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Effect of Irrigation Schedules and Sowing Dates on Onset of Phenological Stages and Growth Parameters of *rabi* Sorghum (*Sorghum bicolor* (L.) Moench)

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ABSTRACT: A field experiment was carried out at on sandy loam soils of Indian Institute of Millets Research, Rajendranagar, Hyderabad to investigate the effect of irrigation schedules and sowing dates on growth parameters of rabi sorghum during 2022-2023. The experiment was laid out in split plot design with twelve treatments replicated thrice. The main plot treatments include three irrigation schedules i.e., I_1-life-saving irrigation, I_2-irrigation at 50%DASM, I_3-irrigation at critical crop growth stages (Tillering, Booting, Anthesis, Grain filling) and sub plot treatments include sowing dates i.e., D1-15th September, 30th September, D_3-15th October and D_4-30th October. The result revealed that there was a significant improvement in growth of rabi sorghum with sowing on 15th September and application of irrigation at critical crop growth stages. Significantly taller plants, higher leaf area and dry matter production were obtained with application of irrigation at critical crop growth stages. While, sowing on 15th September recorded higher growth parameters when compared to other dates of sowing. As the sowing is delayed, decline in the crop growth was observed.

Keywords: Irrigation schedules, sowing dates, growth and rabi sorghum.

INTRODUCTION

Sorghum (*Sorghum bicolor* (L.) Moench) is the fifth most important cereal crop and its importance is ever increasing as it is the source of staple food for poor people, fodder for cattle and raw material for industries. Sorghum is grown under the rainfed as well as irrigated conditions in most of the major states. In India it occupies 40.25 million hectares with a production of 58.70 million tones and productivity of 1458 kg ha^{-1} (FAO, 2021). India is the second largest sorghum growing country accounting for 13.6% of the total cultivated area with a production of 4.31 million tones and a productivity of 1250 kg ha^{-1} (Kumar *et al*., 2022). In Telangana, the crop is grown in an area of 91,000 acres (Agricultural statistics, 2021) and is grown mostly by small and marginal farmers in resource constraint areas. The crop is sown during both *kharif* (rainy) and *rabi* (post rainy) seasons. *Kharif* sorghum is primarily used for poultry feed, animal feed industries and alcohol (Patil *et al*., 2014), whereas *rabi* sorghum is grown for household consumption, fodder purposes, fiber, and fuel (Kumara *et al*., 2014). Although sorghum has great importance and considerable area under *Rabi* sorghum its productivity is very low due to some factors like use of local low yielding varieties, low adoption of improved technology, untimely sowing, weather variables, erratic distribution of monsoons and over exploitation of ground water etc. Depending upon the harvesting period of previous *kharif* crop, farmers sow *rabi* sorghum during the second fortnight of September and extends till the second fortnight of October to the first fortnight of November. Since development rate and duration of phenological stages were largely determined by prevailing temperatures, therefore, sowing date is one of the most important management practices to obtain optimum crop productivity. *Rabi* season is characterized by limited rainfall, cooler temperature and shorter days, resulting in lower potential crop evapo-transpiration. However, increased temperatures and shallow marginal soils of *rabi* areas limit the antecedent moisture storage capacity often resulting in exhaustion of available moisture leading to moisture stress early in the crop cycle and thus reduced grain and stover yield (Kassahun *et al*., 2010). In this context, irrigation plays a crucial role in enhancing the growth and productivity of *rabi* sorghum. Optimum irrigation scheduling ensures an adequate water supply to meet the crop's water requirements and optimize yield. Timely irrigation during critical growth stages, such as flowering and grain development, plays a vital role for optimizing *rabi* sorghum productivity (Gupta, 2017). Therefore, so as to find out most suitable time for planting and irrigation schedule of *rabi* sorghum, four sowing dates and three irrigation schedules respectively have been investigated in this study.

MATERIALS AND METHODS

A field experiment was conducted during *rabi* season in 2022-23 at ICAR-Indian Institute of Millets Research, Rajendranagar, Hyderabad. The farm is situated at an altitude of 476.5 meters above mean sea level, 17°04' N latitude and 75°54' E longitude. The soil of experimental field was fairly levelled and sandy loam in texture, low in available nitrogen (187 kg ha^{-1}), medium in phosphorus (38.7 kg ha^{-1}) and high in potassium (381.4 kg ha^{-1}), low in organic carbon content (0.39%). The experiment was conducted in Split Plot Design with three main plot treatments, four subplot treatments and were replicated three times. The main plot treatments comprise irrigation schedules viz., life-saving irrigation (I_1), irrigation AT 50% DASM (I_2), irrigation at critical growth stages (I_3) and subplot treatments comprise four sowing windows *viz.*, sowing on 15th September(D1), 30th September (D2), 15th October (D3) and 30th October (D4). Sorghum variety M35-1 was sown with spacing of 45×15 cm. The recommended dose of fertilizer (80:40:40 kg NPK ha^{-1}) was applied to crop and all the other inter-cultivation operations were practiced regularly. For recording non-destructive sampling parameters like plant height five plants were selected randomly and tagged from each experimental plot and five plants were uprooted and dried in the hot air oven at 60°C till constant weights were obtained. Final weights were expressed in kg ha^{-1}**.** The data recorded was statistically analysed by following procedure described by Gomez and Gomez.

RESULTS AND DISCUSSION

The results of the present investigation based on means, and their test statistics were interpreted under appropriate heads here in. The differences among irrigation schedules and sowing dates were significant. The irrigation schedule I_3 irrigation at critical stages has given significantly taller plants, higher number of leaves and dry matter at different stages as compared to the rest of irrigation treatments. Among the sowing dates, sowing on 15th Sept. recorded significantly higher plant height, number of leaves and dry matter at different stages as compared to rest of the three sowing dates. There was no significant difference in the interaction effect of irrigation schedules and sowing dates on the plant height, days to phenological stages, leaf area and dry matter production.

Table 1: Number of days to phenological stages as influenced by irrigation schedules and sowing dates.

Treatments	Days to phenological stages			
	Vegetative stage	Panicle initiation	Heading	Physiological maturity
Main plot treatments				
I_1: Life-saving irrigation	21.8	31.6	61.0	101.8
I_2: Irrigation at 50% DASM	23.9	34.0	62.8	104.9
I_3: Irrigation at critical growth stages	24.1	40.0	64.3	106.9
SEm(±)	0.3	0.2	0.8	1.0
CD(p=0.05)	1.0	0.6	NS	NS
Sub plot treatments				
S_1: 15 Sep	24.9	40.0	66.3	117.8
S_2: 30 Sep	23.8	36.7	64.0	107.4
S_3: 15 oct	22.9	33.3	61.3	99.9
S_4: 30 Oct	21.4	30.7	59.0	93.0
SEm(±)	0.2	0.3	0.5	1.2
CD(p=0.05)	0.6	0.9	1.6	3.7
Interaction				
Sub treatment at same level of main treatment				
SEm(±)	0.4	0.6	1.3	2.4
CD(p=0.05)	NS	NS	NS	NS
Main treatment at same level of sub treatment				
SEm(±)	0.3	0.5	0.9	2.1
CD(p=0.05)	NS	NS	NS	NS

A. Onset of phenological stages

The results of the current study revealed that, irrigation scheduling practices were shown significant influence on onset of phenological stages (Table 1) at vegetative stage and panicle initiation and sowing dates at vegetative stage, panicle initiation, heading and physiological maturity. Among different irrigation schedules, the number of days to attain maximum tillering (21.8), panicle initiation (31.6), heading (61) and physiological maturity (101.8) was less in I_1(life-saving irrigation) when compared to other treatments. Among different sowing dates, the number of days to attain maximum tillering (21.4), panicle initiation (30.7), heading (59) and physiological maturity (93) was less in S4 (30th October).

B. Growth parameters

(i) Plant population. The mean data pertaining to initial and final plant population were tabulated in Table 2. The data indicated that plant population did not differ significantly due to individual as well as interaction effects of irrigation schedules and sowing dates at both the stages of the observations *viz.*, 20 DAS and at harvest. Plant stand was not significantly affected by irrigation schedules however, higher initial (123535) and final plant population (114887) was seen I_3 *i.e.*, irrigation at critical stages of crop growth and the lower initial (119908), final plant population (111514) was seen under I_1 *i.e.*, life-saving irrigation. Plant stand was significantly affected by sowing dates. However, the higher initial (124692) and final plant population (115964) was observed in S_1 *i.e.*, 15th September treatment. Whereas lower initial plant population (119239) and final plant population (110893) were observed in S4 *i.e.*, sowing on 30th October.

Table 2: Plant population and plant height as influenced by irrigation schedules and sowing dates.

Treatments	Plant population (No. ha^{-1})		Plant height (cm)			
	initial	final	Vegetative stage	Panicle initiation	Heading	Physiological maturity
Main plot treatments						
I_1: Life-saving irrigation	119908	111514	52	98	175	195
I_2: Irrigation at 50% DASM	122146	113595	62	103	189	207
I_3: Irrigation at critical growth stages	123535	114887	62	108	205	217
SEm(±)	2656	2470	1.9	1.7	5.0	4.2
CD(p=0.05)	NS	NS	7.5	6.8	19.6	16.4
Sub plot treatments						
S_1: 15 Sep	124692	115964	65	113	211	218
S_2: 30 Sep	123458	113859	63	108	198	215
S_3: 15 oct	120062	112615	58	98	189	210
S_4: 30 Oct	119239	110893	50	92	161	182
SEm(±)	2888	2685	1.3	1.6	4.5	3.0
CD(p=0.05)	NS	NS	3.9	4.9	13.4	8.9
Interaction						
Sub treatment at same level of main treatment						
SEm(±)	5866.81	5456.14	3.2	3.5	9.7	7.1
CD(p=0.05)	NS	NS	NS	NS	NS	NS
Main treatment at same level of sub treatment						
SEm(±)	5001.38	4651.29	2.3	2.9	7.8	5.2
CD(p=0.05)	NS	NS	NS	NS	NS	NS

(ii) Plant height. There was an increase in plant height of sorghum with the advancement of age of the crop and attained its maximum at maturity. Plant height significantly differed among different irrigation schedules. Improved plant height was observed with I_3 (irrigation at critical stages) at 30 DAS (62 cm), at 60 DAS (107 cm), and 90 DAS (205 cm) and at harvest (217 cm) while I_1 (life-saving irrigation) recorded significantly shorter plants (195 cm at harvest) at all the stages. The increase in plant height might be due to sufficient soil moisture, nutrient uptake and better translocation of nutrients with a greater number of irrigations when compared to other irrigation treatments. Increased plant height with increasing number of irrigations was also reported by Naaiik *et al*. (2015); Wakchaure *et al*. (2016). Plant height was significantly influenced by different sowing dates in sorghum crop. Among different dates of sowings, early swing on 15th Sept (S1) maintained superiority by recording taller plants of (65 cm) at 30 DAS, (114 cm) at 60 DAS, (211 cm) at 90 DAS and while S4 (30th October) treatment has recorded significantly shorter plants (182 cm) among all the treatments. Taller plants were recorded with crops sown on 15th September might be due to optimum weather conditions. Favourable weather conditions resulted in a rapid cell division and elongation of plants. Secondly, better utilization of available resources, precipitation and soil moisture contributed to increased plant height. Similar results were found by Waghmare *et al*. (2010). Interactions of irrigation schedules and sowing dates were failed to exert significant difference at all stages of crop growth.

(iii) Leaf area (cm^2). The result pertaining to the leaf area was significantly influenced by irrigation schedules and sowing dates at all the crop growth stages. There was a gradual increase in leaf area of sorghum from 30 DAS up to 60 DAS and decreased at harvest due to gradual senescence of leaves (Table 3). Highest leaf area was obtained at 60 DAS under irrigation at critical stages (2370 cm^2) which was significantly superior over remaining treatments. Significantly lowest leaf area (2081 cm^2) was observed in I_1 (life-saving irrigation). Similar results were found by Satish *et al.* (2016). The profound influence of irrigation on leaf area might be attributed to the better crop growth scenario by providing good amount of soil moisture which gave scope for plant to establish and grow vigorously. This vigorous growth led to better crop stand and facilitated vegetative growth. Increased leaf area helps in better production of photosynthates as reported by Kumar and Angadi (2016). The water stress reduced leaf area due to reduced cell division. Water stress might reduce the turgor pressure and hence cell expansion, resulting in retention of roughly the same dry mass within a reduced leaf area, consequently increasing density (Hsiao, 1973; Rascio *et al*., 1990). As the sowing is delayed the crop was shown a decline in the leaf area. The highest leaf area was recorded at 60 DAS (2694 cm^2) in sowing during 15^{th} September and the lower leaf area (1532 cm^2) was recorded in S_4 treatment. Interaction effect between irrigation schedules and sowing dates was found to be non-significant with respect to plant height at all stages of crop growth. The highest leaf area observed during 15^{th} September might be due to the favorable weather conditions especially temperature. Early sown crop enjoys the favorable weather conditions which recorded high germination percentage with high vigor and helps in production of greater number of leaves which in turn reflects in the high leaf area that was observed during panicle initiation. Similar findings are given by Verma *et al.* (2012).

Table 3 : Leaf area and dry matter production as influenced by irrigation scheduling practices and sowing dates.

Treatments	Plant population (No. ha^{-1})		Plant height (cm)			
	initial	final	Vegetative stage	Panicle initiation	Heading	Physiological maturity
Main plot treatments						
I_1: Life-saving irrigation	119908	111514	52	98	175	195
I_2: Irrigation at 50% DASM	122146	113595	62	103	189	207
I_3: Irrigation at critical growth stages	123535	114887	62	108	205	217
SEm(±)	2656	2470	1.9	1.7	5.0	4.2
CD(p=0.05)	NS	NS	7.5	6.8	19.6	16.4
Sub plot treatments						
S_1: 15 Sep	124692	115964	65	113	211	218
S_2: 30 Sep	123458	113859	63	108	198	215
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S_4: 30 Oct	119239	110893	50	92	161	182
SEm(±)	2888	2685	1.3	1.6	4.5	3.0
CD(p=0.05)	NS	NS	3.9	4.9	13.4	8.9
Interaction						
Sub treatment at same level of main treatment						
SEm(±)	5866.81	5456.14	3.2	3.5	9.7	7.1
CD(p=0.05)	NS	NS	NS	NS	NS	NS
Main treatment at same level of sub treatment						
SEm(±)	5001.38	4651.29	2.3	2.9	7.8	5.2
CD(p=0.05)	NS	NS	NS	NS	NS	NS

(iv) Dry matter production. The results showed that there was a progressive increase in dry matter accumulation with the age of the crop. Dry matter accumulation is significantly influenced by irrigation schedules and dates of sowing but their interaction was found to be non-significant at all the stages of crop growth (Table 3). At harvest, irrigation at critical stages was recorded the highest dry matter production (12948 kg ha^{-1}). Significantly lower dry matter production (11435 kg ha^{-1}) was observed under life-saving irrigation. Higher dry matter accumulation with irrigation scheduled at critical stages of the crop might be due to a greater number of irrigations scheduled with less irrigation interval when compared to other irrigation schedules. Similar results were also reported by Ikramullah *et al*. (1996). Dry matter production significantly varied among different dates of sowing. At harvest S_1 recorded significantly higher dry matter production (15098 kg ha^{-1}). Significantly lower dry matter production (9998 kg ha^{-1}) was observed in S_4. High dry matter production during S1 might be due to early sown crop may enjoy favourable climatic conditions in terms of temperature and other climatic parameters during various crop growth stages which reflected into better crop growth and dry matter accumulation. This is also attributed to early germination and initial vigorous growth of plants in early sowings compared to late sowing. Similar results were also reported by Kalhapure and Shete (2013); Reddi *et al*. (2013). Early sown crops have a longer growing cycle from planting to maturity, this leads to more leaf area, increased rate of photosynthesis, and more efficient allocation of resources to reproductive processes which improved the growth, development and dry matter accumulation per plant with respective date of sowing due to optimum sowing time, suitable growth period and favourable climatic conditions especially temperature compared to late sown crops. Similar findings were reported by Qasim *et al*. (2008); Sattar *et al*. (2010), both of whom concluded that earlier sowing results in improved yield characteristics.

CONCLUSIONS

From results of the data, it is evident that irrigation schedules and sowing dates significantly affected the plant height, leaf area and dry matter production and days to phenology. As there was a sufficient rainfall at initial stages of the crop growth, plant population was not influenced by irrigation schedules and sowing dates.

FUTURE SCOPE

The present investigation was confined to a short-term trial to study the effect of sowing dates and irrigation schedules on growth of the *rabi* sorghum. However, the trial needs to be repeated with large scale of field trials to draw the actual conclusions.

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Conflict of Interest. None.

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