values were 44.4 to 30% and 40.5 to 22.9% at the 2nd and 3rd cut during 2016. A similar trend was also observed in L:S ratio in 2017.

Sowing dates had a significant influence on all morpho-physiological responses (plant height, leaf area index, number of tillers and leaf to stem ratio) of sorghum plant in all three cuts (1st, 2nd, and 3rd cut) in both years (2016 and 2017) except for the number of tillers in both years at 3rd cut (Tables1 and 2). In general, the plant height, leaf area index and the number of tillers were observed to decrease at 2nd and 3rd cut, in contrast, to increase in these morpho-physiological parameters seen at 1st cut when the crop was sown from 10th April to 30th May in both the years of study whereas L:S showed an opposite trend. Plant height, leaf area index, and the number of tillers were slightly higher in 2016 than 2017. Crop sown on 30th May recorded significantly higher plant height over the rest of the treatments at 30 DAS and 45 DAS in both years. At 2nd cut 120 and 130 %, higher LAI was obtained in 10th April sown crop as compared to 30th May sown crop in 2016 and 2017, respectively. The LAI of 10th April sown crop was double than LAI of 30th May at 3rd cut in both years. The crop sown on 30th May produced 35 tillers during 2016 and 36 tillers in 2017 which was at par with 20th May sown crop but were significantly higher than the rest of sowing dates. The crop sown on the 10th of April has been recorded with a significantly higher L:S ratio of 0.60 in 2016 and 0.50 in 2017 at 1st cut over the rest of sowing dates and as compared to the 2nd and 3rd cut.

Interaction between irrigation regimes and sowing dates were noticed to be significant at 30, 45, and 60 DAS during both years except at 30 DAS in 2017 (Supplementary Table S6). At every moisture regime, crop sown on 30th May showed significantly higher plant height at 30 DAS but at 45 DAS, statistically similar plant height was obtained when irrigated at 60 CPE and 120 CPE. Effect of sowing dates on plant height was more pronounced in irrigation at 120 CPE and no irrigation during both years of the study. Crop irrigated at 60 CPE and crop sowed on 20th April was at par in

Table 2 - Effect of sowing time and moisture regimes on leaf area index (LAI), number of tillers and leaf to stem ratio (L:S) of fodder sorghum. (DAS-Days after sowing; CPE-Cumulative pan evaporation).

Treatments	LAI						Number of Tillers						L:S					
	1st cut		2nd cut		3rd cut		1st cut		2nd cut		3rd cut		1st cut		2nd cut		3rd cut	
	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017
Main plot (Irrigation regimes)																		
60 CPE	4.1	3.7	2.5	2.8	3.0	2.3	32.0	33.1	16.2	14.1	13.8	15.8	0.30	0.32	0.36	0.43	0.42	0.53
120 CPE	3.7	3.1	2.2	2.2	2.1	2.0	31.1	32.3	18.4	16.2	14.8	16.9	0.36	0.37	0.40	0.50	0.48	0.55
No irrigation	2.6	2.2	2.1	2.0	1.9	1.9	29.2	30.1	20.0	19.1	15.6	17.6	0.50	0.51	0.52	0.63	0.59	0.65
CD (p=0.05)	0.3	0.2	NS	0.3	0.2	0.3	NS	NS	2.1	2.9	1.0	0.9	0.05	0.05	0.06	0.06	0.07	0.08
Sub plot (Sowing Dates)																		
10th April	2.7	2.3	3.3	3.0	3.2	2.5	28.3	29.0	21.1	19.1	15.9	16.0	0.60	0.50	0.32	0.46	0.31	0.51
20th April	3.1	2.4	2.7	2.8	2.8	2.3	28.1	29.1	20.2	18.2	15.8	17.2	0.41	0.43	0.38	0.49	0.40	0.49
30th April	3.2	2.6	2.3	2.1	2.5	2.2	29.2	30.2	18.1	16.2	15.3	17.3	0.37	0.40	0.41	0.50	0.43	0.58
10th May	3.7	3.3	2.2	1.6	2.0	2.1	32.0	33.0	18.2	16.1	14.6	15.0	0.35	0.37	0.42	0.55	0.55	0.64
20th May	4.0	3.5	1.7	1.3	1.9	1.6	33.0	34.0	16.4	14.3	13.8	17.2	0.32	0.35	0.49	0.56	0.59	0.60
30th May	4.1	3.9	1.5	1.3	1.6	1.5	35.0	36.0	16.1	14.2	13.0	17.8	0.26	0.34	0.55	0.58	0.68	0.64
CD(p=0.05)	0.4	0.4	0.2	0.3	0.3	0.3	3.0	3.0	3.0	2.1	NS	NS	0.07	0.05	0.05	0.06	0.06	0.51
Interaction (I*D)	0.7	0.6	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	0.12	NS	0.08	NS	0.10	0.08

plant height (at 1st cut) over rest of the sowing dates whereas, crop sown on 10th May and onward resulted in statistically similar plant height when irrigated at 120 CPE and when no irrigation was applied. In 2017, the interaction was not significant at 30 DAS. Crop sown on 30th May recorded statistically similar plant height at every moisture regime at 45 DAS whereas, at 1st cut, crop sown on 30th May recorded significantly higher plant height when irrigated at 60 CPE than rest of the treatments. The significant interaction between sowing times and moisture regimes on the leaf area index was noticed only at 1st cut in both years (Table 2). The interactive effect of sowing dates and irrigation on the leaf stem ratio was significant at all stages during 2016, but in 2017, it was significant only at 3rd cut whereas the non-significant interaction was recorded of irrigation regimes and sowing dates on the number of tillers in both year of study in all three cuts (Table 2).

To have a potential fodder yield it is important to select optimal planting dates that will assure the right synchronization in plant growth and required suitable weather conditions during its developmental stages (Sim *et al.*, 2015). The increase was seen in plant height, leaf area index, and the number of tillers morpho-physiological parameters with delayed sowing (Table 1 and 2) and was mainly attributed to the optimum environmental conditions (air temperature, rainfall, relative humidity, solar radiation and evaporation) due to optimum sowing date (Supplementary Table S1). Under optimum planting date, these climatic conditions play crucial role in improving the growth of plants through the increase of active photosynthetic radiation helping in rapid seed germination and healthy growth, ultimately increasing accumulation of dry matter. Earlier sowing dates coincide with high temperature and low humidity with a negligible amount of rainfall at 1st cut that resulted in lower plant height, LAI and the number of tillers. High rainfall and RH, low temperature at 2nd and 3rd cut resulted in the taller plant which is required for better fodder yield in multi-cut crops indicating early sowing at around 10th to 20th April would prove beneficial. These findings are contradictory to those reported by Dhaliwal (1974) that crop sown on 25th May produce the tallest plant under Punjab conditions and this might be due to changing weather conditions over time. Moreover, as plant height increased, the proportion of stem in the whole plant becomes comparatively higher than leaves; as the number of nodes and numbers of lea-

Table 3 - Effect of sowing times and irrigation regimes on green fodder yield (q/ha) (GFY) and dry fodder yield (q/ha) (DFY) of fodder sorghum. (CPE-Cumulative pan evaporation).

Treatments	GFY								DFY							
	1^{st} cut		2^{nd} cut		3^{rd} cut		Total yield		1^{st} cut		2^{nd} cut		3^{rd} cut		Total yield	
	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017
Main plot (Irrigation regimes)																
60 CPE	416.9	406.2	268.4	252.9	154.6	166.2	839.6	825.3	68.1	77.9	47.3	40.6	25.8	27.4	141.2	145.8
120 CPE	348.0	336.5	236.7	224.6	131.1	145.0	724.8	706.2	67.7	76.9	42.6	45.6	25.9	30.1	133.4	152.6
No irrigation	245.5	236.3	231.3	219.2	115.8	130.1	574.9	585.7	48.5	56.2	43.9	46.1	23.7	28.1	109.4	130.4
CD (p=0.05)	42.9	39.9	28.7	24.9	26.0	10.4	31.8	55.0	9.2	8.4	NS	NS	NS	NS	13.2	7.7
Sub plot (Sowing Dates)																
10^{th} April	270.4	259.4	357.8	341.2	179.4	180.2	805.4	780.9	55.8	63.4	67.7	67.1	28.7	36.6	152.3	167.0
20^{th} April	290.9	280.9	332.5	323.9	163.3	168.0	771.7	772.8	55.9	62.7	62.7	58.0	31.6	33.8	150.1	154.4
30^{th} April	329.2	321.3	235.4	222.1	137.4	148.6	690.1	692.0	64.6	73.4	39.6	39.3	25.3	27.2	129.6	140.0
10^{th} May	360.7	350.3	226.3	214.8	120.0	136.9	714.3	702.1	65.9	73.7	44.0	44.4	25.6	25.4	135.5	143.5
20^{th} May	376.8	365.2	167.6	149.6	108.8	128.0	658.2	642.9	64.5	76.1	28.0	27.9	21.3	24.7	113.9	128.8
30^{th} May	392.8	380.8	153.1	142.0	94.0	120.9	638.7	643.7	61.7	72.8	25.9	27.7	18.4	23.4	105.9	124.0
CD(p=0.05)	41.2	27.3	26.5	26.3	10	14.4	48.1	40.9	7.8	5.3	4.5	5.5	3.2	4.4	12.1	7.7
Interaction (I*D)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

ves along the main stem usually remains same and leaf -stem ratio decreased with increased in plant height thereby, justifying the observed decreased in leaf stem ratio.

The irrigation water is one of the vital factors that influence fodder crop growth, its yield as well as its nutrition (Mohfouz *et al.*, 2020). Water is a constituent of protoplasm which helps in maintaining cell turgor pressure and by encouraging the cell elongation, increases the stem internodal length hence produced taller plants and broader leaves which resulted in higher LAI in frequently irrigated plots in the present study (Table 1 and 2). The results are concurrent with those stated by Abbas *et al.* (2017). At all moisture regimes, plant height increased, however, the extent of increase was higher in frequently irrigated plots than water deficit plot. Moreover, fodder possessing wider leaf–stem ratio is more succulent, palatable, and nutritive (Smart, 1998). In the present investigation, L:S of sorghum fodder increased with the increase in water stress (Table 2) and is supported by the findings of Xiao *et al.* (2015) and Li and Su (2017). This might be due to stunted growth that resulted in stem length reduction along with delay in the maturity of sorghum plants that faced water-limited conditions.

Yields

The green fodder yield (GFY) during 2016 was slightly higher than 2017 in 1^{st} and 2nd cut and the reverse was seen in 3^{rd} cut (Table 3). On the other hand, the higher dry fodder yield (DFY) was observed in 2017 as compared to 2016 at all three cuts, whereas, higher DFY was obtained in 2^{nd} cut in 2016 compared to 2017. Fodder green and dry matter yield at three cuts were significantly affected by different irrigation regimes (Table 3). At 1^{st} cut, more pronounced green and dry fodder yield were recorded when irrigated at 60 CPE followed by 120 CPE over no irrigation regime in both years. The crop irrigated at 60 CPE yielded 19.7 % and 20.7 % higher GFY than crop irrigated at 120 CPE and 69.8 % and 71.9 % higher than no irrigated crop in 2016 and 2017, respectively. In the 1^{st} cut, crop irrigated at 60 CPE gave significantly higher DFY of 68.1 q/ha and 77.9 q/ha during both years of study over no irrigation and was at par with crop irrigated at 120 CPE. At both the 2^{nd} and 3^{rd} cut, crop irrigated at 60 CPE recorded significantly higher GFY over no irrigation in 2016 and 2017.

Table 4 - Effect of sowing time on crude protein (%) (CP) and mineral matter (%) of fodder sorghum under different moisture regimes. (DAS-Days after sowing; CPE-Cumulative pan evaporation).

	Crude Protein										Mineral Matter									
	30 DAS		45 DAS		1st cut		2nd cut		3rd cut		30 DAS		45 DAS		1st cut		2nd cut		3rd cut	
	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017
Main plot (Irrigation regimes)																				
60 CPE	14.5	13.7	14.5	13.8	13.1	12.3	10.5	9.7	10.8	10.0	10.7	9.0	9.5	7.9	8.8	7.6	7.8	7.5	8.1	7.2
120 CPE	13.7	12.8	13.4	12.7	12.4	11.6	9.5	8.9	10.8	9.9	9.9	8.2	9.1	7.5	8.6	7.4	7.7	7.1	8.0	7.1
No irrigation	12.3	11.6	12.8	12.3	11.2	10.5	9.3	8.5	9.8	8.9	9.5	7.6	8.7	7.1	7.9	6.7	7.5	6.9	7.7	6.8
CD (p=0.05)	0.3	0.9	1.1	0.6	0.7	0.7	0.7	0.7	0.4	0.4	0.7	0.6	0.5	0.5	0.6	0.6	NS	NS	0.2	0.3
Sub plot (Sowing Dates)																				
10th April	12.1	11.4	10.8	9.9	11.2	10.3	9.7	8.9	11.0	10.2	9.9	8.1	9.0	7.4	8.1	6.8	8.3	8.1	8.4	7.5
20th April	12.2	11.4	12.9	11.8	11.8	10.6	9.5	8.7	11.1	10.3	10.2	8.3	8.9	7.3	8.4	7.1	7.6	7.5	7.7	6.8
30th April	12.4	11.6	13.5	13.0	12.7	11.5	10.3	9.6	10.4	9.6	10.0	8.3	8.8	7.2	8.2	7.0	7.7	7.4	8.0	7.1
10th May	13.1	12.3	13.4	13.8	13.1	11.3	10.0	9.5	10.3	9.5	10.1	8.0	9.1	7.5	8.4	7.2	7.8	7.6	7.9	7.0
20th May	15.4	14.5	15.3	14.6	13.7	12.5	9.5	8.7	10.0	9.2	9.9	8.6	9.2	7.6	8.7	7.4	7.3	7.2	7.7	6.8
30th May	15.9	15.1	15.5	14.6	14.0	12.6	9.5	8.7	9.9	9.1	10.0	8.3	9.7	8.1	8.9	7.6	7.3	7.0	8.0	7.1
CD (p=0.05)	1.5	1.0	1.3	1.2	1.2	1.0	NS	NS	0.9	0.9	NS	NS	0.5	0.5	0.4	0.4	0.4	0.1	NS	NS
Interaction (I*D)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Both the green and dry fodder yields increased with delay in sowing at 1st cut, whereas, higher fodder yields were obtained in early sowing at 2nd and 3rd cut (Table 3). The higher GFY of 1st cut (392.8 q/ha in 2016 and 380.8 q/ha in 2017) was observed in 30th May sown crop whereas, in the 2nd and 3rd cut, significantly higher GFY was obtained in 10th April sown crop. Similarly, at 1st cut highest DFY was obtained in 10th May (65.9 q/ha) sown crop in 2016, whereas, 20th May sown crop produced significantly higher DFY (76.1 q/ha) in 2017. In 2nd cut, 10th April sown crop recorded significantly higher DFY (67.7 q/ha in 2016 and 67.1 q/ha in 2017) over rest of the sowing dates during both the years and at 3rd cut, 20th April and 10th April sown crop showed highest DFY of 31.6 q/ha and 33.6 q/ha in 2016 and 2017, respectively.

The magnitude of increase in total GFY at 60 CPE was 15.8 % and 46% during 2016 and 16.8 % and 40.9 % during 2017 over 120 CPE and no irrigation, respectively. The crop sown on 10th April recorded 26.1% higher total green fodder yield over 30th May sown crop during 2016 and 21.3% higher total green fodder yield over 30th May sown crop during 2017. Similarly, crop irrigated at 60 CPE gave significantly higher DFY (141.2 q/ha) over no irrigation in 2016 however, the significantly higher DFY was obtained when the crop was irrigated at 120 CPE (152.6 q/ha) over no irrigation (130.4 q/ha) in 2017. The significantly higher total DFY of 152.3 q/ha and 167.0 q/ha in two consecutive years were obtained when the crop was sown on 10th April. In dry and fresh fodder yield, the interactive effect of sowing dates and irrigation was found to be non-significant at all cuts and in total yields during both years of study. The lesser availability of water in early sowing might be the reason for the clear decline in GFY in the present study (Table 3). Whereas high available soil moisture, reduction in extreme temperature, less evaporation due to high humidity at 2nd and 3rd cuts in early sown crop (10th April) produced taller plant (Table 1), higher LAI (Table 2) and more tiller (Table 2), which leads to high total GFY and this might be due to reason that growth of delayed sown crop might get retarded due to reduction in temperature when 2nd and 3rd cuts were taken from the crop sown on 30th May, thereby, giving an advantage of having 3rd cut from hybrid fodder sorghum when sown early compared to sown on 30th May. In the present investigation, the higher total dry matter yield from three cuts with early sowing (10th to 20th

Table 5 - Effect of sowing time on crude fiber content (%) and in vitro Dry Matter Digestibility (%) (IVDMD) of fodder sorghum under different moistureregimes. (DAS-Days after sowing; CPE-Cumulative pan evaporation).

Treatments	30 DAS		45 DAS		1st cut		2n^{d} cut		3rd cut		30 DAS		45 DAS		1st cut		2nd cut		3rd cut	
	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017
Main plot (Irrigation regimes)																				
60 CPE	20.4	23.4	21.8	24.1	22.3	24.3	23.7	25.2	24.7	25.6	67.7	66.3	66.4	65.3	64.4	63.0	67.9	66.4	62.9	61.5
120 CPE	22.5	25.9	24.0	26.5	25.8	27.8	25.7	27.4	26.8	27.8	65.3	63.9	63.5	62.0	61.5	60.1	65.9	64.5	61.0	59.2
No irrigation	25.7	28.3	26.7	29.9	29.7	31.7	26.4	29.2	29.4	30.4	58.2	56.8	56.1	55.0	55.3	53.9	58.1	56.7	57.0	55.6
CD (p=0.05)	0.84	1.2	0.7	1.6	2.3	1.8	1.2	1.8	1.5	2.0	4.1	3.2	2.4	3.8	3.9	3.3	2.3	2.5	2.6	3.4
Sub plot (Sowing Dates)																				
10th April	25.1	28.0	25.8	28.9	28.2	30.0	23.0	25.8	25.0	26.1	62.5	61.0	59.4	58.2	57.6	56.2	64.3	62.9	61.8	60.3
20th April	23.7	27.1	24.9	27.5	27.0	29.1	23.6	26.1	26.1	27.4	63.2	61.8	60.4	59.0	58.4	57.0	64.4	63.0	62.5	61.1
30th April	22.0	26.0	24.1	26.8	26.2	28.4	23.3	26.9	27.2	28.3	63.7	62.3	60.8	59.4	59.3	58.0	63.9	62.5	62.2	60.7
10th May	22.2	25.7	23.8	26.2	25.8	27.8	24.2	27.5	27.8	28.1	63.9	62.5	62.7	61.0	60.9	59.5	63.5	62.1	58.4	57.0
20th May	22.1	24.7	23.5	26.0	24.5	26.5	26.5	28.6	27.8	29.0	64.3	62.9	63.2	62.7	62.8	61.3	63.2	61.8	57.2	55.7
30th May	21.8	23.8	23.0	25.6	23.8	25.8	27.1	28.6	27.8	28.9	64.9	63.5	65.4	64.3	63.6	62.1	62.5	61.0	57.2	55.7
CD (p=0.05)	1.8	1.9	1.4	1.5	2.6	2.8	2.2	1.4	1.7	1.9	NS	NS	3.8	3.8	3.3	2.8	NS	NS	3.5	3.4
Interaction (I*D)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

April) as compared to late sowing might be due to high moisture content due to more rainfall at the time when 2nd and 3rd cuts were taken (Supplementary Table S1 and Table 3) which facilitated better nutrient uptake by roots (Kramer and Boyer, 1995). In several studies, an increase in fodder sorghum dry matter yield has been associated with higher irrigation (Vasilakoglou *et al.*, 2011; Jahanzad *et al.*, 2013).

Fodder Quality attributes

Crop irrigated at 60 and 120 CPE, recorded significantly higher moisture content at all growth stages over no irrigated crop except at 30 DAS during both seasons (Supplementary Table S5). Crop sown on 30th May recorded in significantly higher moisture content up to 1st cut during both years. Moisture regimes and sowing dates resulted significant decline in crude protein (CP) with age up to 2nd cut during both years (Table 4). At 30 DAS, CP content ranged between 12.3 to 14.5% during 2016 and 11.6 to 13.7% during 2017, which declined to 11.2 to 13.1% during 2016 and 10.5 to 12.5% during 2017 at 1st cut. At the 3rd cut, the higher CP content was obtained in the early sown crop. Highest CP content was observed in the 20th April sown crop which was significantly higher over 20th and 30th May sown crop during both years but was at par with the rest of the sowing dates. At 30 and 45 DAS, crop irrigated at 60 CPE recorded significantly higher CP over 120 CPE and no irrigation treatments whereas, at 1st cut the higher CP content of 13.1% in 2016 and 12.3% in 2017 was obtained in crop irrigated at 60 CPE which was significantly higher over other irrigation regimes. A similar trend in CP content was also observed at the 2nd and 3rd cut. The moisture regime impacted the mineral matter at all stages (except at 1st cut) during both the years and the increase of mineral matter was recorded as irrigation frequency was increased. The mineral matter was affected significantly with different sowing dates except at 30 DAS and 3rd cut (Table 4). Mineral matter increased with delay in sowing up to 1st cut whereas, the highest mineral matter was noticed in the 10th April sown crop in the 2nd and 3rd cut. At 45 DAS and 1st cut, 30th May sown crop produced significantly higher mineral matter whereas, at the 2nd cut, the significantly higher mineral matter was observed in the 10th April sown crop.The proteins are most important as they are essential for supplying the amino acids to the animals for the production of their body protein and CP content was more in younger plants and reduced as the

Table 6 - Effect of sowing time on mineral matter (%) and water-soluble carbohydrates (%) and HCN (ppm) of fodder sorghum under differentmoistureregimes. (DAS-Days after sowing; CPE-Cumulative pan evaporation).

Treatments	Water soluble carbohydrates										HCN									
	30 DAS		45 DAS		1st cut		2nd cut		3rd cut		30 DAS		45 DAS		1st cut		2nd cut		3rd cut	
	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017
Main plot (Irrigation regimes)																				
60 CPE	10.3	11.5	10.9	12.0	11.0	12.3	11.0	12.2	10.6	11.8	73	85	59	71	49	65	76	88	77	80
120 CPE	11.9	12.7	12.5	13.6	12.1	13.4	11.3	12.6	11.4	12.7	102	114	82	92	69	83	84	95	98	102
No irrigation	12.3	13.8	13.2	14.2	13.2	14.5	11.8	13.1	11.8	13.0	127	138	89	101	83	101	96	101	106	116
CD (p=0.05)	1.2	0.9	0.8	0.9	0.89	0.9	NS	NS	NS	NS	4	3	6	6	4	4	5	5	5	6
Sub plot (Sowing Dates)																				
10th April	12.6	13.6	13.1	14.2	13.1	14.3	12.8	14.0	10.8	12.1	124	136	108	120	91	105	73	85	85	86
20th April	11.8	13.2	12.6	13.7	12.7	14.0	11.6	12.9	10.8	12.0	110	121	96	108	85	98	78	86	89	91
30th April	11.3	12.6	12.1	13.2	12.1	13.4	10.7	11.9	10.7	11.9	104	116	86	97	67	81	79	86	88	100
10th May	11.4	12.6	12.0	13.1	12.0	13.2	10.8	12.0	11.2	12.5	100	110	76	86	64	77	83	91	91	98
20th May	11.0	12.2	11.9	13.0	11.6	12.9	11.4	12.7	11.6	12.9	84	96	52	64	48	60	92	98	101	106
30th May	11.0	11.8	11.4	12.5	11.2	12.5	11.0	12.3	12.5	13.7	83	95	42	53	45	59	104	118	108	116
CD (p=0.05)	1.0	0.9	1.0	1.0	1.1	1.1	NS	NS	0.9	0.9	9	11	8	9	9	9	8	8	7	9
Interaction (I*D)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	14	NS	15	15	14	13	NS	NS

plant grew older because of more accumulation of dry matter and increased fiber content (Table 3, 4 and 5). The higher CP content under frequently irrigated condition during both the years might be due to the reason that favorable soil moisture enhanced transpiration which ultimately increased the uptake of original and applied nitrogen. Moreover, higher activity of nitrate reductase under higher levels of irrigation helped in the conversion of nitrate form of nitrogen into amino acids led to high CP (Carmi *et al.*, 2006).

The perusal of data revealed the opposite trend between CF and IVDMD with the advancement in stage up to 1st cut. In this study, plots having a better water status (60 CPE and 120 CPE) had less CF than plots with water deficit during both the years. Crop irrigated at 60 recorded significantly higher IVDMD of 67.7% (30 DAS), 66.4% (45 DAS), 64.4% (1st cut), 67.9% (2nd cut), 62.9% (3rd cut) and 66.3% (30 DAS), 54.3% (45 DAS), 63.0% (1st cut), 66.4% (2nd cut), 61.5% (3rd cut) over no irrigation at all the stages of crop during 2016 and 2017, respectively but differences between 60 and 120 CPE were not significant. Planting date significantly affected both crude fiber (CF) and in vitro dry matter digestibility (IVDMD) fodder quality indices of sorghum plant throughout the growth of the plant (30DAS to 1st cut, and at 3rd cut) in both years (Table 5). The crude fiber content was found to decrease with delay in sowing i.e. higher CF was seen on 10th April at 30 DAS (25.1% in 2016 and 28.0% in 2017), 45 DAS (25.8% in 2016 and 28.9% in 2017) and 1st cut (28.2% in 2016 and 30.0% in 2017) but the trend was reversed in 2nd and 3rd cut *i.e.* higher value was noted on 30th May. On the other hand, IVDMD increased with delay in sowing up to 1st cut whereas, the highest IVDMD was observed in the early sown crop at 3rd cut.

For higher forage intake and for the increase in forage digestibility, a lower fiber concentration is vital. The higher crude fiber contents under water deficit condition and at 1st cut in early sown crop (Table 5) were supported by Liu *et al.* (2018). Thus, it might be postulated that exposure to drought, such as the treatment applied in this study, challenges plants to alter their cell wall structure and hemicelluloses cross-link to lignin and cellulosic fibers contributing to the rigidity of cell walls (Le Gall *et al.*, 2015). In drought treated plants, these increase hemicelluloses contribute towards upholding of their structural rigidity and not let them compromise on cell wall plasticity (Tenhaken, 2015). Further, lower

IVDMD under no irrigation treatment shows a negative correlation with crude fiber content (Table 5) and ultimately lower digestibility. The 1st cut of 30th May sown crop i.e. delayed sowing and 2nd and 3rd cuts of 10th to 20th April sown crop results in better digestibility due to lesser crude fiber content which might be due to better nitrogen uptake under well-moistened soil which is the constituent of amino acids and protein and it might also lead to decreased the pectin, cellulose and hemicellulose content which are major constituents of fiber and which thereby, showed an increase in IVDMD.

Water-soluble carbohydrates (WSC)were significantly affected by irrigation and sowing times (Table 6). Nevertheless, in response to irrigation regimes, WSC followed a different trend than other forage quality parameters did. Among irrigation regimes, crop cultivated under no irrigation conditions had a higher concentration of WSC while lower concentration was observed in crop irrigated at 60 CPE at all the stages of growth but the differences between irrigation regimes were not significant at 2nd and 3rd cut. Except at 2nd cut, WSC was significantly influenced by sowing dates at all stages during both the years. The crop sown on 10th April recorded highest WSC which decreased with delay in sowing up to 2nd cut, whereas, the trend was reversed in 3rd cut and the highest WSC content was noticed on 30th May sown crop. The interaction effect between irrigation regimes and sowing dates in almost all of the forage quality aspects was entailed non-significant. In this study, plots having better water status had more mineral matter which might be due to an increased rate of uptake of minerals by plants in optimum soil moisture which resulted in a higher content of ash (Table 4). Results conform with those obtained by Saini and Tiwana (2013). Mineral matter is essential for the bone formation of the animal body and milk production. Early sowing at 1st cut had more water-soluble carbohydrates (WSC) which might be due to the reason that sugars accumulate in the sugar pool of sorghum plants subjected to moisture stress as cellular growth was reduced compared to late sown (30th May) (Table 6). A high WSC concentration in plants would result in a higher osmotic potential, which drives the uptake of soil water and is therefore of importance to minimize drought stress effects in sorghum (Jahanzad *et al.*, 2013).

Anti-nutrient HCN

The highest HCN content was noticed in no irrigation plots which decreased significantly with increased frequency of irrigation and with the advancement in age up to the 1st cut but values of HCN were within the permissible limit of 200 ppm (Table 6). At 1st cut, HCN content was highest (83 ppm) in no irrigation crop and decreased drastically to 49 ppm in 2016 and 65 ppm in 2017 when the crop was irrigated at 60 CPE. Crop irrigated at 60 and 120 CPE recorded 40.9 and 18.1% less HCN in 2016 and 35.6 and 17.8% less HCN in 2017 over no irrigation. A similar trend was observed in the 2nd and 3rd cut. HCN content was highest at 30 DAS and decreased rapidly with the advancement of crop age up to 1st cut (Table 6) and at 2nd and 3rd cut higher HCN values were noticed. The HCN content decreased drastically with delay in sowing up to 1st cut. The early sown crop recorded significantly higher HCN content at 30 DAS, 45 DAS, and at 1st cut whereas increased in HCN was noticed with delay in sowing at 2nd and 3rd cuts over rest of sowing dates. At 45 DAS, Interaction between irrigation regimes and sowing dates were significant during 2016 at the 1st and 2nd cuts (Supplementary Table S7). At 1st cut, the highest HCN content was noticed in the 10th April sown crop irrigated at 120 CPE and no irrigation during both the years.

Less plant height (Table 1) and higher leaf-stem ratio (Table 2) in the stressed plant (no irrigation treatment) and early sown crop caused proportional increase in weight of plant parts that contain high HCN (*i.e.* leaves) (Table 6) (Gleadow *et al.*, 2016). The HCN concentration at 1st cut in the early sown crop was higher as the growth of early sown crop was limited due to environmental factors but HCN was concentrated in a small permissible amount in plant leaf tissues. HCN is toxic, and yet plants that generate HCN are an important source of green fodder for animals. The low HCN in sorghum under frequent irrigation is consistent with studies in other cyanogenic species (Gleadow and Woodrow, 2002; Vandegeer *et al.*, 2013). However, in C4 plants under water stress, there is relatively limited capacity for photosynthesis to have an alternative electron sink that could result in reactive oxygen species (ROS) production (Ghannoun, 2009), there dhurrin i.e. HCN synthesis and turnover may prove an alternative mechanism for mitigating ROS stress (Gleadow and Moller, 2014). Increased HCN content of sorghum with moisture stress has been reported in some of the previous studies (Saini and Tiwana, 2013; Gleadow *et al.*, 2016).

Conclusions

Before sowing, it is necessary to know crop yield responses to sowing dates and water stress. Selection of the suitable planting time ensures providing an optimal climate condition for the crop in each stage to endure water stress conditions via vigorous growth. When the data of all three cuts were scrutinized, results showed that plant growth parameters, green fodder yield and dry fodder yield, moisture content, crude fiber, CP, mineral matter, and water-soluble carbohydrates improved with early planting date but become limited when planting date was delayed of multi-cut hybrid sorghum. Furthermore, exposure of sorghum plants to drought stress exhibited decreases in morpho-physiological responses and moisture content, CP and green yield, however, showed increases in leaf stem ratio, dry matter yield, crude fiber, and HCN in both years. The delayed sowing (30th May) recorded significantly higher HCN content as when compared to early sowing at the 2nd and 3rd cut. Thus, it can be concluded based on the results of the current investigation that sowing of multi-cut hybrid sorghum from 10th to 20th April and irrigated the crop at 60 CPE ensures higher green fodder yield due to better morpho-physiological attributes with good quality and less HCN content under existing semi-arid climatic conditions.Therefore, findings suggest thatfurther research should be done on sowing date of sorghum under different environmental conditions.

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Table S1 - Average temperature (max, min, mean), relative humidity (RH), rainfall, and evaporation during different sowing dates in 2016 and 2017.

	Year											
	2016						2017					
	Temperature (0C)			RH (%)	Rain fall (mm)	Evaporation (mm)	Temperature (0C)			RH (%)	Rain fall (mm)	Evaporation (mm)
	Max.	Min.	Mean				Max.	Min.	Mean			
1st cut												
10th April	39.2	23.0	31.1	35.1	28.2	559.1	39.0	23.5	31.3	37.8	40.2	513.1
20th April	39.6	24.5	32.1	38.8	29.4	583.3	38.7	24.9	31.8	39.7	71.2	509.1
30th April	39.6	26.2	32.9	45.7	51.0	560.9	38.2	25.6	31.9	43.2	82.0	487.1
10th May	38.7	27.0	32.9	51.8	249.8	508.5	37.4	26.2	31.8	49.9	198.8	460.9
20th May	37.5	27.5	32.5	57.7	302.4	453.9	36.6	26.5	31.6	55.4	208.6	425.3
30th May	36.5	27.8	32.1	62.5	326.5	404.6	35.9	26.7	31.3	60.3	261.0	379.8
2nd cut												
10th April	36.4	28.2	32.3	63.0	281.8	277.9	35.6	26.7	31.1	61	177	261
20th April	35.0	27.9	31.5	70.4	323.3	213.4	34.7	27.3	31	67	208.4	235.8
30th April	34.0	27.5	30.8	73.0	366.7	199.3	34.1	27.4	30.8	71.3	209.6	219.6
10th May	33.6	27.3	30.5	73.9	177.5	197.7	34.3	27.7	31.8	71.7	92.8	212.0
20th May	33.4	26.8	30.1	75.0	191.3	185.2	34.0	27	30.7	73.1	109.6	196.4
30th May	33.2	26.2	29.7	75.3	152.6	176.5	33.5	26.6	30.1	75.1	149.6	184.4
3rd cut												
10th April	33.3	26.6	29.9	75.6	197.3	202.2	33.9	27.2	30.6	73.1	126.4	219.2
20th April	33.3	26.2	29.8	74.8	152.6	205.0	33.6	26.5	30	74.7	149.6	207.7
30th April	33.6	25.8	29.7	73.9	89.0	196.8	33.9	25.7	29.8	73.0	129	203.1
10th May	33.6	25.4	29.5	73.0	89.6	192.7	33.7	24.7	29.2	72.3	136.4	192.9
20th May	33.8	25.0	29.4	71.5	21.0	185.3	33.9	23.6	28.7	70.0	154.4	238.3
30th May	33.8	23.4	28.6	67.8	15.0	184.5	34.3	22.1	28.2	66.8	7.4	189.6

Table S2 - Soil physical-mechanical and chemical properties of field under experiment.

Physical-mechanical properties

Soil depth (cm)	Sand (%)		Silt (%)		Clay (%)		Textural class	Bulk density (g cm-3)	
	2016	2017	2016	2017	2016	2017		2016	2017
0-15	78.0	76.0	12.7	11.6	9.3	12.4	Loamy sand	1.57	1.60
15-30	80.3	79.2	11.1	12.0	8.6	9.7	Loamy sand	1.60	1.62

Chemical properties

Characters	Soil depth (cm)				Rating
	0-15		15-30		
	2016	2017	2016	2017	
pH	8.4	8.3	8.3	8.3	Normal
EC (dSm-1) at 25°C	0.13	0.14	0.17	0.18	Normal
Organic carbon (%)	0.38	0.36	0.33	0.34	Low
Available nutrient (kg ha^{-1})					
N	174.6	170.2	158.8	154.2	Low
P	19.8	18.2	19.0	17.2	Medium
K	147.6	140.2	140.8	13	Medium

Table S3 - Number of irrigations for different irrigation regimes in each sowing dates during 2016 and 2017.

Treatment	No. and date of irrigation in 2016				No. and date of irrigation in 2017			
	1st cut	2nd cut	3rd cut	Total	1st cut	2nd cut	3rd cut	Total
I_1D_1	7	2	1	10	7	3	3	13
I_1D_2	7	1	2	10	6	2	1	9
I_1D_3	7	0	1	8	6	1	2	9
I_1D_4	6	0	2	8	4	2	1	7
I_1D_5	4	1	3	8	2	1	2	5
I_1D_6	2	1	3	6	2	2	3	7
I_2D_1	3	1	0	4	3	1	1	4
I_2D_2	4	0	0	4	2	0	1	3
I_2D_3	3	0	0	3	2	0	0	2
I_2D_4	3	0	1	4	2	0	0	2
I_2D_5	2	0	1	3	1	0	1	2
I_2D_6	1	0	2	3	0	1	1	2
I_3D_1-I_3D_6	No irrigation was given							

I1-Irrigation at 60 CPE, I2-Irrigation at 120-CPE, I3-No irrigation at sub plot, D1-10th April, D2-20th April, D3-30th April, D4-10th May, D5-20th May, D6-30th

Table S4 - ANOVA table for the experiment.

Source of variation	Degrees of freedom (d.f.)	
Replications (R)	(R-1)=r	2
Moisture regimes (A)	(A-1)=a	2
Error a	r*a	4
Sowing dates (B)	(b-1)	5
Moisture regimes x sowing dates (A x B)	a*b	10
Error b	R*a*b	30
Total	N-1	53

Table S5 - Effect of sowing time on moisture content (%) of fodder sorghum under different moisture regimes. (DAS-Days after sowing; CPE-Cumulative pan evaporation).

Treatments	Moisture content									
	30 DAS		45 DAS		1st cut		2nd cut		3rd cut	
	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017
Main plot (Irrigation regimes)										
60 CPE	86	87	86	85	83	80	82	84	83	84
120 CPE	84	84	82	81	79	76	78	80	80	79
No irrigation	81	71	78	77	78	74	78	79	79	78
CD (p=0.05)	3	4	3	4	3	2	3	4	2	3
Sub plot (Sowing Dates)										
10th April	80	78	79	76	78	74	79	80	84	80
20th April	80	78	79	77	80	77	79	82	80	80
30th April	79	80	78	79	80	77	83	82	82	81
10th May	79	81	81	80	82	79	80	79	78	81
20th May	80	81	82	81	83	79	81	82	80	80
30th May	81	82	83	83	84	81	79	80	80	80
CD (p=0.05)	NS	NS	3	3	3	3	NS	2	3	NS
Interaction (I*D)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table S6 - Interactive effect of irrigation and sowing times on periodic plant height of fodder sorghum (2016 and 2017). (DAS-Days after sowing; CPE-Cumulative pan evaporation).

	2016				2017			
	30 DAS				30 DAS			
Treatments	**Irrigation at 60 CPE**	**Irrigation at 120 CPE**	**No irrigation**	**Mean**	**Irrigation at 60 CPE**	**Irrigation at 120 CPE**	**No irrigation**	**Mean**
10th April	25.7	21.7	13.7	21.4	31.0	21.3	17.0	22.0
20th April	29.7	26.0	14.7	25.0	32.3	22.0	19.3	23.0
30th April	37.7	22.7	13.7	25.4	35.3	27.0	16.0	25.3
10th May	50.3	27.0	21.7	32.1	40.0	28.7	19.0	30.1
20th May	57.3	37.3	26.0	40.7	45.3	37.3	27.3	36.2
30th May	80.0	61.0	41.7	64.1	61.3	53.3	51.3	52.1
Mean	46.8	32.6	25.0		40.9	31.6	21.9	
CD (p=0.05)	Irrigation=3.3, Date of sowing =3.1, Interaction=5.5				Irrigation=4.0, Date of sowing =3.0, Interaction=NS			
	45 DAS				45 DAS			
10th April	69.3	53.4	20.7	47.8	69.1	53.4	29.3	48.6
20th April	71.7	58.3	19.4	49.8	78.7	58.3	30.7	54.9
30th April	76.7	60.4	20.0	52.4	85.0	60.4	45.0	62.8
10th May	90.5	67.2	57.7	71.8	108.0	67.2	72.0	86.6
20th May	92.7	87.3	80.0	86.7	114.7	87.3	98.0	104.2
30th May	111.9	101.3	92.1	101.8	123.8	110.3	118.0	117.5
Mean	96.5	75.2	65.5		85.5	71.3	48.3	
CD (p=0.05)	Irrigation=6.2, Date of sowing =8.2, Interaction=14.2				Irrigation=5.1, Date of sowing =6.6, Interaction=11.4			
	1st cut				1st cut			
10th April	123.3	98.3	42.0	87.9	119.9	90.0	25.9	78.6
20th April	143.3	99.0	48.7	97.0	118.5	95.0	30.3	81.3
30th April	155.3	126.0	54.7	112.0	127.8	103.8	49.7	93.8
10th May	159.0	145.7	88.3	131.0	136.3	125.7	100.3	120.8
20th May	151.0	144.3	119.3	138.3	135.9	126.4	104.8	122.7
30th May	151.3	147.0	133.7	143.9	156.2	127.5	133.1	138.6
Mean	125.0	113.0	111.6		132.4	111.4	74	
CD (p=0.05)	Irrigation=10.9, Date of sowing =11.9, Interaction=20.7				Irrigation=13.6, Date of sowing =11.4, Interaction=19.8			

Table S7 -Interactive effect of sowing times and irrigation regimes on periodic HCN content of fodder sorghum (2016). (CPE-Cumulative pan evaporation).

	2016				2017			
	1st cut				1st cut			
Treatments	**Irrigation at 60 CPE**	**Irrigation at 120 CPE**	**No irrigation**	**Mean**	**Irrigation at 60 CPE**	**Irrigation at 120 CPE**	**No irrigation**	**Mean**
10th April	73	99	102	91	85	113	116	105
20th April	62	97	98	85	74	109	112	98
30th April	52	64	87	67	64	77	101	81
10th May	42	53	95	64	56	67	109	77
20th May	32	49	60	48	59	69	95	74
30th May	36	46	52	45	52	62	71	62
Mean	49	69	83		65	82	100	
CD (p=0.05)	Irrigation=4, Date of sowing =9, Interaction=15				Irrigation=4, Date of sowing =9, Interaction=15			
	2nd cut				2nd cut			
10th April	71	83	101	73	71	85	98	85
20th April	65	78	84	78	77	90	92	86
30th April	77	91	77	79	77	90	94	87
10th May	59	73	104	83	82	95	96	91
20th May	66	79	104	92	89	103	104	99
30th May	95	107	116	104	107	119	127	118
Mean	76	84	96		84	97	102	
CD (p=0.05)	Irrigation=5, Date of sowing=8, Interaction=14				Irrigation=5, Date of sowing=8, Interaction=13			