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EVALUATING THE IMPACT OF DIFFERENT SOWING DATES ON SUMMER SORGHUM GROWTH AND YIELD IN NAVSARI, GUJARAT, INDIA

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ABSTRACT

Crop weather relations are always dynamic and studying the crop weather relations is essential for sustainable crop production. Interactions between crop and weather are the backbone for the productivity and stabilized yield. The field trial was conducted on college farm, Navsari Agricultural University, Navsari (Gujarat) during the summer season of the year 2023 to investigate the appropriate date of sowing for growth and yield of sorghum cultivars. The experiment was laid out in a split plot design with three varieties (V_1: GJ-42, V_2: GJ-44 and V_3: GNJ-1) as main plot treatments and three dates of sowing (D_1: 15th January, D_2: 31st January and D_3:15th February) as sub-plot treatments with four replications. The result revealed that the weather played a significant role in deciding the yield of sorghum. However, the impacts were different in different phenophases during its growth period. The sorghum genotypes sown on 15th February (D_3) required a higher accumulation of growing degree days (2211 °C days) from sowing to maturity than those sown on 15th January (D_1), attributable to comparatively higher temperature regimes that significantly influenced crop growth. A similar increasing trend was also observed in the accumulation of heliothermal units (HTU) and photothermal units (PTU). The variety GJ-44 (V_2) sown on 15th February (D_3) produced significantly higher grain (3598 kg ha^{-1}) and dry fodder (11154 kg ha^{-1}) yields. A similar trend was also observed in the plant height, grain yield, test weight and harvest index. The 15th February (D_3) sown crop produced highest grain yield (3253 kg ha^{-1}), dry fodder yield (10839 kg ha^{-1}) as well due to favorable weather conditions.
Keywords : Sowing dates, Summer Sorghum, Grain Yield and Sorghum Cultivars.

Introduction

Sorghum (*Sorghum bicolor* L.) is one of the main staple foods for the world's most food insecure people across the semi-arid tropics. Being known as Jowar, it was originated in Africa and has been spread throughout the globe. On the global scale, it is fifth most important cereal crop followed by rice, wheat, maize and barley. Among the cereals in India, sorghum ranks third, next to rice and wheat (Saini *et al.*, 2018). Andhra Pradesh, Madhya Pradesh, Gujarat, Rajasthan, Uttar Pradesh (Bundelkhand region) and Tamil Nadu are the major jowar growing states According to statistical data, an area of 3.75 million hectares comes under sorghum cultivation in India with an annual production of 4.00 million tonnes and productivity of 1100 kg ha^{-1} during the year 2023-2024 (Anon., 2024a). In Gujarat during the year 2023-2024, area of sorghum was 0.04 million hectares with an annual production of 0.05 million tonnes and productivity of 1336 kg ha^{-1} (Anon., 2024b). Sorghum is known as a camel crop, because it is a most drought-tolerant summer field crop (Obady *et al.,* 2022). Sorghum is a short-day plant. Minimum temperature for germination is 7-8 ºC and suitable temperature for optimum crop growth is 27-32 ºC. It has its specific weather requirements for germination, vegetative growth, flowering and seed development. The length of the growth season is directly influenced by the planting date; this impacts varieties, phenological events and yield. Plants need a specific growing degree day (GDD) based on daily temperature and sowing windows to reach the phenological stages (Bankole, 2022). Temperature plays a major role in determining the time of sorghum phenophasic stages, such as flower initiation and 50 per cent flowering. Understanding this, it is crucial to select the optimum time of sowing that provides ideal growing conditions to obtain the maximum sorghum yield. Optimum planting time of sorghum may vary from one variety to another and from a region to another because of variation in agro-ecological conditions. Planting date affects not only the time from sowing to flowering but time from flowering to physiological maturity of grain sorghum (Clark, 1997).

Materials and Methods

The present field trial was conducted at the Agronomy Farm (E Block), N. M. College of Agriculture, Navsari Agricultural University, during the summer season of 2023. The Navsari Agricultural University is situated at a 20° 57' N latitude, 72° 54' E longitude and elevation of 11.98 m above mean sea level. Positioned 12 km east of the historic site "Dandi" on the Arabian shoreline. In south Gujarat the "Black soils," represents the soil of the Navsari campus where the experiment was conducted, falling under the *Ustochrepts* great group and classified as part of the Jalalpur soil series. The soil observed at the experimental site appeared as a dark greyish brown type, featuring a flat topography with moderate to poor drainage capabilities but good water retention capacity with clayey texture and was characterized by low availability of nitrogen, medium availability of phosphorus and high availability of potassium. The soil was slightly alkaline (pH 7.67) with normal electrical conductivity (0.37 dS/m). The experiment consisted with total thirty-six treatment combinations with three different dates of sowing *viz.* D_1: 15^{th} January, D_2: 31^{st} January and D_3:15^{th} February and three cultivars of sorghum *viz.* V_1: GJ-42, V_2: GJ-44 and V_3: GNJ-1. The experiment was laid out in split plot design with four replications. For recording the crop observations, five plants were selected and tagged from every net plot of all the treatments of each replication. On every alternate day, phenology was observed. Data collected including seed emergence, panicle initiation, no. of leaves per plant, plant height, leaf area index (LAI), dry weight and physiological maturity were visually recorded and five randomly selected plants from each treatment were used for recording various yield attributes viz, Length of ear head, Girth of ear head, Grain weight ear head^{-1}, 1000 seed weight, Grain yield, Dry fodder yield and Harvest index**.** The crop was harvested manually with the help of sickle when seed almost matured and stover had turned yellow. The sun-dried bundles were threshed and winnowed and seed so obtained were weighed and data on seed and stover yields were recorded Saini *et al.* (2018).

Statistical analysis

The statistical analysis of the data of various characters studied in the investigation for summer season of the year 2023 were carried out through the procedure appropriate to the split plot design (SPD) of the experiment.

The significance of differences was tested by 'F' test at 5% level of significance. The critical difference was calculated when differences between the treatments were found to be significant by 'F' test. The co-efficient of variation (CV %) was also worked out to see the extent of variation within the blocks. Coefficient of variation is very useful for the study of variation in more than one sample or series. When the coefficient of variation is high, the sample is less consistent or more variable conversely, if it is low the sample is more consistent or less variable.

$$CV(\%) = \frac{SD}{\overline{X}} \times 100$$

Where,

SD = Standard deviation

$\overline{X}$ = Sample mean

Agrometeorological Indices

Agrometeorological indices like growing degree days (GDD), helio thermal unit (HTU) and photothermal unit (PTU) during different crop stages was related with the yield and yield attributing characters of three cultivar of sorghum were worked out as described by Nuttonson (1955).

Growing Degree Days (GDD)

Growing degree days (GDD) are based on the concept that the actual time required to attain maturity is linearly related to the temperature range between base temperature (Tb) and optimum temperature. The sum of degree days for completion of each phenophases were obtained by following formula:

$$GDD = \sum_{i=ds}^{dh} (T - Tb)$$

Where,

$T = \{(T_{max} + T_{min}) / 2\}$

T_{max} = daily maximum temperature in ºC

T_{min} = daily minimum temperature in ºC

Tb = base temperature in ºC

ds = date of sowing or the date of commencement of the phenophases

dh = date of harvesting or date of ending of the respective phenophase

Helio Thermal Unit (HTU)

The heliothermal unit (HTU) for a given day represents the product of GDD and the actual bright sunshine hour and expressed as ºC days hrs.

$$HTU = \sum GDD \times n$$

Where,

n = actual bright sunshine hour

Photo Thermal Unit (PTU)

The photothermal unit (PTU) for a given day represents the product of GDD and the maximum possible sunshine hour expressed as ºC days hrs.

$$PTU = \sum GDD \times N$$

Where,

N = maximum possible sunshine hours

Results and Discussion

Growth attributes of sorghum

Plant height of sorghum at different growth stages was influenced by varietal and sowing date treatments (Table 2). Among varieties, plant height did not differ significantly at 30, 60 and 90 DAS; however, at harvest maturity, V_2 (GJ-44) recorded significantly taller plants (194.30 cm) compared to V_1 (GJ-42) and V_3 (GNJ-1), as the differences exceeded the CD at 5 per cent. With respect to dates of sowing, a significant effect was observed only at 30 DAS, wherein the crop sown on 15th February (D_3) attained significantly greater height than D_1 (15th January) and D2 (31st January), which were statistically at par. At later growth stages (60 DAS, 90 DAS and harvest), the effect of sowing dates on plant height was non-significant. The interaction between varieties and dates of sowing was non-significant at all stages, indicating uniform varietal performance across sowing windows. The CV values suggested acceptable experimental precision. Damilola *et al.* (2022) who discovered that the plant height was non-significantly influenced by the interaction effect of varieties and dates of sowing in sorghum.

Phenological stages of sorghum

Emergence day and panicle initiation

Emergence and panicle initiation of sorghum were significantly influenced by varietal and sowing date treatments. Among varieties, V_2 (GJ-44) emerged significantly earlier and attained panicle initiation in fewer days compared to V_1 (GJ-42) and V_3 (GNJ-1), as the mean differences exceeded the CD at 5 per cent. With respect to dates of sowing, D_2 (31st January) recorded significantly earlier emergence and panicle initiation, while D_1 (15th January) required the maximum duration. The interaction between varieties and dates of sowing was non-significant, indicating a consistent varietal response across sowing dates.

50% flowering and physiological maturity

Days to 50 per cent flowering and physiological maturity differed significantly due to varieties and dates of sowing. V_2 (GJ-44) reached flowering and maturity significantly earlier than V_1 and V_3, which were statistically at par. This was matched with El-Raouf *et al.* (2023) who reported that earlier sowing dates tended to expand the total number of days from sowing to 50 per cent flowering. The decreased in total number of days from sowing to 50 per cent flowering with late sowing (temperature increased) may be attribute to cumulative growing degree days (°C). This was further confirmed by Karhale *et al.* (2014). Among sowing dates, D_2 resulted in significantly earlier flowering and maturity, whereas D_1 delayed both stages. The non-significant V × D interaction revealed that the effects of varieties and sowing dates were independent. The relatively low CV values reflected good experimental precision and reliability of the treatment effects.

Yield attributes of sorghum

Grain weight earhead^{-1} (g) and 1000-seed weight (g)

Grain weight per earhead was significantly influenced by both varieties and dates of sowing. Among the varieties, GJ-44 produced the highest grain weight per earhead (68.08 g), which was significantly superior to GJ-42 (55.49 g) and GNJ-1 (54.49 g). Regarding sowing dates, the 15th February sowing (D_3) recorded the maximum grain weight (63.05 g), followed by 15 January (60.66 g), while the lowest value was observed under 31 January sowing (54.35 g).

A significant variation in 1000-seed weight was observed among the varieties, with GJ-44 producing the highest test weight (26.42 g), while GNJ-1 recorded the lowest (22.41 g). However, the effect of sowing dates was comparatively narrow, with values ranging between 24.32 g and 24.83 g. The differences were statistically significant, but the V × D interaction was non-significant.

Grain yield (kg ha^{-1}) and Dry fodder yield (kg ha^{-1})

Varietal differences had a significant impact on grain yield. GJ-44 recorded the highest grain yield (3598 kg ha^{-1}), followed closely by GNJ-1 (3512 kg ha^{-1}), while GJ-42 produced the lowest yield (2435 kg ha^{-1}). Among sowing dates, the highest grain yield (3253 kg ha^{-1}) was obtained with the 15 February sowing (D_3), whereas the 31st January sowing (3109 kg ha^{-1}) gave the lowest yield. A similar result was reported by Damilola *et al.* (2022) and Sindhu *et al.* (2023), Mishra *et al.* (2017) further confirmed that lower yield in early sowing date might be due to lack of accumulation of adequate photosynthates owing poor vegetative growth.

Significant differences were noted among varieties in dry fodder yield. The variety GJ-42 produced the highest fodder yield (11154 kg ha^{-1}), while GJ-44 gave the lowest (10632 kg ha^{-1}). For sowing dates, dry fodder yield ranged from 10553 to 11135 kg ha^{-1}, with the highest productivity recorded under 31 January sowing (D_2). The interaction effect was non-significant.

Harvest index (%)

Harvest index was significantly influenced by varietal and sowing date treatments. V_2 (GJ-44) recorded a significantly higher harvest index compared to V_1, while it was statistically at par with V_3. Among sowing dates, D_1 (15th January) registered a significantly higher harvest index than D_2, while D_3 remained statistically at par with D_1. The non-significant interaction effect indicated a uniform response of varieties across sowing dates. Overall, the low CV values reflected good experimental precision and reliability of the observed treatment effects. Generally, harvest index increases with late sowing in summer sorghum due to higher ratio of grain yield and dry fodder yield, as stated by Sindhu *et al.* (2023).

Table 1: Emergence day, panicle initiation and Physiological maturity influenced by various treatments.

Treatment	Emergence day (DAS)	Panicle initiation (DAS)	50 per cent flowering (DAS)	Physiological maturity (DAS)
Varieties (V)				
V_1: GJ-42	6.67	34.33	69.75	110
V_2: GJ-44	5.67	30.33	66.00	108
V_3: GNJ-1	6.68	36.00	70.83	111
SEm±	0.32	0.54	0.89	0.26
CD at 5%	0.67	1.89	3.14	0.93
Date of sowing (D)				
D_1: 15th January	6.60	36.00	72.00	112
D_2: 31st January	5.67	32.33	66.33	107
D_3: 15th February	6.70	32.31	68.00	109
SEm±	0.20	0.22	1.42	0.31
CD at 5%	0.60	0.67	2.97	0.90
CV %	13.60	7.91	7.12	7.67
Interaction V x D				
SEm±	0.43	0.62	2.19	0.51
CD at 5%	NS	NS	NS	NS

Table 2: Plant height (cm) influenced by varieties and date of sowings

Treatment	Plant height (cm)			
	30 DAS	**60 DAS**	**90 DAS**	**At harvest maturity**
Varieties				
V_1: GJ-42	57.34	164.13	177.63	180.75
V_2: GJ-44	59.98	158.63	180.07	194.30
V_3: GNJ-1	58.65	159.52	180.57	182.12
SEm±	1.74	3.41	3.37	3.32
CD at 5%	NS	NS	NS	2.21
Date of sowing				
D_1: 15th January	57.71	163.32	179.21	183.08

D_2: 31st January	56.75	161.52	179.56	181.82
D_3: 15th February	61.51	157.45	180.48	185.27
SEm±	0.95	2.30	1.64	1.21
CD at 5%	2.84	NS	NS	NS
CV %	8.71	8.22	7.21	9.52
Interaction V x D				
SEm±	2.71	6.39	6.27	7.83
CD at 5%	NS	NS	NS	NS

Table 3: Grain weight earhead^{-1} (g), 1000 seed weight (g), Grain yield (kg ha^{-1}), dry fodder yield (kg ha^{-1}) and harvest index (%) influenced by various treatments.

Treatment	Grain weight earhead^{-1} (g)	1000 seed weight (g)	Grain yield (Kg ha^{-1})	Dry fodder yield (Kg ha^{-1})	Harvest index (%)
Varieties (V)					
V_1: GJ-42	55.49	25.05	2435	11154	17.92
V_2: GJ-44	68.08	26.42	3598	10632	25.30
V_3: GNJ-1	54.49	22.41	3512	10741	24.64
SEm±	2.07	0.01	31.69	109.33	0.61
CD at 5%	7.30	0.04	111.78	385.67	2.14
Date of sowing (D)					
D_1: 15th January	60.66	24.73	3223	10553	23.39
D_2: 31st January	54.35	24.32	3109	11135	21.83
D_3: 15th February	63.05	24.83	3253	10839	23.08
SEm±	1.70	0.01	22.65	117.69	0.64
CD at 5%	5.09	0.03	67.82	352.37	1.97
CV %	9.92	4.15	7.88	10.69	7.88
Interaction V x D					
SEm±	3.17	0.02	45.06	199.13	0.89
CD at 5%	NS	NS	NS	NS	NS

Agrometeorological Indices During Crop Growth Period

Results pertaining to various agrometeorological parameters during different phenological stages *viz.* sowing to emergence, emergence to panicle initiation, panicle initiation to flowering, flowering to dough and dough to physiological maturity in all the treatment have been presented with the following sub-headings.

Growing degree days (GDD)

Growing degree days (GDD) has been used for characterizing the thermal response in sorghum crop. The accumulated GDD during different growth stages of the sorghum are presented in Table 4. The significantly higher value of total GDD was observed in variety GNJ-1 (V_3) followed by variety GJ-42 (V_1) under the third sowing date (D_3) 2211 ºC day. Results showed that total GDD values increased with delayed sowing that might be due to higher temperature condition affecting significantly to growth condition in sorghum. According to the results, the value of GDD was in an increasing trend with delayed sowing. These results are supported by the findings of Ammaiyappan *et al.* (2023) and Sindhu *et al.* (2024) that might be due to higher temperature condition affecting significantly to growth condition in sorghum.

Helio thermal unit (HTU)

Helio thermal unit (HTU) helps in understanding how temperature and solar radiation affect the growth stages of crops. It provides insights into the relationship between environmental conditions and crop development, allowing for better predictions of growth rates and developmental milestones. The accumulated HTU during different growth stages of the sorghum are presented in Table 5.

In variety GNJ-1(V_3) and variety GJ-42 (V_1) significantly higher value of total HTU was 17755 and 17526, respectively. Under the third sowing date (D_3) 19283 ºC day hr. followed by second sowing date (D_2) 17214 ºC day hr. Results showed that total HTU was increased with the delay of sowing due to the greater absorption of GDD and higher actual bright sunshine hours (BSS) on the third sowing date (D_3). Results are supported by the finding of Ammaiyappan *et al.* (2023) Moreover, Sindhu *et al.* (2024) confirmed that though the duration of light intensity is less, there might be optimum light intensity, which led to higher grain yield of late sown crop compared to other two sowings.

Photo thermal unit (PTU)

Photo thermal unit (PTU) is a measure used in agriculture to quantify the combined effect of temperature and day length (photoperiod) on crop growth and development. It integrates the cumulative influence of daily temperatures with the duration of daylight to assess how these factors collectively impact plant development stages. The accumulated PTU during different growth stages of the sorghum are presented in Table 6.

In variety GNJ-1(V_3), significantly higher value of total PTU was observed 26071 ºC day hr. followed by GJ-42 (V_1) and GJ-44 (V_2) was 25784 and 25166, respectively. Under the third sowing date (D_3) was observed higher PTU 27650 ºC day hr. Results showed that total PTU values were increased with delay in sowing this is attributed to the higher GDD accumulation and the greater number of sunshine hours available during the third sowing date (D_3). These results are supported by the finding of Ammaiyappan *et al.* (2023). Furthermore, Sindhu *et al.* (2024) confirmed that among the three sowing windows, late sown crop has accumulated maximum photo-thermal units (26787.2 °C day hrs) followed by mid sown (25797.1 °C day hrs) and early sown (24459.8 °C day hrs) crop and maximum PTU accumulation for attaining maturity also followed similar trend as that of HTU.

Table 4: Accumulated growing degree days (GDD) (ºC days) during different growth stages of sorghum crop.

Treatment	Sowing to Emergence	Emergence to Panicle initiation	Panicle initiation to Flowering	Flowering to Dough stage	Dough to Physiological Maturity	Total (Sowing to Maturity)
Varieties (V)						
V1: GJ-42	99	462	671	642	225	2099
V2: GJ-44	84	404	672	658	236	2053
V3: GNJ-1	99	493	660	647	225	2121
Mean	94	453	668	649	229	2091
Date of sowing (D)						
D1: 15th Jan	81	441	654	616	215	2005
D2: 31st Jan	89	444	640	650	239	2057
D3: 15th Feb	113	475	709	682	232	2211
Mean	94	453	668	649	229	2091

Table 5: Accumulated helio thermal unit (HTU) (ºC days hour) during different growth stages of sorghum crop.

Treatment	Sowing to Emergence	Emergence to Panicle initiation	Panicle initiation to Flowering	Flowering to Dough stage	Dough to Physiological Maturity	Total (Sowing to Maturity)
Varieties (V)						
V1: GJ-42	802	3795	5982	5922	2236	17526
V2: GJ-44	669	3215	4854	5999	2342	17099
V3: GNJ-1	799	3821	4953	5953	2244	17755
Mean	757	3610	5263	5958	2274	17460
Date of sowing (D)						
D1: 15th Jan	686	3182	4577	5257	1997	15882
D2: 31st Jan	445	4135	4338	5808	2522	17214
D3: 15th Feb	1139	3515	6875	6809	2303	19283
Mean	757	3610	5263	5958	2274	17460

Table 6 : Accumulated photo thermal unit (PTU) (°C days hour) during different growth stages of sorghum crop.

Treatment	Sowing to Emergence	Emergence to Panicle initiation	Panicle initiation to Flowering	Flowering to Dough stage	Dough to Physiological Maturity	Total (Sowing to Maturity)
Varieties (V)						
V1: GJ-42	1125	5365	8152	8200	2940	25784
V2: GJ-44	953	4676	8130	8332	3075	25166
V3: GNJ-1	1126	5732	8040	8224	2949	26071
Mean	1068	5258	8108	8252	2988	25673
Date of sowing (D)						
D1: 15th Jan	885	4997	7770	7708	2773	24133
D2: 31st Jan	1012	5139	7753	8196	3136	25237
D3: 15th Feb	1307	5637	8800	8852	3055	27650
Mean	1068	5258	8108	8252	2988	25673

Conclusion

The results of the study clearly indicate that sowing sorghum on 15 February (D_3), corresponding to the second fortnight of February, is optimal for achieving higher grain yield under the climatic conditions of the South Gujarat Heavy Rainfall Zone. This sowing window ensured more favorable weather conditions throughout the crop growth period, thereby enhancing overall productivity. The GDD was higher on the 15th February of sowing (D_3) as compared to 15th January of sowing (D_1) due to the duration of phenophase increased, which caused an increase in the thermal indices. Similar trend followed in case of utilization of HTU and PTU. Among the varieties evaluated, GJ-44 (V_2) consistently outperformed GJ-42 (V_1) and GNJ-1 (V_3) in key growth and yield attributes, demonstrating its superiority for cultivation in this region. These findings, which align with previous research reports, highlight the critical role of selecting an appropriate variety in combination with the most suitable sowing time to maximize sorghum yield and production efficiency.

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