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RESEARCH ARTICLE :

Optimization of irrigation water for drip irrigated *Rabi* sorghum by using aquacrop model

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SUMMARY : 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 to study the effect of different drip irrigation levels on optimization of drip irrigated *Rabi* sorghum *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 upto flowering 0.8 ETc later on (I_5), 0.6 ETc upto flowering 1.0 ETc later on (I_6), 0.6 ETc upto flowering 1.2 ETc later on (I_7), 0.8 ETc upto flowering 1.0 ETc later on (I_8), 0.8 ETc upto flowering 1.2 ETc later on (I_9) and in addition to surface furrow irrigation at 0.8 IW/CPE ratio (I_{10}). Results indicated that Observed grain yield values varied at estimated 0.6 ETc with drip irrigation 4209 kg ha^{-1} to 8464 kg ha^{-1} at 1.2 ETc among different irrigation levels to *Rabi* sorghum during 2014-15, while simulated grain by AquaCrop model ranged from 4030 kg ha^{-1} to 8075 kg ha^{-1}, respectively under the same irrigation treatments. The observed and simulated yields were almost equal; correlation coefficient is 0.98, so Aqua Crop model can be used under varying moisture levels.

KEY WORDS :
Drip irrigation, Optimization, *Rabi* sorghum, AquaCrop model

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BACKGROUND AND OBJECTIVES

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 the fifth most important cereal crop and is the dietary staple for more than 500 million people in 30 countries. Globally, sorghum is cultivated in 41 m ha to produce 64.20 mt, with productivity around 1.60 tonnes ha^{-1}. India contributes about 16 per cent of the world's sorghum production (*www.icrisat.org/sorghum.htm*). Sorghum is well adapted to semi-arid regions with minimum annual precipitation of 350-400mm. In dry areas with low or erratic rainfall the crop can respond very favorably to supplemental irrigation. The crop does well on most soils but better in light to medium textured soils. The soil should preferably be well-aerated and well-drained. Sorghum is relatively tolerant to short periods of water logging. Sorghum can produce an extensive fibrous root system as deep as 5-6 feet. It generally extracts more than 75 per cent of its water and nutrients from the top 3 feet of soil. As moisture is depleted from the top 3 feet, the crop will extract water (if available) from deeper in the root zone. Plants can use about 50 per cent of the total available water without undergoing stress. 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 1015 kg ha^{-1}, respectively (DoES, 2014).Water is increasingly becoming scarce because of erratic distribution of monsoons and uncontrolled exploitation of ground water. The basic information needed to optimize irrigation includes the precise knowledge of the relations between water use and crop yield. *i.e*. water production functions.

Aqua Crop is a windows-based software programme designed to simulate biomass and yield responses of field crops to various degrees of water availability. It is a tool for predicting crop production under different water-management conditions and different management strategies (including rainfed and supplementary, deficit and full irrigation), under present and future climate change conditions. AquaCrop model is simpler one, requires fewer input data, and it is highly reliable for the simulations of biomass, yield, and water demand. As such, it is recommended for applications under different climatic conditions (Stricevic *et al*., 2011). AquaCrop requires input data *viz*., weather data (air temperature, reference evapotranspiration and rainfall), soil texture type (% of sand, clay, loam) and crop parameters (initial, final and rate of change in per cent canopy cover, initial, final and rate of deepening in root depth, biomass water productivity, harvest index, typical management conditions such as irrigation dates and amounts, sowing and harvest dates, mulching, etc.).

RESOURCES AND METHODS

The field experiment was conducted at Water Technology Center, College farm, College of Agriculture, Rajendranagar, Professor Jayashankar Telangana State Agricultural University, Hyderabad during *Rabi* 2014-2015 with CSH-16 sorghum hybrid 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 per cent, 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 upto flowering 0.8 ETc later on (I_5), 0.6 ETc upto flowering 1.0 ETc later on (I_6), 0.6 ETc upto flowering 1.2 ETc later on (I_7), 0.8 ETc upto flowering 1.0 ETc later on (I_8), 0.8 ETc upto flowering 1.2 ETc later on (I_9) in addition tosurface furrow irrigation at 0.8 IW/CPE ratio (I_{10}) and replicated thrice. 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 daily wind speed and relative humidity and crop coefficient as per crop stage as per FAO (Allen *et al*., 1988). The data was analyzed statistically and N, P and K were estimated by following standard procedures.

OBSERVATIONS AND ANALYSIS

The results obtained from the present study as well as discussions have been summarized under following heads:

Optimization of water using simulated *Rabi* sorghum yield by AquaCrop :

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

Linear:

$$Y = 21.986\ X + 711.15 \qquad \ldots (1)$$

$R^2 = 0.448$ F value = 6.497

Quadratic:

$$Y = -\ 0.4639\ X^2 + 267.07\ X - 30965 \qquad \ldots (2)$$

$R^2 = 0.8388$ F value = 18.210

The test statistics (R^2 and F – value) of linear production function indicated that it was statistically not significant (Fig.1). The explained total variation (R^2) in *Rabi* sorghum simulated yield was very low *i.e.* 44 per cent (Eq. 1). On the other hand the test statistics and R^2 were significant for quadratic production function (Eq. 2). The explained total variation in *Rabi* sorghum simulated yield was 83.8 per cent, suggesting that in the present study the best fit for the data was obtained with quadratic form of water production function *i.e.* sorghum simulated grain yield was increased with increase in total water applied, but the increase in sorghum yield was not proportional to the total water applied (Fig. 2). The maximum yield (Y_{max}) was bracketed within the administrated water levels. The predicted maximum *Rabi* sorghum yield (Y_{max}) of 7398 kg ha^{-1} was obtained with 287.8 mm of water by AquaCrop model compared to the predicted maximum *Rabi* sorghum yield (Y_{max}) of 7981.8 kg ha^{-1}was obtained with 283.8 mm of water inobserved field conditions. Under deficit irrigation conditions, maximum water productivity was observed at 256 mm of water consumed as per simulated yield by AquaCrop when drip irrigation scheduled at estimated 0.8 ETc throughout the life.

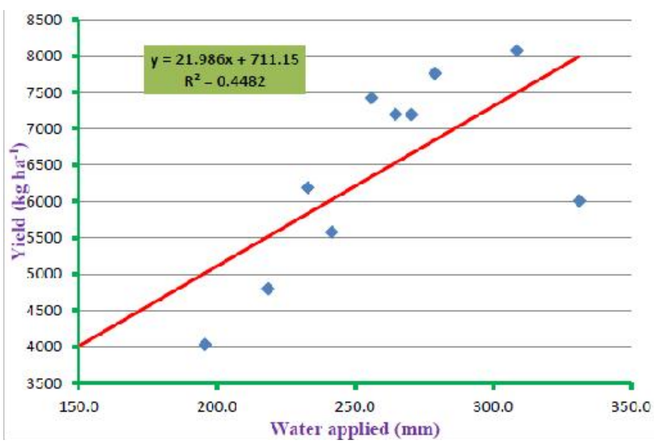

Fig. 1: Linear water production function of *Rabi* sorghum under different irrigation treatments by using AquaCrop model

AquaCrop was used to simulate grain yield compared to those of observed in field experiment with a view to assess the performance of the model in simulating yield. Observed grain yield values varied from 4209 kg ha^{-1} with drip irrigation at estimated 0.6 ETc to 8464 kg ha^{-1} at 1.2 ETc among different irrigation levels to *Rabi* sorghum during 2014-15 (Table 1), while simulated grain yield by AquaCrop model ranged from

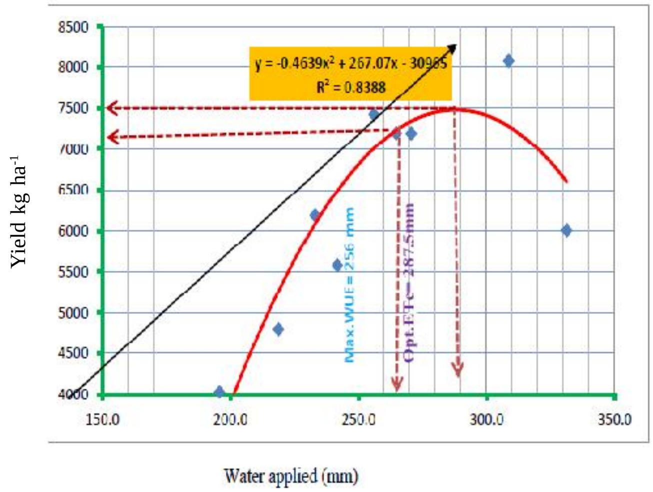

Fig. 2 : Quadratic water production function *Rabi* sorghum under different irrigation treatments by using AquaCrop model

4030 kg ha^{-1} to 8075 kg ha^{-1}, respectively under the same irrigation treatments, wherein 0.6 ETc was lower and 1.2 ETc was higher treatments. Surface irrigation at 0.8 IW/CPE ratio simulated yield value 6009 kg ha^{-1} and it was lower than drip irrigation treatments, though it was higher than drip irrigation at estimated 0.6 ETc throughout the life. The correlation co-efficient (R^2 =0.98) between observed and simulated yield by AquaCrop was significant. The simulations by AquaCrop model was varied by 97 per cent in the yield (Fig. 3). Observed yield values and simulated yield values almost equal, so by using AquaCrop model we can predict the yield of *Rabi* sorghum under varying moisture levels without conducting experiment.

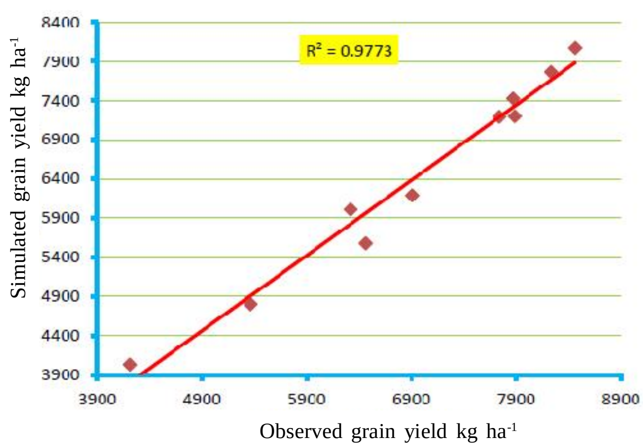

Fig. 3 : Comparison of AquaCrop simulated yield with that observed yield of *Rabi* sorghum

Table 1 : Observed and simulated grain yield of *Rabi* sorghum as influenced by drip irrigation treatments

	Treatments	Observed grain yield (kg ha^{-1})	Simulated grain yield (kg ha^{-1})	Error per cent	RMSE kg ha^{-1}	Water productivity with simulated yield (kg m^{-3})
I_1	Drip Irrigation at estimated 0.6 ETc throughout the life	4209	4030	-4.3	56.6	2.06
I_2	Drip Irrigation at estimated 0.8 ETc throughout the life	6906	6190	-10.4	226.4	2.66
I_3	Drip Irrigation at estimated 1.0 ETc throughout the life	7738	7193	-7.0	172.3	2.66
I_4	Drip Irrigation at estimated 1.2 ETc throughout the life	8464	8075	-4.6	123.0	2.62
I_5	Drip Irrigation at estimated 0.6 ETc upto flowering and 0.8 ETc later on	5364	4798	-10.6	179.0	2.19
I_6	Drip Irrigation at estimated 0.6 ETc upto flowering and 1.0 ETc later on	6464	5578	-13.7	280.2	2.31
I_7	Drip Irrigation at estimated 0.6 ETc upto flowering and 1.2 ETc later on	7887	7197	-8.7	218.2	2.72
I_8	Drip Irrigation at estimated 0.8 ETc upto flowering and 1.0 ETc later on	7870	7424	-5.7	141.0	2.90
I_9	Drip Irrigation at estimated 0.8 ETc upto flowering and 1.2 ETc later on	8233	7763	-5.7	148.6	2.78
I_{10}	Surface furrow irrigation at 0.8 IW/CPE ratio with irrigation water of 50 mm	6318	6009	-4.9	97.7	1.81

Conclusion :

The predicted maximum *Rabi* sorghum yield (Y_{max}) of 7398 kg ha^{-1} was obtained with 287.8 mm of water by AquaCrop model compared to the predicted maximum *Rabi* sorghum yield (Y_{max}) of 7981.8 kg ha^{-1} was obtained with 283.8 mm of water in observed field conditions. Observed yield values and simulated yield values almost equal, so by using AquaCrop model we can predict the yield of *Rabi* sorghum under varying moisture levels without conducting experiment.

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