Environment & Ecology 35 (3C) : 2329—2333, July—September 2017
Website: environmentandecology.com ISSN 0970-0420

Water Productivity of Drip Irrigated *Rabi* Sorghum Influenced by Different Irrigation Levels

C. Satish, K. Avil Kumar, V. Praveen Rao, M. Uma Devi

Received 20 October 2016; Accepted 22 November 2016; Published online 12 December 2016

Abstract The field experiment was conducted during *rabi* 2014-2015 with CSH-16 sorghum hybrid to study the effect of different drip irrigation levels i.e. drip irrigation at estimated 0.6 ETc throughout the life (I_1), 0.8 ETc throughout the life (I_2), 1.0 ETc throughout the life (I_3), 1.2 ETc throughout the life (I_4), 0.6 ETc up to flowering 0.8 ETc later on (I_5), 0.6 ETc up to flowering 1.0 ETc later on (I_6), 0.6 ETc up to flowering 1.2 ETc later on (I_7), 0.8 ETc up to flowering 1.0 ETc later on (I_8), 0.8 ETc up to flowering 1.2 ETc later on (I_9) and in addition to surface furrow irrigation at 0.8 IW/CPE ratio (I_{10}) on water productivity of drip irrigated *rabi* sorghum. Results indicated that the under deficit irrigation conditions, drip irrigation at 0.8 ETc up to flowering and 1.0 or 1.2 ETc later on followed by 0.6 ETc up to flowering and 1.2 ETc later on can be recommended over the drip irrigation 1.0 to 1.2 ETc throughout the life with minimum reduction in yield and for higher water productivity.

Keywords Drip irrigation, Surface irrigation, Water productivity, Relative water content *rabi* sorghum.

C. Satish*
Central Research Institute for
Dry Land Agriculture-CRIDA,
Hyderabad 500059, India

K. A. Kumar, V. P. Rao, M. U. Devi
Water Technology Center,
College of Agriculture Professor Jayashankar
Telangana State Agricultural University,
Rajendranagar, Hyderabad 500030, India
e-mail : satishchidrawar@gmail.com
*Correspondence

Introduction

Sorghum (*Sorghum bicolor* (L.) Moench) is one of the main staple crop for the world's poorest and most food-insecure people. It belongs to the family *Poaceae*, used for food, fodder, the production of alcoholic beverages and biofuels. Sorghum is truly a dual-purpose crop where both grain and stover are highly valued outputs. In large parts of the developing world, stover represents up to 50% of the total value of the crop, especially in drought years. Sorghum is the fifth most important cereal crop and is the dietary staple for more than 500 million people in 30 countries and grown in an area of 40 million ha in 105 countries of which USA, India, Mexico, Nigeria, Sudan and Ethiopia are the major sorghum producers [1]. The sorghum area in India is 6.10 million ha (2012-13), out of which 3.78 million ha in the post rainy (*rabi*) season and in Telangana it is grown in 1.09 lakh ha area with productivity of 1,015 kg ha^{-1}, respectively [2]. Water is increasingly becoming scarce because of erratic distribution of monsoons and uncontrolled exploitation of ground water. The global challenge for the coming decades is to increase the food pro-

Table 1. Irrigation, total water applied, effective rainfall and water productivity of *rabi* sorghum as influenced by different drip irrigation treatments.

Treatments	Irrigation water applied (mm)	Effective rainfall (mm)	Total water applied (mm)	Total water applied (m^3)	WP (kg m^{-3})	Grain yield (kg ha^{-1})
I_1- Drip irrigation at estimated 0.6 ETc throughout the life	177.4	18.34	195.7	1957.4	2.15	4209
I_2- Drip irrigation at estimated 0.8 ETc throughout the life	215.5	17.5	233.0	2330.0	2.96	6906
I_3- Drip irrigation at estimated 1.0 ETc throughout the life	253.7	16.75	270.5	2704.5	2.86	7738
I_4- Drip irrigation at estimated 1.2 ETc throughout the life	291.8	16.75	308.6	3085.5	2.74	8464
I_5- Drip irrigation at estimated 0.6 ETc up to flowering and 0.8 ETc later on	200.4	18.34	218.7	2187.4	2.45	5364
I_6- Drip irrigation at estimated 0.6 ETc up to flowering and 1.0 ETc later on	223.4	18.34	241.7	2417.4	2.67	6464
I_7- Drip irrigation at estimated 0.6 ETc up to flowering and 1.2 ETc later on	246.4	18.34	264.7	2647.4	2.98	7887
I_8- Drip irrigation at estimated 0.8 ETc up to flowering and 1.0 ETc later on	238.5	17.5	256.0	2560.0	3.07	7870
I_9- Drip irrigation at estimated 0.8 ETc up to flowering and 1.2 ETc later on	261.5	17.5	279.0	2790.0	2.95	8233
I_{10}- Surface furrow irrigation at 0.8 IW/CPE ratio with irrigation water of 50 mm	313.0	18.34	331.3	3313.4	1.91	6318
Mean	242.2	17.8	259.9	2599.3	2.68	6945
SEm±					0.13	325
CD (p=0.05)					0.39	965
CV					8.43	8.1

duction with less utilization of water. It can be partially achieved by increasing crop water use efficiency (WUE).

Materials and Methods

The field experiment was conducted during *rabi* 2014-2015 with CSH-16 sorghum hybrid at Water Technology Center College Farm, College of Agriculture, Rajendranagar, Professor Jayashankar Telangana State Agricultural University, Hyderabad on a sandy clay loam soil, alkaline in reaction and non-saline, low in available nitrogen, high in available phosphorus and available potassium, medium in organic carbon content with field capacity and permanent wilting point of 21.7 and 9.60%, respectively having available soil moisture of 76.50 mm in 0–45 cm depth, the recommended dose of fertilizer 100-60-40 kg NPK ha^{-1}, entire dose of P and K was applied as basal before sowing and N applied as fertigation in 6 splits of equal doses at 10 days interval from 15 days after sowing (DAS). The experiment was conducted in a randomized block design with ten treatments of drip irrigation schedules viz., drip irrigation at 0.6 ETc throughout the life (I_1), 0.8 ETc throughout the life (I_2),1.0 Etc throughout the life (I_3), 1.2 ETc throughout the life (I_4), 0.6 ETc up to flowering 0.8 ETc later on (I_5), 0.6 ETc up to flowering 1.0 ETc later on (I_6), 0.6 ETc up to flowering 1.2 ETc later on (I_7), 0.8 ETc up to flowering 1.0 ETc later on (I_8), 0.8 ETc up to flowering 1.2 ETc later on (I_9) in addition to surface furrow irrigation at 0.8 IW/CPE ratio (I_{10}) and replicated thrice. The data was analyzed statistically and N, P and K were estimated by following standard procedures. Sorghum was sown on October 2014 adopting a spacing of 0.40 m between rows and 0.15 m between plants to mean population of 1,66,666 plants ha^{-1}. Irrigation was scheduled based on USWB class a pan evaporation rates by estimating ETc by adopting suitable pan coefficient based on dally wind speed and relative

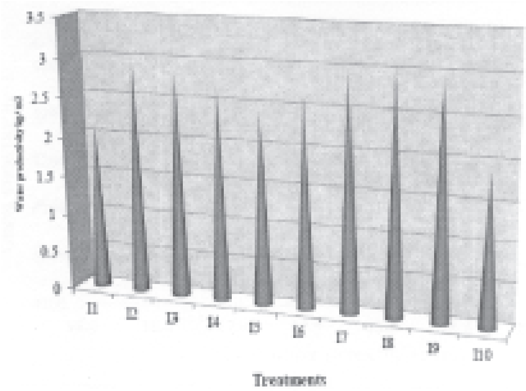

Fig. 1. Water productivity of *rabi* sorghum influenced by different irrigation levels.

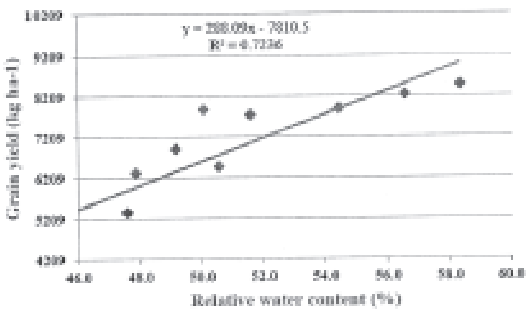

Fig. 2. Regression of grain yield kg ha^{-1} on relative water content (%).

humidity and crio coefficient as per crop stage as per FAO.

Results and Discussion

The data pertaining to quantity of water applied to *rabi* sorghum indicated that the ratio of ETc increased the quantity of water applied increased (Table 1). The quantity of irrigation water applied in each irrigation treatment was 177.4, 215.5, 253.7, 291.8, 200.4, 223.4, 246.4, 238.5, 261.5 and 313.5 mm and total water consumed including effective rainfall was 195.7, 233.0, 270.5, 308.6, 218.7, 241.7, 264.7, 256.0, 279.0 and 313.3 in 0.6 ETc throughout the life, 0.8 ETc throughout the life, 1.0 ETc throughout the life, 1.2 ETc throughout the life, 0.6 ETc up to flowering and 0.8 ETc later on, 0.6 ETc up to flowering and 1.0 ETc later on, 0.6 ETc up to flowering and 1.2 ETc later on, 0.8 ETc up to flowering and 1.0 ETc later on, 0.8 ETc up to flowering and 1.2 ETc later on and surface irrigation at 0.8 IW/CPE ratio, respectively.

Water productivity of drip irrigated *rabi* sorghum varied among different treatments and significantly higher water productivity (3.07 kg m^3) was recorded with estimated at 0.8 ETc up to flowering and 1.0 later on over the drip irrigation at 0.6 ETc up to flowering and 0.8 or 1.0 ETc later on, drip irrigation at estimated 0.6 ETc throughout the life and surface irrigation at 0.8 IW/CPE ratio and was on par with drip irrigation at 0.8 or 1.0 or 1.2 ETc throughout the life, drip irrigation at estimated 0.6 ETc up to flowering and 1.2 ETc later on and drip irrigation at 0.8 ETc up to flowering and 1.2 ETc later on (Table 1 and Fig. 1). With the increase in irrigation level, the WP decreases. Significantly lower water productivity (2.15 kg m^3) was observed drip irrigation at estimated ETc of 0.6 throughout the life and it was on par with surface irrigation 0.8 IW/CPE ratio and 0.6 ETc up to flowering and 0.8 ETc later on. Whereas surface furrow irrigation at 0.8 IW/CPE ratio recorded significantly lower productivity (1.91 kg m^3) compared to rest of drip irrigation treatments and except with drip irrigation at estimated 0.6 ETc throughout the life which was on par, as a result of water stress experienced by crop as evidenced by low leaf water content and high leaf water potential [3]. Similar results were reported in maize crop [4, 5].

Relative water content

The periodical relative leaf water content was recorded by taking leaf fresh weight, dry weight and turgid weights at different irrigation levels. Persual of data indicated that relative water content of *rabi* sorghum was progressively decreased with the age of the crop irrespective of the treatment (Fig. 2).

Drip irrigation scheduled at 1.2 ETc throughout the life recorded higher relative leaf water content (54.2 to 64.2%) as it maintained favorable soil moisture in the root zone. This enabled the plant to extract

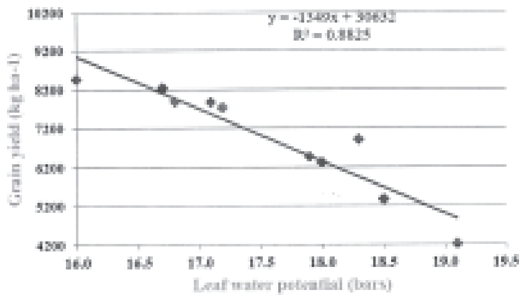

Fig. 3. Regression of grain yield kg ha^{-1} on leaf water potential.

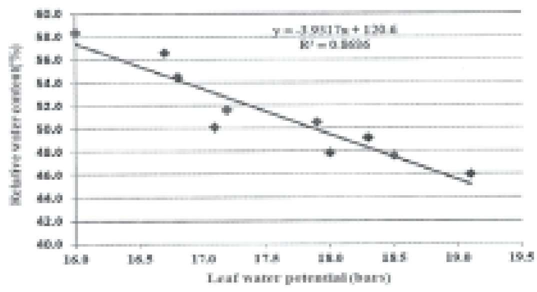

Fig. 4. Regression of relative water content on leaf water potential.

the water sufficiently so as to maintain leaf turgid over rest of the schedulings except with irrigation scheduled at 0.8 ETc up to flowering and 1.2 ETc later on (52.3 to 60.2%). While drip irrigation scheduled at 0.6 ETc throughout the life recorded lower relative leaf water content (39.8 to 52.2%). In case of surface irrigation scheduled at 0.8 IW/CPE ratio, though maintained lower relative water content (43.9 to 54.2%) as the plant extracted low moisture at higher depletion level as consequence of longer intervals between two successive irrigations.

There was a positive correlation (R^2=0.72, p<0.001) between yield and relative water content. As the relative water content increased significantly yield was increased as indicated from RWC of 46 to 58.3% yield increased from 4,209 to 8,464 kg ha^{-1}, respectively.

Leaf water potential

The periodical leaf water potential was monitored by pressure chamber apparatus at different drip irrigation treatments (Fig. 3). Persual of data showed that higher leaf water potential (-15.5 to -22.8 bars) was observed with drip irrigation at 0.6 ETc throughout the life, closely followed by drip irrigation scheduled at 0.6 ETc up to flowering and 0.8 ETc later on (-14.9 to -20.8 bars). Whereas, drip irrigation scheduled at 0.8, 1.0 and 1.2 ETC, 0.8 ETc up to flowering and 1.0 or 1.2 ETc later on and 0.6 ETc up to flowering and 1.0 or 1.2 ETc later on levels recorded lower leaf water potential compared to 0.6 ETc throughout the life and 0.6 ETc up to flowering 0.8 ETc later on. This may be due to high level of moisture depletion in root zone depth there by recorded lower leaf water potential. Whereas in surface irrigation scheduled at 0.8 IW/CPE ratio maintained higher leaf water potential (-14.7 to -20.3 bars) compared to other treatments as it received more amount of water (50 mm) per irrigation which recouped the soil moisture to the field capacity but showed low leaf water potential as crop plants sensed moisture stress at higher depletion level as a consequence of longer intervals between irrigations.

There was a positive correlation between leaf water potential and yield (R^2=0.88, p<.001) as indicated in Figure 4. Similarly, a positive correlation between leaf water potential and leaf relative water content (R^2=0.86, p<.001) was observed as Figure 4 as leaf water potential increased significantly yield was decreased as indicated from -16.0 to -19.1 bars yield decreased from 8,464 to 4,209 kg ha^{-1}, respectively.

Optimization of drip irrigation
for *rabi* sorghum

The functional relationship between *rabi* sorghum grain yield and total water applied was established following both linear and quadratic water production functions. The resultant functions and test statistics are as follows:

Linear:

$$Y = 21.113\ X + 1457.6 \qquad \text{....(Equation 3.1)}$$

R^2 = 0.3908 $\quad$ F value = 5.317

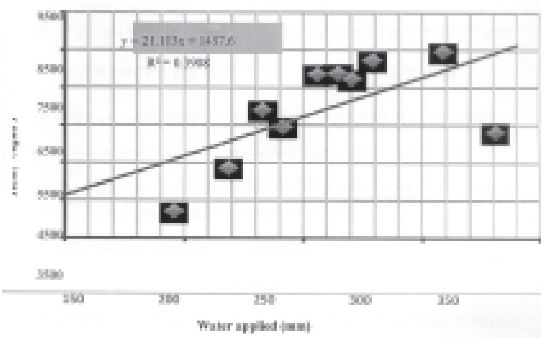

Fig. 5. Linear water production function *rabi* sorghum under different irrigation treatment.

Quadratic:

$Y = -0.5445 X^2 + 308.81 X - 35726$ .... (Equation 3.2)

$R^2 = 0.8997$ F value = 31.385

The test statistics (R^2 and F –value) of linear production function indicated that it was statistically not significant (Fig. 4). The explained total variation (R^2) in *rabi* sorghum yield was very low i.e. 39% (Equation 3.1). On the other hand the test statistics and R^2 were significant for quadratic production function (Equation 3.2). The explained total variation in *rabi* sorghum yield was 90.0% suggesting that in the present study the best fit for the data was obtained with quadratic form as water production function i.e. sorghum grain yield was increased with increase in total water applied, but the increase in sorghum yield was not proportional to the total water applied. The maximum yield (Y_{max}) was bracketed within the administrated water levels. The predicted maximum *rabi* sorghum yield (Y_{max}) of 7981.8 kg ha^{-1} was obtained with 283.8 mm of water. However, maximum water use efficiency was observed at 256 mm of water applied, where increase in a unit quantity of water increase in yield was at increasing rate and after that the yield was increased at decreasing rate. Hence under deficit irrigation maximum water productivity can be obtained by applying 256 mm water with drip irrigation at estimated 0.8 ETc up to flowering and 1.0 later on with 17% saving in water compared to drip irrigation at 1.2 ETc throughout the life as priority is increasing water productivity under shortage of water rather than higher productivity.

Conclusion

Water productivity of drip irrigated *rabi* sorghum varied among different treatments and significantly higher water productivity was recorded with estimated at 0.8 ETc up to flowering and 1.0 later on over the drip irrigation at 0.6 ETc up to flowering and 0.8 or 1.0 ETc later on, drip irrigation at estimated 0.6 ETc throughout the life and surface irrigation at 0.8 IW/CPE ratio. With the increase in irrigation level, the WP decreases. Under deficit irrigation conditions, drip irrigation at 0.8 ETc up to flowering and 1.0 or 1.2 ETc later on followed by 0.6 ETc up to flowering and 1.2 ETc later on can be recommended over the drip irrigation 1.0 to 1.2 ETc throughout the life with minimum reduction in yield and for higher water productivity. Maximum *rabi* sorghum yield (Y_{max}) of 7981.9 kg ha^{-1} was obtained with 283.8 mm of water in observed field conditions.

References

1. www.icrisat.org/sorghum.htm
2. DoES (2014) Season and crop report Telangana. Directorate of Economics and Statistics (DoES), Government of Telangana, pp 51.
3. Simsek M, Abdullah C, Nihat D, Tahsin T (2011) The effects of different irrigation regimes on yield and silage quality of corn under semi-arid conditions. Afri J Biotechnol 10 : 5869—5877.
4. Roncucci N, Triana F, Tozzini C, Bonari E (2014) Double row spacing and drip irrigation as technical options in energy sorghum management. Italian J Agron 9 : 563.
5. Manal M, El- Tantawy, Samiha OA, Fouad KA (2007) Irrigation scheduling for maize (*Zea mays* L.) grown under middle Egypt conditions. Res J Agric and Biol Sci 3 : 456—462.