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Effect of irrigation schedules and sowing time on growth, yield attributes, yield and water use efficiency of sorghum during *rabi* season

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Abstract
A field experiment was conducted on clay soils of Advanced Post Graduate Centre, Lam, Guntur to study the effect of irrigation schedules and sowing time on growth, yield attributes, yield and water use efficiency of sorghum during *rabi* 2018-19. The experiment was laid out in strip-plot design with three irrigation schedules *i.e.*, 0.3 W/CPE (I_1), 0.5 IW/CPE (I_2) and 0.7 IW/CPE (I_3) were allotted in horizontal strips and four dates of sowing *i.e.*, 2nd fortnight of September (D_1), 1st fortnight of October (D_2), 2nd fortnight of October (D_3) and1st fortnight of November (D_4) in vertical strips and replicated thrice. Among the different irrigation schedules, irrigation scheduled at 0.7 IW/CPE recorded the highest plant height, dry matter production, yield attributes, grain yield and straw yield when compared to 0.5 IW/CPE and 0.3 IW/CPE. Sorghum crop sown on 1st fortnight of October (D_2) recorded significantly higher growth, yield attributes, grain yield and harvest index when compared to 2nd fortnight of October (D_3) and 1st fortnight of November (D_4) but comparable with 2nd fortnight of September (D_1). The grain yield reduction in 1st fortnight of November (D_4) was 52 % when compared to 1st fortnight of October due to low temperatures recorded at flowering stage. The highest water use efficiency was recorded in I_2D_3 (0.5 IW/CPE and 2nd fortnight of October sown crop) which was comparable with I_1D_2 (0.7 IW/CPE and 1st fortnight of October sowing).

Keywords: Sorghum, irrigation schedules, sowing time, yield, water use efficiency

Introduction
India is the second largest producer of sorghum in the world, it occupies an area of 5.6 m ha with a production of 4.5 m t and productivity of 812 kg ha^{-1}. In Andhra Pradesh it is grown in an area of 0.97 lakh hectares with a production of 1.98 lakh tonnes and productivity of 2041 kg ha^{-1} (www.indiastat.com). Maharashtra ranks first in area and production and Andhra Pradesh ranks first in productivity. *Rabi* sorghum (post rainy season) has multifaced problems. Generally, the crop is raised mostly under rainfed conditions with the help of stored moisture. Therefore, the moisture deficit especially during later stages of crop growth poses a serious threat to the crop consequently and resulted in lower yields.Water stands next to fertilizer in augmenting the crop yield. Agricultural productivity cannot be maintained without assured supply of moisture to the plant, which is accomplished by irrigation. Proper irrigation scheduling is essential for efficient use of water and optimum crop production. Among different approaches, scheduling irrigation to crops based on climatological approach (based on irrigation water and cumulative pan evaporation ratio) is the most appropriate, as it integrates all the weather parameters giving their natural weightage in a given soil-plant-atmosphere continuum. Grain yield of sorghum was significantly higher when irrigation was given at 0.8 IW: CPE ratio as compared to other irrigation regimes *viz*., IW: CPE ratio of 0.65, 0.50, 0.35, 0.20 and 0.05 (Wakchaure *et al*. 2016) [15]. Sorghum is a warm-season, annual crop, favored by high day and night temperatures and intolerant to low temperatures. The proper sowing time exerts a marked effect on the growth and eventually on the yield of a crop. Sowing of the crop at right time ensures better plant growth and also inhibits weed growth. There are evidences that optimum time of sowing is one of the several cultural manipulations and play vital role in boosting up the yield, particularly in Indian subcontinent where the optimum time of sowing varies to great extent due to varying agro-climatic conditions.

First fortnight of October recorded significantly higher grain yield of sweet sorghum as compared to sowing of crop in second fortnight of September and second fortnight of October in medium black clay soils of Dharwad (Reddi *et al.*, 2013) [11]. Crop sown on 1st week of October showed higher grain yield when compared to crop sown on 3rd week of October and 1st week of November (Hulihalli *et al*., 2016) [5].

Materials and Methods

The field experiment was conducted during the *rabi* season of 2018-19 at Advanced Post Graduate Centre, Lam, Guntur. The experimental site was geographically situated at an altitude of 315 m above mean sea level, 16° 36´ N latitude and 80° 43´ E longitude and falls under Krishna Agro-climatic Zone of Andhra Pradesh, India.

The experiment was laid out in strip-plot design with three irrigation schedules *i.e.*, 0.3 IW/CPE (I_1), 0.5 IW/CPE (I_2) and 0.7 IW/CPE (I_3) in horizontal strips and four dates of sowing *i.e*., 2nd fortnight of September (D_1), 1st fortnight of October (D_2), 2nd fortnight of October (D_3) and 1st fortnight of November (D_4) in vertical strips and replicated thrice.

The soil of the experimental site was clay with pH 8.3, medium in organic carbon (0.6 %) and low in available nitrogen (183 kg ha-1), medium in available phosphorus (17 kg ha^{-1}) and potassium (189 kg ha^{-1}). Recommended dose of fertilizer @ 80 kg N ha^{-1}, 60 kg P_2O_5 ha^{-1} and 40 kg K_2O ha^{-1} was applied uniformly to all the experimental plots. Entire dose of phosphorus in the form of single super phosphate and potassium in the form of muriate of potash and half of the dose of nitrogen in the form of urea were applied as basal and the remaining half of the nitrogen was applied at 40 DAS. Irrigations were given to I_1, I_2 and I_3 treatments when the cumulative pan evaporation values reached to 200 mm, 120 mm and 85.76 mm, respectively.

Results and Discussion

A significant increase in plant height (278 cm) was observed at harvest with irrigation scheduled at 0.7 IW/CPE but it was found on par with irrigation scheduled of 0.5 IW/CPE (270 cm) and significantly superior over irrigation scheduled at 0.3 IW/CPE (248 cm). Increased plant height with increasing number of irrigations was also reported by Balazzii Naik *et al.* (2015) [2]. Wakchaure *et al*. (2016) [15]. and Chaitanya *et al*. (2017) [4]. Significantly higher plant height was recorded in 1st fortnight of October (278 cm) and statistically on a par with 2nd fortnight of September (273 cm), but significantly superior over the crops sown at 2nd fortnight of October (264 cm) and 1st fortnight of November (246 cm). Similar results were also reported by (Ikramullah *et al*., 1996) [8]. and (Hussein and Sabbour., 2012) [6]. The yield components *viz*., number of earheads per m^2 (12.6), number of grains per earhead (1471) and 1000 grain weight (35.7 g) were highest when irrigations were given with 0.7 IW/CPE (I_3) compared to other irrigation treatments. The lowest number of grains per earhead recorded at 0.3 IW/CPE might be due to lower moisture availability. Among the dates of sowing, 1st fortnight of October (D_2) sown crop recorded higher yield components such as number of earheads per m^2 (12.7), number of grains per earhead (1672) and 1000 grain weight (35.7 g) followed by 2nd fortnight of September (D_1) and 2nd fortnight of October (D_3), whereas the lowest yield components were recorded in 1st fortnight of November (D_4). Maulana and Tesso (2013) [9]. reported that the number of seeds per panicle in sorghum was 388 when crop suffer with cold temperature stress at flowering and pollination compared to 846 grains per earhead under normal temperature. Less number of seeds per ear head in late sowing was due to less production of photosynthates.

Among different irrigation schedules higher grain yield (3003 kg ha^{-1}) and straw yield (6535 kg ha^{-1}) were recorded with irrigation scheduled at 0.7 IW/CPE (I_3) and lower grain yield and straw yield were recorded with 0.3 IW/CPE (I_1). This might be due to decreasing water supply by increasing the time between irrigations and resulted in a significant reduction in growth, yield parameters and grain yield of sorghum. Similar results were reported by Sepaskhah and Ghasemi (2008) [13]. and Pradhan *et al*. (2015) [10].

Among different dates of sowings, higher grain yield and straw yield were observed when sorghum was sown during 1st fortnight of October (D_2) as compared to other dates of sowing *viz.*, 2nd fortnight of October (D_3) and 1st fortnight of November (D_4). However, the grain yield recorded at First fortnight of October (3278 kg ha^{-1}) was on a par with 2nd fortnight of September (3145 kg ha^{-1}) sown crop. The lowest grain yield (1576 kg ha^{-1}) was recorded when crop sown on 1st fortnight of November due to low temperatures at flowering and pollination which might have caused pollen sterility. Taylor (1973) [14]. reported that poor grain sorghum yield in New Zealand was due to pollen sterility induced by low temperature. These results are supported by Reddy *et al*. (2007) [12]. Reddi *et al.* (2013) [11]. and Hulihalli *et al*. (2016) [5].

Harvest index of sorghum (31.1 %) was significantly higher when irrigations were scheduled at 0.7 IW/CPE as compared to irrigation scheduled with 0.3 IW/CPE but found on par with 0.5 IW/CPE (30.0 %). Similar results were also reported by Aulakh *et al.* (2013) [1]. Among different dates of sowing significantly higher harvest index was observed when crop was sown on 2nd fortnight of September (33.2 %) than 1st fortnight of November and on a par with 1st fortnight of October and 2nd fortnight of October sown crop. Similar results were reported by Hadebe *et al.* (2017) [7].

Interaction between irrigation schedules and dates of sowing on water use efficiency of sorghum was found to be significant. Highest water use efficiency (18.2 kg ha.mm^{-1}) was observed when crop sown on 2nd fortnight of October with irrigation scheduled at 0.5 IW/CPE (I_2D_3) compared to all the treatment combinations but comparable with 1st fortnight of October sowings with irrigation scheduled at 0.3 IW/CPE (I_1D_2) Significantly lower water use efficiency (5.0 kg ha-mm^{-1}) was recorded in I_3D_4 (0.7 IW/CPE ratio and 1st fortnight of November). The results are in accordance with the findings of Hadebe *et al.* (2017) [7]. and Baumhardt and Howell (2006) [3].

Table 1: Effect of irrigation schedules and dates of sowing on plant height (cm) and dry matter accumulation (kg ha^{-1}) of sorghum at harvest

Treatment	Plant height at harvest (cm)	Dry matter production at harvest (kg ha^{-1})
Irrigation schedules		
I_1- Irrigation at 0.3 IW/CPE ratio	248	13029
I_2- Irrigation at 0.5 IW/CPE ratio	270	14000
I_3- Irrigation at 0.7 IW/CPE ratio	278	15535
SEm±	4.5	290.0
CD (p=0.05)	17.5	1138.6
CV %	5.8	7.1
Dates of sowing		
D_1- 2nd FN of September	273	14468
D_2- 1st FN of October	278	15019
D_3- 2nd FN of October	264	13788
D_4- 1st FN of November	246	13476
SEm±	4.6	280.7
CD (p=0.05)	15.9	972.7
CV %	5.2	5.9
Interaction (H×V)	NS	NS

Table 2: Effect of irrigation schedules and dates of sowing on yield attributes of sorghum

Treatment	Number of earheads m^{-2}	Number of grains per earhead	1000 grains weight (g)
Irrigation schedules			
I_1- Irrigation at 0.3 IW/CPE ratio	10.7	1220	33.2
I_2- Irrigation at 0.5 IW/CPE ratio	12.1	1402	34.9
I_3- Irrigation at 0.7 IW/CPE ratio	12.6	1471	35.7
SEm±	0.2	24.7	0.4
CD (p=0.05)	1.0	96.9	1.6
CV %	7.3	6.3	4.2
Dates of sowing			
D_1- 2nd FN of September	12.3	1625	34.9
D_2- 1st FN of October	12.7	1672	35.7
D_3- 2nd FN of October	11.6	1553	34.3
D_4- 1st FN of November	10.7	608	33.5
SEm±	0.4	19.1	0.4
CD (p=0.05)	1.3	66.4	1.3
CV %	9.2	4.2	3.3
Interaction (H×V)	NS	NS	NS

Table 3: Effect of irrigation schedules and dates of sowing on grain yield (kg ha^{-1}), straw yield (kg ha^{-1}) and Harvest index (%) of sorghum

Treatment	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Harvest index (%)
Irrigation schedules			
I_1- Irrigation at 0.3 IW/CPE ratio	2511	5924	29.0
I_2- Irrigation at 0.5 IW/CPE ratio	2731	6277	30.0
I_3- Irrigation at 0.7 IW/CPE ratio	3003	6535	31.1
SEm±	47.6	110.7	0.4
CD (p=0.05)	186.9	434.8	1.5
CV %	6.0	6.1	4.3
Dates of sowing			
D_1- 2nd FN of September	3145	6314	33.2
D_2- 1st FN of October	3278	6799	32.7
D_3- 2nd FN of October	2993	6140	32.6
D_4- 1st FN of November	1576	5729	21.7
SEm±	56.5	130.5	0.8
CD (p=0.05)	195.8	452.2	2.9
CV %	6.2	6.3	8.2
Interaction (H×V)	NS	NS	NS

Table 3: Effect of irrigation schedules and dates of sowing on Water Use Efficiency (kg ha.mm^{-1}) of sorghum

Horizontal strips(H)-Irrigation levels	Vertical strips (V) –Dates of sowings				
	D_1	**D_2**	**D_3**	**D_4**	**Means**
I_1	16.4	17.6	16.3	7.8	14.5
I_2	12.1	11.9	18.2	5.2	11.8
I_3	7.5	8.3	12.0	5.0	8.2
Means	12.0	12.6	15.5	6.0	
	SEm±		CD (p=0.05)		CV %
Irrigation levels	0.2		0.9		7.0
Dates of sowings	0.3		1.0		7.5
Interaction					
(H×V)	0.5		1.5		
(V×H)	0.5		1.5		

Conclusion

Irrigation scheduled at 0.7 IW/CPE recorded significant increase in plant height at harvest but it was found on a par with irrigation scheduled at 0.5 IW/CPE. The highest dry matter accumulation was also recorded at 0.7 IW/CPE. The increase in plant height and dry matter accumulation when irrigation scheduled at 0.7 IW/CPE might be due to sufficient soil moisture, nutrient uptake and better translocation of nutrients with more number of irrigations. The data recorded on yield attributes such as number of earheads per m^2, number of grains per earhead and 1000 grain weight indicated that irrigation scheduled at 0.7 IW/CPE ratio recorded higher values of yield attributes but on a par with 0.5 IW/CPE and significantly superior over 0.3 IW/CPE ratio. Irrigation scheduled at 0.7 IW/CPE ratio recorded higher growth and yield attributing parameters of sorghum leading to a significant increase in grain yield, straw yield and harvest index of sorghum. Sowing on first fortnight of October recorded the highest growth and yield attributing parameters of sorghum leading to a significant increase in grain and straw yield. However, the grain yield recorded at 2nd fortnight of September was comparable with 1st fortnight of October. The highest harvest index was recorded when the crop was sown during 2nd fortnight of September when compared to 1st fortnight of November but statistically on a par with 1st fortnight of October and 2nd fortnight of October sowings. The highest water use efficiency was recorded with I_2D_3 (0.5 IW/CPE and 2nd fortnight of October) which was comparable with I_1D_2 (0.3 IW/CPE and 1st fortnight of October sown crop).

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