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Yield Potential and Yield Components of *Rabi* Sorghum (*Sorghum bicolor* L. Moench) as Influenced by Drip Irrigation

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ABSTRACT: A field experiment was conducted during consecutive three *rabi* seasons (2009-10, 2010-11 and 2011-12) at Water Management Research Station, Marathwada Krishi Vidyapeeth, Parbhani. Experiment had two main treatment of sorghum varieties as V1- SPV 1595 (Parbhani Jyoti) and V2- AKSV 18R (PKV Kranti) and five sub treatments of irrigation schedules such as I_1- drip at 100% ET_c, I_2- drip at 75% ET_c, I_3- drip at 100% ET_c during critical growth stages only, I_4- surface control at 0.8 IW/CPE and I_5- rainfed in statistical design FRBD with three replications. Gross plot size of 6.6 x 5.4 m and net plot size of 4.8 x 6.0 m for wide row (2.4 x 6.0 m) for pair row of 30 cm after 90 cm spacing. Three years pooled data of *rabi* sorghum revealed significantly highest grain yield (57.67 q/ha) in treatment I_1 irrigation schedule. The next best irrigation schedule was I_2 with 53.78 q/ha grain yield. Irrigation treatments I_1 and I_2 were at par for grain yield and significantly superior over I_3, I_4, & I_5. Among different sorghum cultivar, PKV Kranti has recorded better grain yield (41.85 q/ha) as compared to Parbhani Jyoti (38.44 q/ha). Among different genotypes of *rabi* sorghum, the grain yield of PKV Kranti was found better for all irrigation schedules. Maximum water use efficiency was recorded (21.37 kg/ha mm.) for irrigation schedule at 75% ET_c followed by irrigation schedule at 100% ET_c (18.07 kg/ha mm) in 2011-12 year.

Key words: Drip irrigation, sorghum, water use efficiency

Introduction

Sorghum (*Sorghum bicolor* L. Moench) is recognized as biologically drought tolerant and is typically grown under rainfed conditions in regions where water is a main factor for limiting yield (Rosenow *et al.,* 1983). It is the main dryland cereal crop grown for food, feed and fodder. In India, it ranks third in the major food grain crops after rice and wheat. It is widely cultivated in the region of low rainfall both during rainy and post-rainy season in India and also adopted in South Africa, Sudan, Egypt, North America and China in large scales. The area under *rabi* sorghum is mainly concentrated in semi-arid region of Deccan plateau consisting the states like Maharashtra, Karnataka and Andhra Pradesh. At present Maharashtra is largest producer of sorghum in India accounting for 50% of the total area *i.e.* 50.10 lakh hectares with a production of 28.90 lakh tones and productivity was about 657 kg/ha (Awaghad *et al.,* 2010). In addition to grain and fodder, sorghum is being used as industrial raw material in various industries in the USA and other developed countries. India has the largest share (32.3%) of world's area under sorghum and rank second in production after the United States. Among various factors responsible for low productivity, soil-moisture availability is the most limiting factor because crops are very much sensitive to soil moisture stress, particularly at their critical stages. Not only quality but ample water availability, time, method of application is also important for producing higher yield. There is an evidence of stagnation or decline in the productivity of *rabi* sorghum even with the application of recommended dose of fertilizer under rainfed areas. Limited and erratic rainfall in the rainfed areas makes *rabi* sorghum vulnerable to moisture stress conditions during the later part of its growth, resulting in severe yield reduction.

Farmers frequently face crop failure due to drought, however supplementary or full irrigation for this crop through drip has never been tried out. This is partially because of insufficient water resources in these regions (Vidharbha and Marathwada) as the available scarce groundwater resources are used mostly for human consumption and others. The wells are usually 8 to 20 m deep and they dry out after couple of consecutive dry years. So there is a need for assessment of the varietal response to drip irrigation, particularly under conditions of limited soil water availability in medium to deep black cotton soils ranging from 30 cm to 150 cm (Order *Inceptisol* and *Vertisol*) commonly found in semi-arid regions of Maharashtra. As a result, it is now more necessary than ever to achieve the best grain yield and quality per unit of water applied. Management of crop water stress at different grain formation stages offers an opportunity to conserve water during late-season crop development without adversely affecting yield and quality. With the belief that high water applications increase grain weight and yield during all crop growth stages. The objective of optimum irrigation management during grain formation is to sustain economic productivity while reducing the water applied. Change in spacing of *rabi* sorghum play remarkable yield potential with drip irrigation using high water use efficiency. Therefore, a reasonable irrigation scheduling is a key factor to help farmers increase crop yield and save water regarding limited water resources. The water use efficiency (WUE) is one of the most important indices for determining optimal water management practices; its use has been reviewed by Srivastava *et al.* (2009) found water use efficiency was appreciably higher (2.66 g/kg) for the variety as compared to that for sorghum hybrid (2.01 g/kg). Mourad *et al.* (2000) found that panicle weight, grain weight per panicle, 1000 kernel weight, green yield, total biomass and grain yield characters of sorghum increased by increasing number of irrigations from 2 to 5 irrigations. As in other crops Brown *et al.* (1970) showed a 34% yield increase in corn (*Zea mays* L.) grown on 51 cm rows compared with 102 cm rows. Fulton (1970) reported that under conditions of adequate soil moisture, higher corn plant densities (54, 360 plants/ha) produced greater yields than lower densities (39, 540 plants/ ha), and rows spaced at 50 cm produced higher yields than rows spaced 100 cm apart. The row spacing in a crop can also impact crop yield potential. Staggenborg *et al.* (1999) reported that crop row spacing of less than 76 cm would increase grain yield in areas with high yield potential with little risk of reduced yield in areas with lower yield potential. The purpose of this paper is to help sorghum growers to determine the optimum time and amount of the irrigation application needed to sustain economic return from sorghum.

Materials and Methods

The response of two sorghum varieties with 5 treatments was tested, in a factorial randomized block design (FRBD) with 3 replications. Keeping objectives of assessing the response to different irrigation schedule, water use efficiency and economic feasibility of drip irrigation for maximum yield of *rabi* sorghum. As main two sorghum varieties treatment V1- SPV 1595 Parbhani Jyoti) and V2- AKSV 18R (PKV Kranti) and five irrigations schedules (3 day based CPE for drip) sub treatment as I_1- drip at 100% ET_c, I_2- drip at 75% ET_c, I_3- drip at 100% ET_c during CGS only, I_4- surface control at 0.8 IW/CPE and I_5- rainfed. The treatments consist of drip irrigation at 0.6, 0.8 and 1.0 ET_c (crop evapo-transpiration) compared with CGS stages and farmer's practice (flood irrigation method). Irrigation was given at every fourth day in drip treatments as per the treatments requirement by adjusting the duration of water release at constant flow rate 4 lph.

The experimental soil was medium clayey in texture having sand: silt: clay % (14:21:57), cation exchange capacity (54 C mol (P+) kg/ha), pH (7.8), EC (0.43 dS/m), organic carbon (6.2 g/kg), available N (240 kg/ha), $P_2 0_5$ (16.7 kg/ha), $K_2 0$ (450 kg/ ha), S (10.0 mg/kg). A fundamental requirement for accurate irrigation scheduling is to determine crop water needs or crop evapotranspiration (ET_c). The drip irrigation treatments were scheduled based on ET_c. The most common and practical approach used for estimating crop evapotranspiration is using ET_c = CPE x pan coefficient x K_c. The drip inline laterals of 16 mm, 4 lph, 60 cm dripper spacing were placed for paired rows at 120 cm apart. Irrigation was fully automated, and application depths were determined, using a class A open evaporation pan for matching the evapotranspiration needs. The surface irrigation at four critical crop growth stages was applied through check basin. Fertilizer management as recommended. Seed treatment was given before sowing (Azotobacter and PSB). The recommended dose of fertilizer 80:40:40 kg/ha N, P and K were applied. In drip irrigated plots Nitrogen was applied in three splits (40, 20 and 20 kg/ha) at 15, 30 and 60 DAS. Phosphorus was applied in two equal splits (20 kg/ha) at sowing and 30 DAS whereas Potassium was applied in three splits (20, 10 and 10 kg/ ha) at sowing and at 30 and 60 DAS. In surface irrigated plots Nitrogen applied in two splits (40 kg/ha) each at sowing and 30

Table 1 : Growth and yield attributing characters of *rabi* sorghum as influenced by irrigation levels (pooled data)

Treatments	Primaries/panicle				Panicle length (cm)				Panicle girth (cm)			
Genotypes	**2009-2010**	**2010-2011**	**2011-2012**	**Pooled**	**2009-2010**	**2010-2011**	**2011-2012**	**Pooled**	**2009-2010**	**2010-2011**	**2011-2012**	**Pooled**
V1-SPV 1595	62	60	65	62.33	20.32	17.30	17.93	18.52	21.17	21.74	18.00	20.30
V2-AKSV 18R	70	65	63	66.00	21.64	21.03	17.70	20.12	24.19	25.34	18.00	22.51
SE ±	0.80	1.79	0.57	--	0.12	0.59	0.24	--	0.26	0.49	0.30	--
CD at 5 %	2.39	NS	1.7	--	0.38	1.75	0.74	--	0.79	1.46	0.90	--
Irrigations												
I_1	82	72	75	76.33	23.87	22.48	18.38	21.58	25.34	29.84	20	25.06
I_2	77	70	71	72.76	22.99	21.04	18.35	20.79	25.08	26.99	19	23.69
I_3	64	66	66	65.33	20.79	19.50	17.76	19.35	23.29	24.93	18	22.07
I_4	60	60	62	60.67	20.02	18.02	17.78	18.61	21.90	20.98	18	20.29
I_5	46	45	45	45.33	17.22	14.79	16.80	16.27	17.80	14.97	17	16.59
SE ±	1.27	2.83	0.91	--	0.20	0.93	0.39	--	0.42	0.78	0.48	--
CD at 5 %	3.77	8.40	2.7	--	0.60	2.76	1.17	--	1.24	2.31	1.43	--
Interaction (G x I)												
SE ±	1.80	4.00	1.29	--	0.28	1.32	0.55	--	5.95	1.10	0.68	--
CD at 5 %	NS	NS	3.48		NS	NS	1.65		NS	NS	2.02	

DAS and P and K at the time of sowing. The biometric and yield observations were taken. The growth of the crop was measured by means of plant heights, which were determined periodically throughout the growing period. Gross plot size of plot was 6.00 x 6.75 m and net plot size was 3.50 x 6.6 m for wide row 45 x 12- 75 cm for paired row of 45 cm after 75 cm spacing.

Results and Discussion

In Maharashtra state, *rabi* sorghum depends upon residual soil moisture of monsoon. This research project work was initiated with objectives to assess the response of sorghum varieties to drip irrigation. The experimental soil shows *Vertisol* (light to medium black with moderate drainage) property. The soil pH is around 8.26 in the ploughed layers. The soils are medium in organic carbon (0.65%) and P_2O_5 (10.26 kg/ha) and high in K_2O (445 kg/ha) and calcareous in nature. Bartlet test of homogeneity indicated that the variance of data of all seasons was insignificant. Thus, combined analysis was carried out for data for all traits. Year effect and its interaction with the factors under investigation were insignificant. Accordingly, means of all seasons were calculated.

Yield and yield attributing characters: Results pertaining to the yield and yield attributes parameters are presented in Table 3. Three years pooled analysis data indicate that irrigation schedule systems significantly affected grain yield. Data indicated that the drip irrigation system gave significantly the highest (57.67 q/ha) grain yield with treatment I_1 irrigation schedule (drip at 100% CPE). The next best irrigation schedule was I_2 (irrigation at 75% CPE) with (53.78 q/ha) grain yield. Irrigation treatment I_1 and I_2 were at par for grain yield and significantly superior over I_3, I_4 & I_5. Among cultivar response, PKV Kranti (AKSY 18 R) variety was recorded higher grain yield (41.85 q/ha) as compared to Parbhani Jyoti (38.44 q/ha). Interaction effect on grain yield was found non-significant. In respect of fodder yield, PKV Kranti was recorded higher fodder yield as compared to Parbhani Jyoti but effect was non-significant. Irrigation treatment I_1 and I_2 are statistically at par for fodder yield but significantly superior over I_3, I_4 and I_5. The interaction effect was non significant. In case of 100 seed weight variety Parbhani Jyoti was recorded significantly higher seed weight as compared to Akola Kranti. Similarly irrigation schedule I_1 was significantly superior over I_3, I_4 and I_5 whereas it was at par with I_2. The interaction effect on 100 seed weight was non significant. In case of sorghum plant height, variety Akola Kranti was recorded significantly higher plant height as compared to Parbhani Jyoti. Similarly, irrigation schedule I_2 was significantly superior over I_3, I_4 and I_5 whereas it was at par with I_1. Growth attributing and yield attributing characters (like test weight; panicle per plot, panicle weight, panicle length, panicle girth, primaries per panicle, grain wt per panicle and panicle wt. per plot.) were significantly influenced by different irrigation methods and cultivars of *rabi* sorghum. Influenced irrigation levels showed remarkable changes among different cultivar as shown in Table 1 and 2. Drip irrigated sorghum significantly produced more yield with higher test weight over surface irrigated sorghum during all three years of experimentation.

The low yield obtained with I_4 and I_5 treatment could be

Table 2 : Growth and yield attributing characters of *rabi* sorghum as influenced by irrigation levels (pooled data)

Treatments	Panicle/plot				Panicle weight (g)				Grain wt/Panicle				Panicle wt/Plot			
Genotypes	2009-2010	2010-2011	2011-2012	Pooled	2009-2010	2010-2011	2011-2012	Pooled	2009-2010	2010-2011	2011-2012	Pooled	2009-2010	2010-2011	2011-2012	Pooled
V1-SPV 1595	344	171	309	274.67	119	102	133	118.00	115.60	85.41	110.77	103.93	11.87	6.63	14	10.83
V2-AKSV 18R	347	176	309	277.33	125	115	132	124.00	120.80	94.46	111.28	108.85	14.28	7.33	14	11.87
SE ±	1.12	1.45	0.49	1.02	2.02	1.02	1.47	1.50	1.45	0.24	1.49	1.06	0.57	0.28	0.07	0.31
CD at 5 %	NS	4.30	1.47		6.00	3.02	4.37	4.46	4.31	0.72	4.4	3.14	1.71	0.84	0.23	0.93
Irrigations																
I_1	370	185	311	288.67	152	147	160	153.00	142.50	134.00	137.62	138.04	19.50	9.61	19.29	16.13
I_2	361	180	311	284.00	145	136	155	145.33	139.50	121.44	135.32	132.09	17.72	9.29	17.25	14.75
I_3	359	177	309	281.67	135	119	148	134.00	130.00	80.87	128.27	113.05	14.50	7.50	14.12	12.04
I_4	348	166	307	273.67	118	92	128	112.67	112.00	66.94	103.12	94.02	8.38	5.16	12.60	8.71
I_5	377	158	308	281.00	75	49	73	65.67	67.00	46.43	50.80	54.74	5.73	3.33	8.36	5.81
SE ±	12.84	2.29	0.49	5.21	3.20	1.61	2.33	2.38	2.29	0.38	2.35	1.67	0.91	0.44	0.12	0.49
CD at 5 %	38.08	6.80	1.47	15.45	9.49	4.78	6.91	7.06	6.82	1.14	6.99	4.98	2.70	1.33	0.37	1.47
Interaction (G x I)																
SE ±	18.15	3.24	1.11	7.50	4.52	2.28	3.29	3.36	3.25	0.54	3.33	2.37	1.29	0.63	0.17	0.70
CD at 5 %	NS	NS	3.30		NS	NS	9.77		NS	1.61	9.89		NS	NS	0.52	

explained, as highlighted by the crop water stress since all crop management factors were similar for all treatments. Indeed, the water stress was caused by the large irrigation interval on January-February which occurred during the flowering and grain filling stage and reduces the number of primaries per panicle, grain wt per panicle and panicle wt. per plot. Pre-flowering drought is most harmful at panicle differentiation since panicle size may be directly affected, which later reduces grain number and grain yield (Tuinstra *et al.,* 1996). However, plants are most sensitive to drought at flowering for the same reasons. Post-flowering drought is expressed when moisture stress occurs during grain development. During this period, there is a fast premature leaf death that often leads to charcoal rot, stalk lodging and yield losses (Nooden *et al.,* 1997). However, no significant differences were observed in case of number of panicle per plot due to irrigation methods and cultivars. This indicates that panicle number/plant is a genetic character and cannot be altered easily. This result was consistent with the findings of Sakellariou and Makrantonaki (2007) in sweet sorghum and Lamm *et al.* (2010) in sunflower, soybean and grain sorghum crop.

In pooled analysis, among different cultivars, maximum test weight (100 seed weight) (3.40 g.) recorded with Parbhani Jyoti (SPV-1595), whereas cultivar PKV Kranti (AKSV- 18R) recorded lowest 100 seed weight (3.24 g.). Among different irrigation levels, I_1 (irrigation at 1.0 ET_c drip) recorded maximum 100 seed weight (3.889) in three years pooled results which was found at par with I_2 treatment *i.e.* (irrigation at 0.75 ET_c drip) and were found significantly superior over rest of treatments. The lowest 100 seed weight (2.76 g.) was observed in *rabi* sorghum with I_5 (rainfed). The interaction effect was found non-significant.

As regards the panicle weight per plot, maximum panicle weight (11.87 kg/plot) was observed in PKV Kranti (AKSV-18R) followed by (10.83 kg/plot) in Parbhani Jyoti (SPV-1595). Among different irrigation levels, irrigation at 1.0 ET_c drip *i.e.* I_1 treatment recorded maximum panicle weight (16.13 kg/plot) which was at par with I_2 irrigation level (14.75 kg/plot) whereas lowest panicle weight (5.81 kg/plot.) observed in I_5 (rainfed).

Water use efficiency (2009-10, 2010-11 and 2011-12) and B:C ratio: Irrigation scheduling involves the determination of the appropriate timing of irrigation and the necessary amount of water to be applied so that the plant water stress can be controlled at critical growth stages. The combination of cultivating drought-tolerant crops using surface or subsurface drip irrigation could be characterized as positive as far as water-use efficiency is concerned. Furthermore, advanced technologies can be used to optimize water-use efficiency. Results pertaining to water use efficiency as affected by different treatments are presented in Table 4. Surface irrigation recorded the lowest water use efficiency (9.67 kg/ha-mm). As compare to different irrigation schedule, the highest water use efficiency (19.72 kg/ha-mm) was observed under drip irrigation of 0.75 ET_c (I_2). In the year 2010-11 and 2011-12 surface irrigation recorded the lowest water use efficiency (7.87 kg/ha-mm) and (12.54 kg/ha-mm), respectively. As compare to different irrigation schedules, the highest water use efficiency (18.83 kg/ha-mm and 21.37 kg/

Table 3 : Growth and yield attributing characters of *rabi* sorghum as influenced by irrigation levels (Pooled data)

Treatments	100 Seed wt (g)				Grain yield (q/ha)				Fodder yield (q/ha)				Harvest index			
Genotypes	2009-2010	2010-2011	2011-2012	Pooled	2009-2010	2010-2011	2011-2012	Pooled	2009-2010	2010-2011	2011-2012	Pooled	2009-2010	2010-2011	2011-2012	Pooled
V1-SPV 1595	3.68	3.23	3.28	3.40	36.53	36.03	42.77	38.44	71.53	68.51	61.02	67.02	26.44	34.49	40.02	33.65
V2-AKSV 18R	3.43	2.99	3.31	3.24	43.69	39.78	42.07	41.85	71.56	75.07	61.57	69.40	29.29	33.63	39.52	34.15
SE ±	0.024	0.188	0.05	0.06	1.10	1.14	0.58	0.93	2.66	2.27	0.58	1.91	0.11	0.67	0.39	-
CD at 5 %	0.072	NS	NS	0.17	3.28	NS	NS	2.77	NS	NS	NS	NS	0.34	NS	1.17	-
Irrigations																
I_1	4.04	3.87	3.72	3.88	57.34	52.49	61.58	57.67	82.25	97	81.65	88.57	32.75	35.83	42.98	37.19
I_2	3.93	3.58	3.55	3.68	54.63	49.82	55.41	53.78	94.16	86	77.16	85.83	33.64	37.09	40.86	37.20
I_3	3.75	2.92	3.16	3.27	40.84	39.59	37.11	39.88	73.75	81	54.34	69.68	27.55	34.16	40.54	34.08
I_4	3.13	2.65	3.24	3.01	31.88	26.77	39.49	33.49	62.91	65	56.96	61.46	24.94	33.13	40.94	33.00
I_5	2.94	2.53	2.81	2.76	15.86	12.51	18.52	15.92	39.66	30	36.36	35.51	20.46	30.09	33.52	28.02
SE ±	0.038	0.297	0.087	0.09	1.75	1.80	0.92	1.47	4.21	3.60	0.92	3.02	10.11	1.06	0.62	-
CD at 5 %	0.114	0.881	0.263	0.28	5.20	5.35	2.73	4.39	12.49	10.68	2.73	8.96	0.54	3.15	1.86	-
Interaction (G x I)																
SE ±	0.05	0.42	0.12	0.13	2.47	2.55	1.3	2.09	5.59	5.09	1.30	8.86	0.25	1.50	0.88	-
CD at 5 %	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	2.63	-
				3.32				40.15				68.21				

Table 4 : Water use efficiency of *rabi* sorghum (kg/ha-mm) (2009-10, 2010-11 and 2011-12)

Irrigation Schedule	Grain yield q/ha	Irrigation water use (mm)	Eff. Rain (mm)	Total water use (mm)	WUE kg/ ha-mm
WUE 2009-10 (kg/ha-mm)					
I_1 - Irrigation of 1.0 ET_c (drip)	57.34	279.4	44.8	324.2	17.69
I_2 - Irrigation of 0.75 ET_c (drip)	54.63	232.16	44.8	276.96	19.72
I_3 - Irrigation of 1.0 ET_c at CGS (drip)	40.84	203.16	44.8	247.96	16.47
I_4 - Surface-irrigation at CGS (4 irrigations)	31.88	285.0	44.8	329.8	9.67
I_5 - Rainfed	15.87	30.0	44.8	74.8	21.21
WUE 2010-11 (kg/ha-mm)					
I_1 - Irrigation of 1.0 ET_c (drip)	52.49	295.6	25	320.6	16.37
I_2 - Irrigation of 0.75 ET_c (drip)	49.82	239.64	25	264.64	18.83
I_3 - Irrigation of 1.0 ET_c at CGS (drip)	39.59	225.62	25	250.62	15.79
I_4 - Surface-irrigation at CGS (4 irrigations)	26.77	315.0	25	340.0	7.87
I_5 - Rainfed	12.51	30.0	25	55.0	22.75
WUE 2011-12 (kg/ha-mm)					
I_1 - Irrigation of 1.0 ET_c (drip)	61.58	340.8	0.00	340.8	18.07
I_2 - Irrigation of 0.75 ET_c (drip)	55.41	259.3	0.00	259.3	21.37
I_3 - Irrigation of 1.0 ET_c at CGS (drip)	37.11	251.10	0.00	251.10	14.78
I_4 - Surface-irrigation at CGS (4 irrigations)	39.49	315.0	0.00	315.0	12.54
I_5 - Rainfed	18.52	75.0	0.00	75.0	24.69

Table 5 : B:C ratios of different drip irrigations schedules for *rabi* sorghum 2011-12

Treatments	Pool grain yield	Pool fodder yield	Cost of cultivation	Net returns (₹)	B:C
I_1	61.58	88.57	32309	110890	3.47
I_2	55.41	85.83	32309	98689	3.12
I_3	37.11	69.68	32309	69694	2.09
I_4	39.49	61.46	24382	69080	2.95
I_5	18.52	35.51	17795	28377	1.90

ha-mm) was observed under drip irrigation of 0.75 ET_c (drip). Similar reasons were put forward by Kharroul *et al*. (2011). Similar water use efficiency and yield result was observed in winter wheat under different irrigation regimes in a semi-arid region. As shown in Table 5, B:C ratio was found maximum in I_1 irrigation schedule (B:C:3.47) followed by I_2 (3.12) in 2011-12 year.

Based on 3-year study performance of sorghum cultivars under levels of irrigation in winter season, it is concluded that the drip method excels the quantitative and qualitative characteristics of growth, productivity and the water use efficiency of the *rabi* sorghum var. AKSV 18R (PKV Kranti) cultivation in Maharashtra. Cultivars AKSV 18R produced significantly higher grain and fodder yield over SPV 1595 and highest water use efficiency (19.72 kg/ha-mm) was observed under drip irrigation of 0.75 ET_c over surface irrigated sorghum in all three years. This superiority is mainly owing to the best water distribution in the depth of the rooting zone. Using such systems, irrigation water and injected fertilizers are delivered directly to the crop's rooting zone, this is particularly advantageous for nutrients with low mobility in the soil. The high installation cost and the difficulty of inspecting and repairing the system may be considered disadvantages to this method.

Conclusions

A field experiment was conducted during consecutive three *rabi* seasons 2009-10, 2010-11 and 2011-12 to evaluate the performance of sorghum cultivars under different levels of irrigation in winter season. As a general conclusion, based on the above analysis, the cultivation of energy plant sorghum seems to be profitable under drip irrigation conditions. The use of new technology (irrigation scheduling with ET_c) is profitable for the farmer, while the system proved quite reliable in the open-field conditions under consistent full use. A combination of new technology and certain cultivation techniques could increase the gross margin for the farmer even more. Among the cultivars 'AKSV 18R' (PKV Kranti) produced significantly higher grain yield and fodder yield over all other cultivars in all three years. The highest water use efficiency (19.72 kg/ha-mm) was observed under drip irrigation of 0.75 ET_c over surface irrigated sorghum in all three years. So, under the Marathwada, Vidharbha and Western Maharashtra conditions, it can be suggested that farmers cultivate *rabi* sorghum and schedule their irrigations using soil moisture with drip.

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References

Awaghad PR, Ganvir BN and Bhopale AA. 2010. Growth and instability of *kharif* sorghum in Western Vidarbha region. J. Soils Crops, 20(1): 111-117.

Brown RH, Beaty ER, Ethredge WJ and Hays DD. 1970. Influence of row width and plant population on yield of two varieties of corn (*Zea mays* L.). Agron. J., 62: 767-770.

Fulton JM. 1970. Relationships among soil moisture stress, plant populations, row spacing, and yield of corn. Canadian J. Plant Sci., 50: 31-38.

Lamm FR, Abou Kheira AA and Trooien TP. 2010. Sunflower, soybean and grain sorghum crop production as affected by drip line depth. Amer. Soc. Agric. Biol. Eng., 26(5): 873-882.

Mourad AE, Latif SJ and Hovny MRA. 2000. Influence of irrigation numbers and different nitrogen rates on growth and yield of grain sorghum. Egypt J. Appl. Sci., 15(11):192–207.

Kharroul MH, Salah Er-Raki, Ahmed C, Benoit D, Vincent S, Michel L, Lahcen O and Lionel J. 2011. Water use efficiency and yield of winter wheat under different irrigation regimes in a semi-arid region. J. Agric. Sci., 2(3): 273-282.

Nooden LD, Guiamet JJ and John I. 1997. Senescence mechanisms. Physiologia Plantarum, 101:746-753.

Rosenow DR, Quisenberry JE, Wendt CW and Clark LE. 1983. Drought tolerant sorghum and cotton germplasm. J. Agric.Water Manage., 7: 207–222.

Staggenborg SA, Fjell DL and Devlin DL. 1999. Grain sorghum response to row spacing and seeding rates in Kansas. J. Prod. Agric., 12(3): 390-395.

Sakellariou M and Makrantonaki. 2007. Effect of modern irrigation methods on growth and energy production of sweet sorghum (var. Keller) on a dry year in Central Greece. J. Agric. Water Manage., 90: 181-189.

Srivastava NN, Rao VUM and Subba Rao AVM. 2009. Radiation and water use efficiencies of a popular variety (SPV 462) and a promising hybrid (CSH 14) of sorghum under semi-arid climatic conditions of Hyderabad. Indian J. Dryland Agricu. Res. Dev., 24(2): 46-52.

Tuinstra MR, Grote EM, Goldsbrough PB and Ejeta G. 1996. Identification of quantitative trait loci associated with pre-flowering drought tolerance in sorghum. Crop Science, 36: 1337-1344.

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