



Growth, Yield and Water Use Efficiency of Sweet Sorghum [*Sorghum bicolor* (L.) Moench] Affected by Drip Irrigation and Nitrogen Levels through Fertigation

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Authors' contributions

This work was carried out in collaboration between both authors. Author KVM performed the analysis and wrote the first draft of the manuscript. Author RMS managed the conceived and designed the analysis of the study. Both authors read and approved the final manuscript.

Article Information

DOI: 10.9734/IJECC/2022/v12i1131234

Open Peer Review History:

This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: <https://www.sdiarticle5.com/review-history/91612>

Original Research Article

Received 05 July 2022
Accepted 10 September 2022
Published 12 September 2022

ABSTRACT

An experiment entitled "Growth, yield and water use efficiency of sweet sorghum [*Sorghum bicolor* (L.) Moench] affected by drip irrigation and nitrogen levels through fertigation" was carried out on clayey and slightly alkaline soil during *rabi* season of 2019-20 and 2020-21 at the Instructional Farm, Department of Agronomy, College of Agriculture, Junagadh Agricultural University, Junagadh. The experiment was laid out in split plot design with four replications. There were nine treatment combinations. The main plot treatments *viz*; (I₁) drip irrigation at 0.6 PEF, (I₂) drip irrigation at 0.8 PEF and (I₃) drip irrigation at 1.0 PEF; and sub plot consist of three nitrogen fertigation levels *viz*; (N₁) 75% RDN through fertigation, (N₂) 100% RDN through fertigation and (N₃) 125% RDN through fertigation (RDF for sweet sorghum is 90-40-40 N, P₂O₅ and K₂O kg ha⁻¹). The results revealed that drip irrigation scheduling at 1.0 PEF enhance consumptive use of water and nitrogen use efficiency which ultimately resulted in higher grain and fodder yields of sweet sorghum. The results indicated that 125% RDN through fertigation significantly increased water use efficiency, which eventually recorded higher grain and fodder yields of sweet sorghum. Based on the results of two years experimentation, it can be concluded that for getting higher grain and fodder yields, sweet sorghum should be applied two common surface irrigation each of 50 mm

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depth followed by scheduling drip irrigation at 0.8 PEF (operating pressure: 1.2 kg cm⁻² and lateral spacing: 120 cm) at alternate day and crop should be fertilized with 100% RDN through drip fertigation out of which, 50% RDN as basal and remaining 50% RDN in five equal splits at 10 days interval through fertigation started from 35 DAS.

Keywords: Sweet sorghum; drip irrigation; nitrogen; fertigation and water use efficiency.

1. INTRODUCTION

Sorghum (*Sorghum bicolor* L. Moench) can be classified as sweet, grain and forage types. Sweet sorghum can grow almost everywhere where, grain sorghum is grown and is now found in a number of developing and industrialized countries. The plant looks much like grain sorghum, except, that it is often taller (sometimes much taller, reaching up to 4 meters) and it accumulates a great deal of sugary juice in the stalk that can be used for a variety of uses such as food, feed, fodder, fuel and tuber benefiting the sobriquet "Smart crop". "Besides having rapid growth, high sugar accumulation and biomass production potential, sweet sorghum has wider adaptability" [1]. Sweet sorghum usually is planted for sugar and ethanol production (Gnansounou et al., 2005) and [2]. Thus, development of sweet sorghum will play an important role in promoting the development of agricultural production, livestock husbandry [3], energy sources (biofuel), refining sugar, paper making, bedding, roofing, fencing and chewing etc. Sweet sorghum requires one fourth amount of water than that required for sugarcane. The plant matures between 115-125 days after plantation. It can be harvested three times in a year.

"Indian farmers mostly use surface irrigation for growing crops which is mainly responsible for the low water use efficiency and productivity. Sweet sorghum require less fertilizer and water intake, possibility of multiple cropping per year, it is resilient to able to grow on marginal area especially drought prone area, has ratoon capability, wide geographic adaptability" [4,5] and [6]. "Practicing deficit irrigation through drip system could increase the irrigated area with increased yield and quality. By introducing drip with fertigation, it is possible to increase the yield of crops by 3 times from the same quantity of water. There was an increase in the use efficiency of nitrogen, phosphorus and potassium to 95, 45 and 80 per cent, respectively. When fertilizer is applied through the drip, it is observed that besides the yield increase of about 30 per cent of the fertilizer could be saved" [7].

Drip irrigation can achieve 90-95 per cent efficiency by reducing evaporation and deep percolation.

"It is important to determine the optimal N application rate needed to achieve the maximum yield and nitrogen use efficiency (NUE). Many studies have investigated the effects of N application on crop growth, yield and N utilization, especially over single-cropping seasons. In general, reasonable fertilization improves crop growth and yield, but over fertilization can harm plants and lower NUE" (Dai et al., 2015; Yan et al., 2015). "Water supply also influences fertilizer utilization. Under irrigated conditions, N applications promote the growth and development of crops and the optimum N rate is a stable value. However, in rainfed areas, the optimal N application rate is affected by rainfall" (Quemada and Gabriel, 2016). "In these areas, N applications promote crop growth, but can also result in a large amount of unused N remaining in the soil" (Ju et al., 2006; Ju and Christie, 2011; Dai et al., 2015). "In addition, soil water consumption is more intense and can lead to lower soil water content during the mature plant stage" [8], (Qiang et al., 2019).

In India, there is ample scope to grow *rabi* sweet sorghum under irrigated conditions with considerably higher productivity. The information available on drip irrigation and nitrogen levels through fertigation especially in sweet sorghum is very scarce under southwest India in particular. At present there is practically no systemic research work has been carried out on drip irrigation and nitrogen levels through fertigation for *rabi* sweet sorghum in this region. Taking note of the facts highlighted above, the present investigation was conducted during *rabi* season of 2019-20 and 2020-21 with following objectives. (1) To study the effect of drip irrigation on growth and yield of sweet sorghum (2) To find out the effect of nitrogen fertigation levels on growth and yield of sweet sorghum (3) To determine the effect of drip irrigation and nitrogen fertigation levels on consumptive use of water, water use efficiency and fertilizer use efficiency and (4) To study the interaction effect of drip irrigation and nitrogen

fertigation levels on growth, yield and quality of sweet sorghum if any.

2. MATERIALS AND METHODS

2.1 Study Site

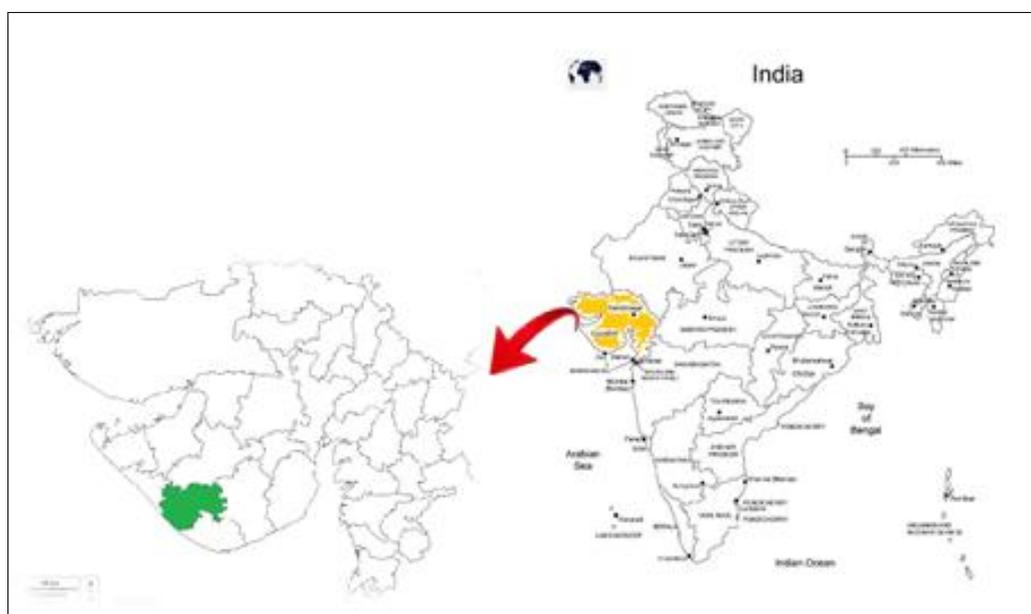
The field trials were conducted from November 2019 to February 2020 and November 2020 to February 2021 at Junagadh Agricultural University (21°31'N latitudes and 70°33'E longitudes, 83 m MSL) in Junagadh, Gujarat, India. The mean maximum and minimum temperature during the crop growth and development period of 2019-20 ranged between 25.4 to 34.3°C and 9.7 to 22.0°C, respectively. The range of mean morning and evening relative humidity, bright sun shine, wind speed and daily evaporation were 56 to 82% and 24 to 51%, 3.2 to 9.1 h, 2.2 to 4.9 km/h and 3.1-5.8 mm, respectively during the year 2019-20. While in year 2020-21, the mean maximum and minimum temperature during the crop growth and development period were ranged between 25.3 to 35.2°C and 9.5 to 18.7°C, respectively. The range of average mean morning and evening relative humidity, bright sun shine, wind speed and daily evaporation was 58 to 74% and 18 to 44%, 3.4 to 10.3 h, 1.9 to 7.3 km/h and 3.4 to 7.0 mm, respectively.

Soil of the experimental plot was clayey in texture, medium in organic carbon (0.60 and

0.59% in 2019-20 and 2020-21, respectively) and slightly alkaline in reaction with pH 8.00 and 7.79, EC 0.47 and 0.34 dS m⁻¹. The soil was medium in available nitrogen (258.30 and 255.80 kg ha⁻¹ 2019-20 and 2020-21, respectively), phosphorus (37.48 and 34.89 kg ha⁻¹ in 2019-20 and 2020-21, respectively) and potash (225.60 and 205.00 kg ha⁻¹ in 2019-20 and 2020-21, respectively). Open well water was the main source of irrigation.

2.2 Experimental Design, Treatments and Field Management

The experiment comprising of nine treatment combinations and it was laid out in Split Plot Design (SPD) with four replications. The main plot treatments viz; (I₁) drip irrigation at 0.6 PEF, (I₂) drip irrigation at 0.8 PEF and (I₃) drip irrigation at 1.0 PEF; and sub plot consist of three nitrogen fertigation levels viz; (N₁) 75% RDN through fertigation, (N₂) 100% RDN through fertigation and (N₃) 125% RDN through fertigation (RDF for sweet sorghum is 90-40-40 N, P₂O₅ and K₂O kg ha⁻¹). Entire doses of Phosphorus and Potassium were applied in previously opened furrows just before sowing as basal application in form of single super phosphate (16% P) and muriate of potash (60% K), respectively and later furrows were covered with soil. Nitrogen was applied in the form of urea (46% N) through drip fertigation. The seeds of sweet sorghum variety CSV 24SS was used for



Map 1. Study area

sowing. The sowing of 15 kg ha⁻¹ seeds were done at 4-5 cm deep in furrow of each plot in row at 10 cm spacing. After emergence of crop, gap filling and thinning operations were carried out to maintain intra row spacing and plant stand. All other agronomic practices were carried out for the all treatments uniformly.

2.3 Data Analysis

Entire doses of Phosphorus and Potassium were applied in previously opened furrows just before sowing as basal application in form of single super phosphate (16% P) and muriate of potash (60% K), respectively and later furrows were covered with soil. Nitrogen was applied in the form of urea (46% N) through drip fertigation. The seeds of sweet sorghum variety CSV 24SS was used for sowing. The sowing of 15 kg ha⁻¹ seeds were done at 4-5 cm deep in furrow of each plot in row at 10 cm spacing. After emergence of crop, gap filling and thinning operations were carried out to maintain intra row spacing and plant stand. All other agronomic practices were carried out for the all treatments uniformly.

Randomly selected five plants per treatment and replication were tagged in the field for observation recording for plant height, dry matter accumulation plant⁻¹, grain yield and dry fodder yield at the time of harvest. Seed yield plant⁻¹ was recorded and converted to seed yield per ha.

Water use efficiency values as kg ha⁻¹ mm⁻¹ of irrigation water applied were calculated for each treatment after harvest using equation (1) according to Condon and Hall (1913).

$$\text{WUE} \left(\frac{\text{kg ha}^{-1}}{\text{mm}^{-1}} \right) = \frac{\text{Grain yield (kg ha}^{-1})}{\text{Total quantity of irrigation water applied (mm)}} \quad \text{----- (1)}$$

Nitrogen use efficiency values in kg grain ha⁻¹ and dry fodder yield ha⁻¹ nutrients were calculated for each treatment using equation (2) as suggested by Veeranna (2000).

$$\text{NUE} \left(\text{Kg kg}^{-1} \right) = \frac{\text{Yield (kg ha}^{-1})}{\text{Total quantity of nutrients applied (kg ha}^{-1})} \quad \text{----- (2)}$$

The data were subjected to statistical analysis by adopting appropriate analysis of variance as

described by Gomez and Gomez (1984). Wherever the F values found significant at 5 per cent level of probability, the critical difference (CD at 5%) values were computed for making comparison among the treatment means.

3. RESULTS

3.1 Growth Parameters

The data regarding plant height at harvest (Table 1) showed that significantly maximum plant height of 219.7, 221.0 and 220.3 cm were recorded under drip irrigation scheduled at 1.0 PEF (I₃) during 2019-20, 2020-21 and in pooled results, respectively which was found statistically at par with drip irrigation scheduled at 0.8 PEF (I₂) during individual years and in pooled results. Significantly lower plant height of 182.1, 183.4 and 182.8 cm were noted under drip irrigation scheduled at 0.6 PEF (I₁) during 2019-20, 2020-21 and in pooled results, respectively. The data presented in Table 2 indicated that there was a significant effect of drip irrigation schedules on dry matter accumulation plant⁻¹ at harvest during 2019-20, 2020-21 and in pooled results. Significantly the maximum dry matter plant⁻¹ of 111.2, 130.3 and 120.7 g plant⁻¹ was recorded at harvest under drip irrigation scheduled at 1.0 PEF (I₃) during 2019-20, 2020-21 and pooled results, respectively. However, it was remained at par with treatment I₂ (drip irrigation scheduled at 0.8 PEF) in 2019-20, 2020-21 and in pooled results. Whereas, significantly the lowest dry matter accumulation plant⁻¹ at harvest of 82.3, 101.3 and 91.8 g was noted with drip irrigation scheduled at 0.6 PEF (I₁) during 2019-20, 2020-21 and in pooled results, respectively.

The data (Table 1) clearly indicated that different nitrogen fertigation levels produced their significant effect on plant height at harvest. The higher plant height of 221.1, 223.6 and 222.4 cm were recorded when crop was fertilized with 125% RDN through drip fertigation during 2019-20, 2020-21 and in pooled results, respectively and it was remained at par with nitrogen fertigation level (N₂) during 2019-20, 2020-21 and in pooled results. Significantly lower plant height of 178.0, 178.6 and 178.3 cm were recorded when crop was fertilized with 75% RDN (N₁) through drip fertigation during individual years and in pooled results, respectively. It was revealed from the results presented in Table 2 on dry matter accumulation plant⁻¹ at harvest that different nitrogen fertigation levels produced their significant effect on dry matter accumulation

plant⁻¹ at harvest. The treatment N₃ (125% RDN through drip fertigation) recorded higher dry matter accumulation plant⁻¹ of 107.1, 129.9 and 118.5 g plant⁻¹ being at par with treatment N₂ (100% RDN) during the year 2019-20, 2020-21 and in pooled results, respectively. The lowest dry matter accumulation plant⁻¹ at harvest of 89.5, 102.3 and 95.9 g was observed under the treatment N₁ (75% RDN) during 2019-20, 2020-21 and in pooled results, accordingly.

The interaction effect between drip irrigation schedules and nitrogen fertigation levels (I x N) for dry matter accumulation plant⁻¹ at harvest was found significant during 2019-20, 2020-21 and in pooled results (Table 3, 4 and 5). Application of irrigation through drip at 0.8 PEF and fertilized the crop with 100% RDN through drip fertigation (I₂N₂) produced significantly maximum dry matter accumulation plant⁻¹ at harvest of 127.7 g plant⁻¹ during 2019-20 which

Table 1. Effect of drip irrigation schedules and nitrogen fertigation levels on plant height of sweet sorghum at harvest

Treatments	Plant height at harvest (cm)		
	2019-20	2020-21	Pooled
Drip irrigation schedules (I)			
I ₁ : Drip irrigation 0.6 PEF	182.1	183.4	182.8
I ₂ : Drip irrigation 0.8 PEF	214.0	211.6	212.8
I ₃ : Drip irrigation 1.0 PEF	219.7	221.0	220.3
S.Em. ±	6.9	6.5	4.7
C.D. (P=0.05)	23.9	22.5	14.6
C.V. (%)	11.67	10.99	11.34
Nitrogen fertigation (N)			
N ₁ : 75% RDN	178.0	178.6	178.3
N ₂ : 100% RDN	216.6	213.8	215.2
N ₃ : 125% RDN	221.1	223.6	222.4
S.Em. ±	6.8	6.1	4.6
C.D. (P=0.05)	20.1	18.3	13.1
C.V. (%)	11.44	10.38	10.92
I x N interaction			
S.Em. ±	11.7	10.6	7.9
C.D. (P=0.05)	NS	NS	NS

Table 2. Effect of drip irrigation schedules and nitrogen fertigation levels on dry matter accumulation of sweet sorghum at harvest

Treatments	Dry matter accumulation at harvest (g plant ⁻¹)		
	2019-20	2020-21	Pooled
Drip irrigation schedules (I)			
I ₁ : Drip irrigation 0.6 PEF	82.3	101.3	91.8
I ₂ : Drip irrigation 0.8 PEF	109.9	129.9	119.9
I ₃ : Drip irrigation 1.0 PEF	111.2	130.3	120.7
S.Em. ±	2.4	3.5	2.1
C.D. (P=0.05)	8.4	12.2	6.6
C.V. (%)	8.30	10.12	9.45
Nitrogen fertigation (N)			
N ₁ : 75% RDN	89.5	102.3	95.9
N ₂ : 100% RDN	106.7	129.3	118.0
N ₃ : 125% RDN	107.1	129.9	118.5
S.Em. ±	2.3	3.0	1.9
C.D. (P=0.05)	6.9	9.0	5.5
C.V. (%)	8.01	8.67	8.43
I x N interaction			
S.Em. ±	4.1	5.2	3.3
C.D. (P=0.05)	12.0	15.5	9.5

Table 3. Interaction effect between drip irrigation schedules and nitrogen fertigation levels on dry matter accumulation (g plant⁻¹) of sweet sorghum at harvest during 2019-20

Drip irrigation schedules \ Fertigation	I ₁	I ₂	I ₃
N ₁	74.9	83.3	110.5
N ₂	81.4	127.7	111.2
N ₃	90.8	118.6	111.8
S.Em. ±			4.4
C.D. (P=0.05)			12.0

Table 4. Interaction effect between drip irrigation schedules and nitrogen fertigation levels on dry matter accumulation (g plant⁻¹) of sweet sorghum at harvest during 2020-21

Drip irrigation schedules \ Fertigation	I ₁	I ₂	I ₃
N ₁	94.2	103.7	109.1
N ₂	98.8	146.5	142.6
N ₃	110.9	139.5	139.4
S.Em. ±			5.2
C.D. (P=0.05)			15.5

Table 5. Interaction effect between drip irrigation schedules and nitrogen fertigation levels on dry matter accumulation (g plant⁻¹) of sweet sorghum at harvest on pooled basis

Drip irrigation schedules \ Fertigation	I ₁	I ₂	I ₃
N ₁	84.5	93.5	109.8
N ₂	90.1	137.1	126.9
N ₃	100.9	129.0	125.6
S.Em. ±			3.3
C.D. (P=0.05)			9.5

was remained statistically at par with treatment combination I₂N₃ during 2019-20. Application of irrigation at 0.6 PEF through drip and fertilized the crop with 75% RDN through fertigation (I₁N₁) recorded significantly minimum dry matter accumulation plant⁻¹ at harvest of 74.9 g during 2019-20 and it was remained at par with treatment combination I₁N₂ and I₂N₁. During the year 2020-21, application of irrigation through drip at 0.8 PEF and fertilized the crop with 100% RDN through drip fertigation (I₂N₂) produced significantly maximum dry matter accumulation plant⁻¹ at harvest of 146.5 g and which was remained statistically at par with treatment combination I₃N₂, I₂N₃ and I₃N₃. Significantly minimum dry matter accumulation plant⁻¹ at harvest of 94.2 g plant⁻¹ was recorded with the application of irrigation at 0.6 PEF through drip and fertilizing the crop with 75% RDN through drip fertigation (I₁N₁) and it was comparable with

treatment combination I₁N₂, I₂N₁ and I₃N₁. Application of irrigation through drip at 0.8 PEF and fertilized the crop with 100% RDN through drip fertigation (I₂N₂) produced significantly maximum dry matter accumulation plant⁻¹ at harvest of 137.1 g on pooled data basis and which was remained statistically at par with treatment combination I₂N₃. Significantly lower dry matter accumulation plant⁻¹ at harvest of 84.5 g was recorded with application of irrigation at 0.6 PEF through drip and application of 75% RDN through drip fertigation (I₁N₁) and it was remained on same bar with treatment combination I₁N₂ and I₂N₁.

3.2 Grain Yield and Dry Fodder Yield

A perusal of data furnished in Table 6 revealed that different drip irrigation schedules significantly influenced grain yield during the year 2019-20,

2020-21 and in pooled results. Significantly higher grain yield of 1391, 1622 and 1506 kg ha⁻¹ during 2019-20, 2020-21 and in pooled results, respectively was recorded when sweet sorghum was irrigated through drip at 1.0 PEF (I₃), however it remained statistically at par with I₂ i.e. irrigating the crop through drip at 0.8 PEF during 2019-20, 2020-21 and in pooled results. Irrigating the crop through drip at 0.6 PEF produced significantly minimum grain yield of 1027, 1256 and 1142 kg ha⁻¹ during 2019-20, 2020-21 and in pooled results, respectively. The per cent increase in grain yield under drip irrigation scheduled at 1.0 PEF (I₃) over (I₁) 0.6 PEF were to the tune of 35.4, 29.1 and 31.9% during 2019-20, 2020-21 and in pooled results, respectively. The data presented in Table 10 revealed that dry fodder yield of sweet sorghum significantly affected due to different drip

irrigation schedules during both the years and in pooled results. Irrigating the crop through drip irrigation at 1.0 PEF (I₃) recorded significantly higher dry fodder yield of 15378, 17893 and 16635 kg ha⁻¹ during 2019-20, 2020-21 and in pooled results, respectively and it was found statistically at par with I₂ (Drip irrigation scheduled at 0.8 PEF) during 2019-20, 2020-21 and in pooled results. Significantly lower dry fodder yield of 11340, 13872 and 12606 kg ha⁻¹ was recorded when crop was irrigated through drip at 0.6 PEF (I₁) during 2019-20, 2020-21 and in pooled results, respectively. The per cent increase in dry fodder yield of sweet sorghum with irrigating the sweet sorghum through drip at 1.0 PEF (I₃) were to the tune of 35.6, 29.0 and 32.0% over drip irrigation scheduled at 0.6 PEF (I₁) during 2019-20, 2020-21 and in pooled results, respectively.

Table 6. Effect of drip irrigation schedules and nitrogen fertigation levels on grain yield of sweet sorghum

Treatments	Grain yield (kg ha ⁻¹)		
	2019-20	2020-21	Pooled
Drip irrigation schedules (I)			
I ₁ : Drip irrigation 0.6 PEF	1027	1256	1142
I ₂ : Drip irrigation 0.8 PEF	1388	1613	1501
I ₃ : Drip irrigation 1.0 PEF	1391	1622	1506
S.Em. ±	40	56	35
C.D. (P=0.05)	140	194	106
C.V. (%)	11.04	12.95	12.23
Nitrogen fertigation (N)			
N ₁ : 75% RDN	1135	1287	1211
N ₂ : 100% RDN	1334	1601	1468
N ₃ : 125% RDN	1337	1603	1470
S.Em. ±	33	42	27
C.D. (P=0.05)	97	124	76
C.V. (%)	8.92	9.68	9.40
I x N interaction			
S.Em. ±	57	72	46
C.D. (P=0.05)	168	215	132

Table 7. Interaction effect between drip irrigation schedules and nitrogen fertigation levels on grain yield (kg ha⁻¹) of sweet sorghum during 2019-20

Fertigation	Drip irrigation schedules		
	I ₁	I ₂	I ₃
N ₁	960	1061	1384
N ₂	971	1631	1401
N ₃	1149	1473	1388
S.Em. ±			57
C.D. (P=0.05)			168

Table 8. Interaction effect between drip irrigation schedules and nitrogen fertigation levels on grain yield (kg ha⁻¹) of sweet sorghum during 2020-21

Drip irrigation schedules \ Fertigation	I ₁	I ₂	I ₃
	N₁	1190	1304
N₂	1221	1815	1768
N₃	1358	1722	1729
S.Em. ±			72
C.D. (P=0.05)			215

Table 9. Interaction effect between drip irrigation schedules and nitrogen fertigation levels on grain yield (kg ha⁻¹) of sweet sorghum on pooled basis

Drip irrigation schedules \ Fertigation	I ₁	I ₂	I ₃
	N₁	1075	1182
N₂	1096	1723	1585
N₃	1254	1597	1558
S.Em. ±			46
C.D. (P=0.05)			132

An appraisal of data presented in Table 7 indicated that different nitrogen fertigation levels exhibited their significant influence on grain yield during the year 2019-20, 2020-21 and in pooled results. Significantly higher grain yield of 1337, 1603 and 1470 kg ha⁻¹ during 2019-20, 2020-21 and in pooled results, respectively was recorded when crop was fertilized with 125% RDN through drip fertigation (N₃). However, it was found at par with 100% RDN (N₂) applied through drip fertigation during both the years as well as on pooled data basis. On the contrary, application of 75% RDN through drip fertigation (N₁) recorded significantly minimum grain yield of 1135, 1287 and 1211 kg ha⁻¹ during 2019-20, 2020-21 and in pooled results, respectively. The per cent increase in grain yield with the application of 125% RDN through drip fertigation (N₃) over N₁ (75% RDN through drip fertigation) were to the tune of 17.8, 24.5 and 21.4% during 2019-20, 2020-21 and in pooled results, respectively. Results presented in Table 10 indicated that nitrogen fertigation levels significantly influenced dry fodder yield during the year 2019-20, 2020-21 and in pooled analysis. Fertigation level N₃ (*i.e.* 125% RDN through drip fertigation) recorded significantly higher dry fodder yield of 14761, 17666 and 16214 kg ha⁻¹ during 2019-20, 2020-21 and in pooled results, respectively which was at par with N₂ (*i.e.* 100% RDN through drip fertigation) during both the years and in pooled results. Application of 75% RDN through drip fertigation (N₁) produced significantly minimum

dry fodder yield of 12588, 14250 and 13419 kg ha⁻¹ during 2019-20, 2020-21 and in pooled results, respectively. The per cent increase in dry fodder yield with the application of 125% RDN through drip over 75% RDN through drip fertigation were to the tune of 17.3, 24.0 and 20.8% during 2019-20, 2020-21 and in pooled results, respectively.

Application of irrigation through drip at 0.8 PEF and fertilized the crop with 100% RDN through drip fertigation (I₂N₂) produced significantly maximum grain yield of 1631 kg ha⁻¹ during 2019-20 which was remained statistically at par with treatment combination I₂N₃ during 2019-20 (Table 7). Application of irrigation at 0.6 PEF through drip and fertilized the crop with 75% RDN through fertigation (I₁N₁) recorded significantly minimum grain yield of 960 kg ha⁻¹ during 2019-20. During the year 2020-21, application of irrigation through drip at 0.8 PEF and fertilized the crop with 100% RDN through drip fertigation (I₂N₂) produced significantly maximum grain yield of 1815 kg ha⁻¹ and which was remained statistically at par with treatment combination I₃N₂, I₃N₃ and I₂N₃ (Table 8). Significantly minimum grain yield of 1190 kg ha⁻¹ was recorded with the application of irrigation at 0.6 PEF through drip and fertilizing the crop with 75% RDN through drip fertigation (I₁N₁). Application of irrigation through drip at 0.8 PEF and fertilized the crop with 100% RDN through drip fertigation (I₂N₂) produced significantly

maximum grain yield of 1723 kg ha⁻¹ on pooled data basis and which was remained statistically at par with treatment combination I₂N₃ (Table 9). Significantly lower grain yield of 1075 kg ha⁻¹ was recorded with application of irrigation at 0.6 PEF through drip and application of 75% RDN through drip fertigation (I₁N₁).

Significantly maximum dry fodder yield of 18032 kg ha⁻¹ during 2019-20 (Table 11) was recorded with irrigating the crop through drip at 0.8 PEF and fertilizing with 100% RDN through drip fertigation (I₂N₂) and it was found on par with I₂N₃ (drip irrigation at 0.8 PEF with drip fertigation of 125% RDN). The treatment combination I₁N₂ recorded significantly lower dry fodder yield of 10666 kg ha⁻¹. Application of drip irrigation at 0.8 PEF and fertilizing the crop with 100% RDN through drip fertigation recorded significantly maximum dry fodder yield of 20058 kg ha⁻¹ (Table 12) and it was found at par with treatment combination I₃N₂, I₃N₃ and I₂N₃ during 2020-21. Significantly lower dry fodder yield of 13194 kg ha⁻¹ was produced under the treatment combination I₁N₁ (application of irrigation through drip at 0.6 PEF with fertigation of 75% RDN) being at par with I₁N₂, I₂N₁, I₁N₃ and I₃N₁. Significantly maximum dry fodder yield of 19045 kg ha⁻¹ on pooled data basis was recorded with irrigating the crop through drip at 0.8 PEF and fertilizing the sweet sorghum with 100% RDN through drip fertigation (I₂N₂) and it was found on par with treatment combination I₂N₃ (*i.e.* Drip irrigation at 0.8 PEF with fertigation of 125%

RDN) on pooled results basis (Table 13). Treatment combination I₁N₁ recorded significantly lower dry fodder yield of 11938 kg ha⁻¹ but it was found on par with I₁N₂ and I₂N₁.

3.3 Water Use Efficiency and Nitrogen Use Efficiency

Irrigating sweet sorghum crop through drip at 0.8 PEF (I₁) recorded significantly maximum water use efficiency of 4.23 and 4.52 kg ha⁻¹ mm⁻¹ during 2019-20 and in pooled results (Table 14), respectively and it was on par with drip irrigation scheduled at 0.6 PEF during 2019-20. The lower water use efficiency of 3.61 and 3.86 kg ha⁻¹ mm⁻¹ was observed under drip irrigation scheduled at 1.0 PEF (I₃) during 2019-20 and in pooled results, respectively. Nitrogen use efficiency (Table 18) increased with increase in number of irrigations from I₁ (*i.e.* Drip irrigation scheduled at 0.6 PEF) to I₃ (*i.e.* Drip irrigation scheduled at 1.0 PEF). Treatments I₁, I₂ and I₃ which recorded NUE of 13.08, 16.95 and 17.28 kg kg⁻¹, respectively. Irrigating the crop at 1.0 PEF through drip (I₃) recorded higher NUE followed by I₂ (*i.e.* Drip irrigation scheduled at 0.8 PEF).

The data furnished in Table 14 showed that water use efficiency was significantly influenced due to various nitrogen drip fertigation levels. Application of 125% RDN through drip fertigation (N₃) to sweet sorghum recorded significantly maximum water use efficiency of 4.11, 4.80 and 4.46 kg ha⁻¹ mm⁻¹ during 2019-20, 2020-21 and

Table 10. Effect of drip irrigation schedules and nitrogen fertigation levels on fodder yield of sweet sorghum

Treatments	Dry fodder yield (kg ha ⁻¹)		
	2019-20	2020-21	Pooled
Drip irrigation schedules (I)			
I ₁ : Drip irrigation 0.6 PEF	11340	13872	12606
I ₂ : Drip irrigation 0.8 PEF	15360	17800	16580
I ₃ : Drip irrigation 1.0 PEF	15378	17893	16635
S.Em. ±	407	613	368
C.D. (P=0.05)	1407	2123	1134
C.V. (%)	10.04	12.86	11.80
Nitrogen fertigation (N)			
N ₁ : 75% RDN	12588	14250	13419
N ₂ : 100% RDN	14730	17648	16189
N ₃ : 125% RDN	14761	17666	16214
S.Em. ±	374	466	299
C.D. (P=0.05)	1112	1385	857
C.V. (%)	9.24	9.77	9.59
I x N interaction			
S.Em. ±	648	807	518
C.D. (P=0.05)	1925	2399	1485

Table 11. Interaction effect between drip irrigation schedules and nitrogen fertigation levels on dry fodder yield (kg ha⁻¹) of sweet sorghum during 2019-20

Drip irrigation schedules \ Fertigation	I ₁	I ₂	I ₃
N ₁	10682	11780	15301
N ₂	10666	18032	15491
N ₃	12672	16268	15342
S.Em. ±			648
C.D. (P=0.05)			1925

Table 12. Interaction effect between drip irrigation schedules and nitrogen fertigation levels on dry fodder yield (kg ha⁻¹) of sweet sorghum during 2020-21

Drip irrigation schedules \ Fertigation	I ₁	I ₂	I ₃
N ₁	13194	14430	15124
N ₂	13396	20058	19491
N ₃	15025	18911	19063
S.Em. ±			807
C.D. (P=0.05)			2399

Table 13. Interaction effect between drip irrigation schedules and nitrogen fertigation levels on dry fodder yield (kg ha⁻¹) of sweet sorghum on pooled data basis

Drip irrigation schedules \ Fertigation	I ₁	I ₂	I ₃
N ₁	11938	13105	15213
N ₂	12031	19045	17491
N ₃	13849	17590	17202
S.Em. ±			518
C.D. (P=0.05)			1485

in pooled results, and it was statistically at par with N₂ (100 % RDN through drip fertigation) during individual years and in pooled results. Significantly lower WUE of 3.46, 3.88 and 3.67 kg ha⁻¹mm⁻¹ was recorded with 75% RDN fertigation (N₁) during both the years and in pooled results, respectively. Water use efficiency (Table 14) was significantly influenced by different nitrogen fertigation levels. Maximum water use efficiency was noted in N₃ (*i.e.* 125% RDN through drip fertigation). Minimum water use efficiency was found in N₁ (*i.e.* 75% RDN through drip fertigation). The effect of different nitrogen fertigation levels on nitrogen use efficiency (Table 18) was found significant. Significantly higher nitrogen use efficiency was recorded when crop was fertilized with 75% RDN (N₁) through drip fertigation and lower nitrogen use efficiency was recorded when crop was fertilized with 125% RDN (N₃) through fertigation.

The data furnished in Table 15 revealed that irrigating the crop at 0.8 PEF through drip and fertilizing with 100% RDN through drip fertigation (I₂N₂) recorded significantly maximum water use efficiency of 4.97 kg ha⁻¹ mm⁻¹ during 2019-20 and it was found at par with I₂N₃. Minimum water use efficiency of 3.23 kg ha⁻¹ mm⁻¹ was observed under treatment I₂N₁ (*i.e.* Irrigating the crop through drip at 0.8 PEF and application of 75% RDN through drip fertigation). Maximum water use efficiency of 5.40 kg ha⁻¹ mm⁻¹ was noted when crop was irrigated through drip at 0.8 PEF and fertilized the crop with 100% RDN through drip fertigation and it was found on par with I₂N₃ (*i.e.* Irrigating the crop through drip at 0.8 PEF and application of 125% RDN through drip fertigation) and I₁N₃ (*i.e.* Irrigating the crop through drip at 0.6 PEF and application of 125% RDN through drip fertigation) during 2020-21 (Table 16). Minimum water use efficiency of 3.46 kg ha⁻¹ mm⁻¹ was noted when crop was irrigated

at 1.0 PEF through drip irrigation and fertilizing the crop with 75% RDN through fertigation (I_3N_1) in 2020-21. The results furnished in Table 17 revealed that treatment combination I_2N_2 (i.e. Drip irrigation scheduled at 0.8 PEF and application of 100% RDN through drip fertigation) recorded maximum WUE of $5.19 \text{ kg ha}^{-1} \text{ mm}^{-1}$ which remained at par with the treatment combination I_2N_3 . Minimum WUE of $3.53 \text{ kg ha}^{-1} \text{ mm}^{-1}$ was observed under treatment combination

I_3N_1 (i.e. Drip irrigation scheduled at 1.0 PEF and application of 75% RDN through drip fertigation) which was found at par with treatment combination I_2N_1 and I_1N_3 on pooled basis.

The data furnished in Table 19 revealed that irrigating the crop at 1.0 PEF through drip and fertilizing the crop with 75% RDN through drip fertigation (I_3N_1) recorded significantly maximum nitrogen use efficiency of 20.50 kg kg^{-1}

Table 14. Effect of drip irrigation schedules and nitrogen fertigation levels on water use efficiency of sweet sorghum

Treatments	Water use efficiency ($\text{kg ha}^{-1} \text{ mm}^{-1}$)		
	2019-20	2020-21	Pooled
Drip irrigation schedules (I)			
I_1 : Drip irrigation 0.6 PEF	3.79	4.54	4.16
I_2 : Drip irrigation 0.8 PEF	4.23	4.80	4.52
I_3 : Drip irrigation 1.0 PEF	3.61	4.11	3.86
S.Em. \pm	0.13	0.17	0.11
C.D. (P=0.05)	0.44	NS	0.33
C.V. (%)	11.45	13.10	12.45
Nitrogen fertigation (N)			
N_1 : 75% RDN	3.46	3.88	3.67
N_2 : 100% RDN	4.07	4.76	4.41
N_3 : 125% RDN	4.11	4.80	4.46
S.Em. \pm	0.11	0.12	0.08
C.D. (P=0.05)	0.32	0.36	0.23
C.V. (%)	9.72	9.31	9.52
I x N interaction			
S.Em. \pm	0.19	0.21	0.14
C.D. (P=0.05)	0.56	0.62	0.40

Table 15. Interaction effect between drip irrigation schedules and nitrogen fertigation levels on water use efficiency ($\text{kg ha}^{-1} \text{ mm}^{-1}$) of sweet sorghum during 2019-20

Fertigation	Drip irrigation schedules		
	I_1	I_2	I_3
N_1	3.54	3.23	3.59
N_2	3.58	4.97	3.64
N_3	4.24	4.49	3.60
S.Em. \pm			0.19
C.D. (P=0.05)			0.56

Table 16. Interaction effect between drip irrigation schedules and nitrogen fertigation levels on water use efficiency ($\text{kg ha}^{-1} \text{ mm}^{-1}$) of sweet sorghum during 2020-21

Fertigation	Drip irrigation schedules		
	I_1	I_2	I_3
N_1	4.30	3.88	3.46
N_2	4.41	5.40	4.48
N_3	4.90	5.12	4.38
S.Em. \pm			0.21
C.D. (P=0.05)			0.62

Table 17. Interaction effect between drip irrigation schedules and nitrogen fertigation levels on water use efficiency ($\text{kg ha}^{-1} \text{mm}^{-1}$) of sweet sorghum on pooled data basis

Drip irrigation schedules	Fertigation		
	I ₁	I ₂	I ₃
N ₁	3.92	3.56	3.53
N ₂	4.00	5.19	4.06
N ₃	4.57	4.81	3.99
S.Em. \pm			0.14
C.D. (P=0.05)			0.40

Table 18. Effect of drip irrigation schedules and nitrogen fertigation levels on nitrogen use efficiency of sweet sorghum crop

Treatments	Nitrogen use efficiency (kg kg^{-1})		
	2019-20	2020-21	Pooled
Drip irrigation schedules (I)			
I ₁ : Drip irrigation 0.6 PEF	11.74	14.42	13.08
I ₂ : Drip irrigation 0.8 PEF	15.64	18.26	16.95
I ₃ : Drip irrigation 1.0 PEF	16.13	18.42	17.28
S.Em. \pm	0.44	0.57	0.36
C.D. (P=0.05)	1.52	1.97	1.11
C.V. (%)	10.52	11.55	11.17
Nitrogen fertigation (N)			
N ₁ : 75% RDN	16.81	19.07	17.94
N ₂ : 100% RDN	14.83	17.79	16.31
N ₃ : 125% RDN	11.88	14.25	13.06
S.Em. \pm	0.37	0.41	0.28
C.D. (P=0.05)	1.10	1.22	0.79
C.V. (%)	8.84	8.37	8.60
I x N interaction			
S.Em. \pm	0.64	0.71	0.48
C.D. (P=0.05)	1.91	2.12	1.38

Table 19. Interaction effect between drip irrigation schedules and nitrogen fertigation levels on nitrogen use efficiency (kg kg^{-1}) of sweet sorghum during 2019-20

Drip irrigation schedules	Fertigation		
	I ₁	I ₂	I ₃
N ₁	14.22	15.72	20.50
N ₂	10.79	18.12	15.57
N ₃	10.22	13.09	12.33
S.Em. \pm			0.64
C.D. (P=0.05)			1.91

during 2019-20. Minimum nitrogen use efficiency of 10.22 kg kg^{-1} was observed under treatment I₁N₃ (i.e. Irrigating the crop through drip at 0.6 PEF and application of 125% RDN through drip fertigation). Significantly maximum nitrogen use efficiency of 20.26 kg ha^{-1} during 2020-21 (Table 20) was noted with irrigating the crop through drip at 1.0 PEF and fertilizing with 75% RDN through drip fertigation (I₃N₁) and it was found on par with I₂N₁ (i.e. Drip irrigation at 0.8 PEF with

drip fertigation of 75% RDN), I₂N₂ (i.e. Drip irrigation at 0.8 PEF with drip fertigation of 100% RDN) and I₃N₂ (i.e. Drip irrigation at 1.0 PEF with drip fertigation of 100% RDN). The treatment combination I₁N₃ recorded significantly lower nitrogen use efficiency of 12.07 kg ha^{-1} . Maximum nitrogen use efficiency of 20.38 kg kg^{-1} was noted when crop was irrigated through drip at 1.0 PEF and fertilized the crop with 75% RDN through drip fertigation (I₃N₁) and it was found on

Table 20. Interaction effect between drip irrigation schedules and nitrogen fertigation levels on nitrogen use efficiency (kg kg^{-1}) of sweet sorghum during 2020-21

Drip irrigation schedules \ Fertigation	I ₁	I ₂	I ₃
N ₁	17.64	19.32	20.26
N ₂	13.56	20.16	19.65
N ₃	12.07	15.31	15.37
S.Em. \pm			0.71
C.D. (P=0.05)			2.12

Table 21. Interaction effect between drip irrigation schedules and nitrogen fertigation levels on nitrogen use efficiency (kg kg^{-1}) of sweet sorghum on pooled data basis

Drip irrigation schedules \ Fertigation	I ₁	I ₂	I ₃
N ₁	15.93	17.52	20.38
N ₂	12.18	19.14	17.61
N ₃	11.15	14.20	13.85
S.Em. \pm			0.48
C.D. (P=0.05)			1.38

par with I₂N₂ (*i.e.* Irrigating the crop through drip at 0.8 PEF and application of 100% RDN through drip fertigation) on pooled data basis (Table 21). Minimum nitrogen use efficiency of 11.15 kg kg^{-1} was noted when crop was irrigated at 0.6 PEF through drip irrigation and fertilizing the crop with 125% RDN through fertigation (I₁N₃) on pooled data basis.

4. DISCUSSION

4.1 Growth Parameters

The response of different drip irrigation levels in terms of overall improvement in growth parameters is further supported by the fact that the higher irrigation frequency, increased the availability of nutrients and thus, enhanced the uptake of nutrients which consequently improved the growth of sweet sorghum. Similar results were observed by Mugalkhod [9] in baby corn, Abdullah [10], Basava [11] and Patel et al. [12] in sweet corn, Calvin and Messing [13] and Qu et al. [14] in sweet sorghum, Lakshmi et al. [15] in sweet corn hybrid and Vinutha et al. [16] in maize. Scheduling drip irrigation at 1.0 PEF had significant improvement in dry matter plant⁻¹ at different growth stages of sweet sorghum seems to an account of better vegetative growth which is well reflected by increase in plant height and length of internode. It is an established fact that the soil water deficiency inhibits leaf expansion and stem elongation in plants through its

reduction of relative turgidity. Reduced water supply also causes closure of stomata which raises the plant temperatures consequently increases respiration leading to higher break down of assimilates and ultimately poor growth and reduced dry matter accumulation under lower drip irrigation at 0.6 PEF. Above ground biomass showed a sigmoidal growing trend, especially in irrigated treatments and it was affected by water availability as reported by Barbanti et al. [17] and Cosentino et al. [18] in sweet sorghum. Similar findings were also reported by Patel et al. [19] in fennel, Rao et al. [20] in cumin. The significant reduction in plant growth with decreased frequency of irrigation seems to be resultant effects of water stress, which might have reduced the availability and uptake of water and nutrients. The results are in close accordance with the findings of Viswanatha [21], Abdullah [10] and Basava [11] in sweet corn, Mugalkhod [9] in baby corn, Patel et al. [22] in fennel, Padmaja [23] and Brar et al. [24] in maize.

Increase in nitrogen rate increased plant height that might have increased photosynthate formation and partitioning into stems that might have favourable impacts on plant height of sweet sorghum. The plant height increased with increasing fertigation level might be due to increased availability of nutrients, better uptake by the roots and increased in the number of internodes and inter nodal distance. This results

are in harmony with those obtained by Taha et al. [25], El-Zeny [26], El-Shafai et al. [27], Ismail et al. [28] and Ismail et al. [29] in sweet sorghum. Profound influence of nitrogen on crop growth seems to be due to congenial nutritional environment of plant systems on account of its greater availability from soil media, which might have resulted in greater synthesis of amino acids, proteins and growth promoting substances, which seems to have enhanced the meristematic activity and increased cell division and their elongation. Further, application might have increased interception, absorption and utilization of radiant energy which in turn increased photosynthesis and thereby crop growth. Similar results were reported by Agung et al. [6], Sawargaonkar et al. [30] and Olugbemi et al. [31] in sweet sorghum; Pennaiah [32], Hassan et al. [33], Basava [11], Khanna [34], Brar et al. [24], Lakshmi et al. [15] and Vineela et al. [35] in maize.

4.2 Grain Yield and Dry Fodder Yield

This might be due to maintaining adequate soil moisture in the root zone depth throughout the crop growth period which facilitated in better uptake of water and nutrients having beneficial effect on growth viz., plant height and LAI which favoured more production and translocation of photosynthates to the sink there by high dry matter production and yield contributing factors viz., ear head weight, ear head length and number of grains earhead⁻¹ ultimately increasing higher grain yield. Similar findings were also reported by Hamidreza et al. [36] and Salemi et al. [37] in maize crop, Ibrahim et al. [38], Sepaskhah and Ghasemi [39] and Satish et al. [40] in sorghum crop. Lower grain yield was observed with deficit drip irrigation scheduled at 0.6 PEF; might be due to moisture stress leading to reduced test weight, grain weight, ear head weight and number of grains ear head⁻¹. The results confirms the findings of Maman et al. [41] and Shirazi et al. [42] in maize crop and Satish et al. [40] in sorghum.

Positive effect of irrigation on plant growth and sweet sorghum crop might have responded well to the applied higher irrigation through drip as sweet sorghum is highly responsive to nutrients and water. The fact that irrigation level increased the availability and maintaining higher soil moisture in the root zone throughout the crop period which reflected in higher relative leaf water content and subsequently in development of yield component and grain and fodder yields.

As water tension increases, the available moisture content decreases and those roots have to exert more energy to get the water from the soil particles. The higher irrigation did not cause water stress at any stage providing favorable conditions for crop growth resulting in increased grain and fodder yields. This could be attributed under more favoured soil moisture availability, better vegetative growth; more dry matter production resulted in higher biological yield as compared to less frequency irrigation scheduling treatments. Similar responses were observed by Singh [43], Bandyopadhyay and Mallick [44], Sanjeev et al. [45], Asim and Mohamed [46], Bozkurt et al. [47], Patil et al. [48], Basava [11], Brar et al. [24] and Lakshmi et al. [15] in maize; Patel et al. [22] in fennel and Satish et al. [40] in sorghum.

Increase in yield under higher nitrogen fertigation schedules might be due to build-up of soil fertility that led to increased nutrient availability that accelerating the process of cell division, enlargement and elongation which in turn showed luxuriant vegetative growth and resulted in higher fodder yield. Similar results were reported by Sonar (2001), Hassanein et al. [49], Sampathkumar and Pandian [50], Muthukrishnan and Fanish [51], Basava [11], Fanish [52], Ibrahim et al. [53], Brar et al. [24], Yadav et al. [54] and Lakshmi et al. [15].

4.3 Water Use Efficiency and Nitrogen Use Efficiency

Water use efficiency was higher under low irrigation regimes this might be due to water stress, applied water most effectively utilized by the crop. Increase in water use efficiency was mainly due to considerable saving of irrigation water, greater increase in yield of crops and higher nutrient use efficiency [55]. Similar results were reported by Karam et al. [56], Fanish and Muthukrishnan [57], Karimi and Gomrokchi [58], Basava [11], Hussein and Pibars [59] and Patel et al. [12]. Increase in NUE with more number of irrigations might be due to better availability of moisture and nutrients throughout the growth stages in drip system leading to better uptake of nutrients for production of higher grain and fodder yields. These results are more or less similar to those reported by Padmaja and Raddy [60] in rice, Karangia et al. [61] in wheat, Wang et al. [8] in maize and Damor [62] in wheat. Split application of fertilizer which frequently increases crop yields, thus, increasing crop water use efficiency. Adequate levels of essential plant

nutrients are needed to optimize crop yields and WUE. The results are in line with that of Fanish [52], Khanna [34], Bibe [63] and Patel et al. [64] in maize and Sawargaonkar et al. [30] in sweet sorghum. The fertigation allows application of right quantity of nutrients uniformly to the wetted root volume, where the active roots are concentrated and this helps to enhance fertilizer use efficiency. This was due to better availability of moisture and nutrients throughout the growth stages in drip and fertigation system leads to better uptake of nutrients and production of sweet sorghum. Fertigation saves fertilizer nutrients as it permits application of fertilizer in small quantity at a time matching with the plants nutrient need thus, leading to higher fertilizer use efficiency. These results are similar to those reported by Hassanein et al. [49], Ramah [55] in maize and Yolcu and Cetin [65] in silage corn.

5. CONCLUSION

Based on the results of two years experimentation, it can be concluded that for getting higher grain and fodder yields, sweet sorghum should be applied two common surface irrigation (first immediately after sowing and second 7 days after first irrigation) each of 50 mm depth followed by scheduling drip irrigation at 0.8 PEF (operating pressure: 1.2 kg cm⁻² and lateral spacing: 120 cm) at alternate day and crop should be fertilized with 100% RDN through drip fertigation out of which, 50% RDN as basal and remaining 50% RDN in five equal splits at 10 days interval through fertigation started from 35 DAS.

ACKNOWLEDGEMENT

Authors are grateful to the Junagadh Agricultural University, Junagadh for providing field for experiment.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Reddy BVS, Ramesh S, Reddy PS, Ramaiah B, Salimath PM, Rajashekar K. Sorghum: A potential alternate raw material for bio-ethanol and bioenergy. *Journal of Semi-Arid Tropical Agricultural Research*. 2005;1(1):1-8.
2. Almodares A, Hadi MR. Bioethanol production from sweet sorghum. *African Journal Agriculture Research*. 2009;4:772-780.
3. Fazaeli H, Golmohammadi HA, Almodares A, Mosharraf S, Shaei A. Comparing the performance of sorghum silage with maize silage in feedlot calves. *Pakistan Journal of Biological Sciences*. 2006;9:2450-2455.
4. Ananda N, Vadlani PV, Prasad PV. Evaluation of drought and heat stressed grain sorghum (*Sorghum bicolor*) for ethanol production. *Industrial Crops and Products*. 2011;33(3):779-782.
5. Andrzejewski B, Eggleston G, Powell R. Pilot plant clarification of sweet sorghum juice and evaporation of raw and clarified juices. *Industrial Crops and Products*. 2013;49:648-658.
6. Agung GA, Sardiana K, Diara W, Nurjaya GM. Adaptations, biomass and ethanol yields of sweet sorghum (*Sorghum bicolor* (L.) Moench) varieties at dryland farming areas of Jimbaran Bali, Indonesia, *Journal of Biology, Agriculture and Healthcare*. 2013;3(17):111-115.
7. Sivanappan RK, Ranghaswami MV. Technology to take 100 tonnes per acre in Sugarcane. *Kissan World*. 2005;32(10):35-38.
8. Wang YL, Sien L, Hao L., Kelim H, Shujing Q, Hui G. Comparison of water and nitrogen use efficiency over drip irrigation with border irrigation based on a model approach. *Agronomy*. 2020;10:1890-2010.
9. Mugalkhod AS. Response of baby corn to planting methods and irrigation schedules under drip. M.Sc. (Agri.) thesis, University of Agricultural Sciences, Dharwad, Karnataka; 2005.
10. Abdullah O. Effects of deficit irrigation on some yield characteristics of sweet corn. *Bangladesh Journal of Botany*. 2008;37(2): 127-131.
11. Basava S. Performance of sweet corn hybrid under different levels of irrigation and nitrogen applied through drip system. M.Sc. (Agri.) thesis, Acharya N. G. Ranga Agricultural University, Hyderabad, Telangana; 2012.
12. Patel JS, Patel GJ, Patel KM. Response of drip irrigation and micronutrient mixture on yield attributes, quality and nutrient uptake in sweet corn. *Green Farming*. 2014;5(4): 596-599.

13. Calvin M, Messing J. Sweet sorghum as a model system for bioenergy crops. *Current Opinion in Biotechnology*. 2012;23:323-329.
14. Qu S, Liu XB, Dong CF, Lu XY, Shen YX. Field performance and nutritive value of sweet sorghum in Eastern China. *Field Crops Research*. 2014;157:84-88.
15. Lakshmi SY, Sreelatha D, Pradeep T. Performance evaluation of sweet corn with different levels of irrigation and nitrogen through drip during post monsoon season at Rajendranagar, Hyderabad. *International Journal of Environment and Climate Change*. 2020;10(12):362-372.
16. Vinutha BB, Denesh GR, Pushpa K. Growth and yield of maize (*Zea mays* L.) as influenced by irrigation levels and chemical weed management in drip irrigated paired row system of maize. *International Journal of Chemical Studies*. 2021;9(1):3172-3175.
17. Barbanti L, Grandi S, Vecchi A, Venturi G. Sweet and fibre sorghum (*Sorghum bicolor* (L.) Moench), energy crops in the frame of environmental protection from excessive nitrogen loads. *European Journal of Agronomy*. 2006;25:30-39.
18. Cosentino SL, Mantineo M, Testa G. Water and nitrogen balance of sweet sorghum (*Sorghum bicolor* (L.) Moench) cv. Keller under semi-arid conditions. *Indusexperiment Crops and Products*. 2012;36:329-342.
19. Patel BS, Patel KP, Patel ID, Patel MI. Response of fennel (*Foeniculum vulgare* Mill) to irrigation, nitrogen and phosphorus. *Indian Journal of Agronomy*. 2000;45(2): 429-432.
20. Rao SS, Singh YV, Regar PL, Chand K. Effect of micro-irrigation on productivity and water use of cumin (*Cuminum cyminum*) at varying fertility levels. *Indian Journal of Agricultural Sciences*. 2010; 80(6):507-511.
21. Viswanatha GB. Effect of drip irrigation and methods of planting on green cob and fodder yield of sweet corn (*Zea mays* L. cv. sachharata). M.Sc. (Agri.) thesis, University of Agricultural Science, Bangalore, Karnataka; 1999.
22. Patel SP, Patel SG, Amin AU, Patel PK. Feasibility of drip irrigation in fennel (*Foeniculum vulgare*). *GAU Research Journal*. 2012;37(1):10-12.
23. Padmaja B. Fertigation studies in aerobic rice-zero tillage maize cropping system. Ph.D. thesis, Acharya N. G. Ranga Agricultural University, Rajendranagar, Hyderabad; 2014.
24. Brar AS, Buttar GS, Vashist KK. Enhancing crop and water productivity of spring maize through drip fertigation. *Indian Journal of Agronomy*. 2019;64(1): 87-92.
25. Taha N, Taha M, El-Koliety MM. Response of sweet sorghum to intervals and nitrogen fertilizer. *Assuit Journal of Agricultural Sciences*. 1999;30(3):65-80.
26. El-Zeny MM. Response of sweet sorghum to appropriate fertilizer regimes. Ph. D. Thesis, Faculty of Agriculture, Moshtohor, Zagazig University, (Benha Branch); 2004.
27. El-Shafai AMA, Bekheet MA, El-Aref KAO. Effect of biological and mineral nitrogen fertilization on sweet sorghum (*Sorghum bicolor* L.), Egypt. *Journal of Applied Sciences*. 2005;20(48):464-483.
28. Ismail AM, Tawfik F, Abo El-Ghait RA. Response of some sweet sorghum varieties (*Sorghum bicolor* L.) to different levels of Nitrogen fertilization. *Journal of Advanced Agricultural Research*. 2005;10(2):517-531.
29. Ismail AMA, Mohamed SA, Mohmoud SY, Zohdy NO. Response of sweet sorghum (*Sorghum bicolor* L.) to mineral nitrogen and biofertilization. *Egypt Journal of Agricultural Research*. 2007;85(2):573-585.
30. Sawargaonkar GL, Patil MD, Wani SP, Pavani E, Reddy BV, Marimuthu S. Nitrogen response and water use efficiency of sweet sorghum cultivars, *Field Crops Research*. 2013;149:245-251.
31. Olugbemi O, Aboyeji CM, Olofintoye JA, Eifediyi EK. Growth and ethanol yield responses of sweet sorghum varieties to nitrogen fertilizer rates. *The Journal of Agricultural Sciences*. 2017;13(1):1-14.
32. Pennaiah H. Effect of irrigation and nutrient levels on yield and quality of rabi maize (*Zea mays* L.). M.Sc. (Agri.) thesis, Acharya N. G. Ranga Agricultural University, Rajendranagar, Hyderabad, Telangana; 2005.
33. Hassan SW, Oad FD, Tunio SD, Gandhi AW, Siddiqui MH, Oad SM, Jagirani AW. Impact of nitrogen levels and application methods on agronomic, physiological and nutrient uptake traits of maize fodder. *Pakistan Journal of Botany*. 2010;42(6): 4095-4101.

34. Khanna R. Effect of precision nutrient and water management with different sources and levels of fertilizers on maize production. M.Sc. (Agri.) thesis. University of Agricultural Sciences, Bengaluru, Karnataka; 2013.
35. Vineela K, Chandrasekhar K, Prathibha S, Lakshmi G, Lakshmi N. Performance of rabi maize to fertigation durations and nitrogen levels. International Journal of Chemical Studies. 2021;9(1):105-108.
36. Hamidreza S, Mohd AMS, Teang SL, Mohd KY, Desa A. Yield attributes and yield of rabi sorghum (*Sorghum bicolor* L. Moench) as influenced by different drip irrigation levels. Pertanika Journal of Tropical Agricultural Sciences. 2011;34(2):207-216.
37. Salemi H, Sood MAM, Lee TS, Yusoff MK, Ahmad D. Effect of deficit irrigation on water productivity and maize yields in arid regions of Iran. Pertanika Journal of Agricultural Science. 2011;34(2):207-216.
38. Ibrahim W, Zalih WS, Mat AA, Mastoi A. Effect of partial root zone drying technique on yield and yield components of sorghum cultivar. Journal of Biology, Agriculture and Horticulture. 2013;3(18):21-24.
39. Sepaskhah AR, Ghasemi MM. Every-other furrow irrigation with different irrigation intervals for Sorghum. Pakistan Journal of Biological Science. 2008;11(9):1234-1239.
40. Satish C, Avilkumar K, Praveen RV, Umadevi M, Sreenivaskumar K. Yield attributes and yield of rabi sorghum (*Sorghum bicolor* L. Moench) as influenced by different drip irrigation levels. International Journal of Agriculture Sciences. 2016b;8(30):1639-1641.
41. Maman N, Drew JL, Stephan CM, Tom DG, Higgins R. Pearl millet and grain sorghum yield response to water supply in Nebraska. Agronomy Journal. 2003;95:1618-1624.
42. Shirazi SM, Sholichin M, Mohammed J, Shatirah A, Mokhtar A. Effects of different irrigation regimes and nitrogenous fertilizer on yield and growth parameters of maize (*Zea mays* L.). International Journal of Physical Sciences. 2011;6(4):677-683.
43. Singh SSD. Effect of irrigation regimes and nitrogen levels on growth, yield and quality of baby corn. Madras Agricultural Journal. 2001;88(7-9):367-370.
44. Bandyopadhyay PK, Mallick S. Effect of soil moisture levels on root distribution, water uptake and crop coefficient of winter maize in a humid tropic region. Journal of Food, Agriculture and Environment. 2003;1:141-147.
45. Sanjeev K, Shivani S, Mishra S, Singh VP. Effect of tillage and irrigation on soil-water-plant relationship and productivity of winter maize (*Zea mays*) in north Bihar. Indian Journal of Agricultural Sciences. 2006;76(9):526-530.
46. Asim OE, Mohamed AE. Irrigation scheduling for maize (*Zea mays* L.) under desert area conditions - North of Sudan. Agriculture and Biology Journal of North America. 2011;41(4):645-651.
47. Bozkurt S, Yazar A, Mansuroglu GS. Effects of different drip irrigation levels on yield and some agronomic characteristics of raised bed planted corn. African Journal of Agricultural Research. 2011;6(23):5291-5300.
48. Patil SA, Mahadkar UV, Gosavi SP. Effect of irrigation and fertigation on yield and its components in sweet corn (*Zea mays saccharata*) under medium black soils of North Konkan. Journal of Agricultural Research and Technology. 2011;36(2):223-226.
49. Hassanein MK, Abdrabbo MA, Farag AA. Effect of different nitrogen levels on productivity of three maize hybrids through fertigation. Journal of Agricultural Sciences. 2007;15(2):361-368.
50. Sampathkumar T, Pandian BJ. Effect of fertigation frequencies and levels on growth and yield of maize. Madras Agricultural Journal. 2010;97(7-9):245-248.
51. Muthukrishnan P, Fanish SA. Influence of drip fertigation on yield, water saving and water use efficiency in maize (*Zea mays* L.) based inter cropping system. Madras Agricultural Journal. 2011;98(7/9):243-247.
52. Fanish SA. Influence of drip fertigation on water productivity and profitability of maize. African Journal of Agricultural Research. 2013;8(28):3757-3763.
53. Ibrahim MM, El-baroudy AA, Taha AM. Irrigation and fertigation schedule under drip irrigation for maize crop in sandy soil. International Journal of Agrophysics. 2016;30:47-55.
54. Yadav K, Verma A, Yadav MK, Chaudhary M, Chaudhary KM. Effect of Fertilizer Levels on Fodder Productivity and Quality of Multi-cut Sorghum Genotypes. International Journal of Bio-resource and Stress Management. 2019;10(2):119-123.

55. Ramah K. Study on drip fertigation in maize (*Zea mays* L.) based cropping system. M.Sc. (Agri.) thesis, Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu; 2008.
56. Karam F, Breidy J, Stephan C, Rouphael J. Evapotranspiration, yield and water use efficiency of drip irrigated corn in the Bekaa Vally of Lebanon. *Agricultural Water Management*. 2003;63:125-137.
57. Fanish SA, Muthukrishnan P. Effect of drip fertigation and intercropping on growth, yield and water use efficiency of maize (*Zea mays* L.). *Madras Agricultural Journal*. 2011;98(7-9):238-242.
58. Karimi M, Gomrokchi A. Yield and water use efficiency of corn planted in one or two rows and applying furrow or drip tape irrigation systems in Gazvin Province, Iran. *Irrigation and Drainage*. 2011;60:35-41.
59. Hussein MM, Pibars SK. Maize response to irrigation system, irrigation regimes and nitrogen levels in a sandy soil. *Journal of Applied Sciences Research*. 2012;8(8): 4733-4743.
60. Padmaja B, Reddy M. Drip irrigation and fertigation effects on aerobic rice (*Oryza sativa*) in semi-arid conditions of Telangana State, India. *International Journal of Current Microbiology and Applied Science*. 2018;7(8):1156-1171.
61. Karangiya BA, Mashru HH, Vadher HM. Response of wheat (*Triticum aestivum* L.) under drip fertigation system. *International Journal of Current Microbiology and Applied Sciences*. 2019; 8(6):2519-2526.
62. Damor NN. Response of wheat (*Triticum aestivum* L.) to drip irrigation schedules and levels of soluble fertilizers through fertigation. Ph.D. thesis, Junagadh Agricultural University, Junagadh, Gujarat; 2021.
63. Bibe MS. Studies on irrigation and fertigation management in post kharif maize. M.Sc. (Agri.) thesis. Vasantrao Naik Marathwada Agricultural University, Parbhani, Maharashtra; 2016.
64. Patel JR, Patel GJ, Prajapati KN, Patel KP. Response of time of application and different nitrogen levels through fertigation on growth, cob yield and water use efficiency of sweet corn. *Green Farming*. 2016;7(3): 611-614.
65. Yolcu R, Cetin O. Nitrogen fertigation to improve nitrogen use efficiency and crude protein on silage corn. *Turkish Journal of Field Crops*. 2015;20(2):233-241.

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