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Research Article

Performance of dual-purpose sorghum (*Sorghum bicolor*) under different sowing windows and crop geometry

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Abstract
India is one of the most vulnerable countries to climate change and its impact on agricultural production and livestock. Sorghum (*Sorghum bicolor*) is an important food crop of India cultivated in tropical and subtropical climates, especially the semiarid tropics; varying environmental attributes significantly affect its duration and yield. Therefore, the present research aimed to evaluate the potential of dual-purpose sorghum under varying sowing windows and crop geometry. The experiment was conducted in Eastern block farm of Tamil Nadu Agricultural University during the summer season- 2022. The experiment was laid out in strip plot design with three different dates of sowing in the main plot, *i.e.*, D_1 - First fortnight of February, D_2 - First fortnight of March and D_3 - First fortnight of April and six different crop geometries in the subplot *viz*., 45 x 15 cm (S_1),45 x 10 cm(S_2), 45 x 5 cm (S_3), 30 x 15 cm (S_4),30 x 10 cm (S_5) and 30 x 5 cm (S_6) and replicated thrice.The results revealed that sowing during the first fortnight (I FN) of April with a spacing of 45x 15 cm resulted in maximum grain yield(2585 kg/ha) and for fodder yield, April I FN sowing with a crop geometry of 30x 5 cm resulted in maximum green biomass (43.6 t/ha) as well as dry matter production. So, spacing of 30x 5 cm helps in better utilization of resources along with maximum fodder yield.

Keywords: Crop Geometry, Dual purpose Sorghum, Sowing Window, Yield

INTRODUCTION

India is the largest producer of millet in the world. India's Millet production accounts for 80% of Asia's & 20% of global production (FAOSTAT, 2021. https://www.fao.org/india/fao-in-india/india-at-a-glance/en/).

Sorghum (*Sorghum bicolor*) are one of the major staple food crops after rice and wheat. Sorghum is a short-day plant, and variation in its response to photoperiod and temperatures makes it adaptable to a wide range of different environments (Craufurd *et al*., 1999). Sorghum is one of the most important dryland crops grown in (*kharif* and *rabi)* seasons as a dual-purpose crop in Tamil Nadu. The major sorghum growing districts in Tamil Nadu are Namakkal, Dindigul, Tiruppur, Salem, Coimbatore, Trichy and Dharmapuri. Farmers traditionally grow the crop at low plant densities (10,000 to 14,000 plants/ha) to reduce the risk of water stress. Photoperiod (day length) sensitivity has been shown to affect the duration of plant's vegetative phase based on sowing dates. Optimum sowing date is one of the most important factors that play an important part in yield. Basically, for each product, there is a good planting time which, if not practiced can cause yield loss (Naoura *et al*., 2023)

Livestock plays an important role in the Indian economy and agriculture. India is the fastest growing country and more than 70 percent population of India earns from agricultural and animal husbandry sector (FAO, 2019).Sorghum (*Sorghum bicolor*) is an important food and feed source in mixed crop-livestock production systems where it dual usage is preferred. Despite the importance of sorghum, its cultivation areas have witnessed a remarkable decline by an estimated 0.15 million hectares annually, starting from the mid-eighties, which is the peak of its production until the present time due to climatic changes and lack of interest in this crop (Ajaj *et al.,* 2021). Therefore, the present study aimed to evaluate the best sowing window during the summer season for better grain and fodder yield under different crop geometry.

MATERIALS AND METHODS

Study area

A field experiment was conducted during the summer season (2022) in the Eastern block farm (37F) of Tamil Nadu Agricultural University to study the effect of sowing windows and crop geometry on the yield of dual-purpose sorghum. The experimental site is at an altitude of 420.7 m above mean sea level and is situated at 11°23' N latitude and 77°30' E longitude (MSL).

Methodology

The experiment was laid out in a strip plot design with three replications. Treatments include three different sowing windows in the main plot (D_1 - First fortnight of February, D_2 - First fortnight of March and D_3 - First fortnight of April) and six different crop geometries in the subplot (S_1 - 45 x 15 cm, S_2 – 45 x 10 cm, S_3 – 45 x 5 cm, S_4 – 30 x 15 cm, S_5 – 30 x 10 cm and S_6 – 30 x 5 cm). The soil of the experimental field was sandy loam in texture. The soil's initial nutritional status was low in available nitrogen, medium in available phosphorus, and high in available potassium.All necessary package of practices were followed during the crop growing season as per Tamil Nadu Agricultural University Crop Production Guide 2020 (https://agritech.tnau.ac.in/pdf/AGRICULTURE.pdf) All the necessary weather parameters during the cropping season were retrieved from Agromet observatory of the Agro-Climate Research Centre, Coimbatore. A minimum temperature of 19°C to 25.2 °C, maximum temperature of 31°C to 36.5 °C, bright sunshine hour's upto 10.3 hrs. and rainfall of 148.4 mm were recorded during the growing season, the standard meteorological weeks' weather data during cropping period is presented in Fig.1. Sorghum Variety CO-32 chosen for study was released from TNAU and the seeds were obtained from the Department of Millets, TNAU, Coimbatore. The duration of the CO-32 variety was 105-110 days. Grains were creamy white in color with an average grain yield of 2445 kg/ha under rainfed conditions and 2911 kg/ha under irrigated condition. Five plants were taken for dry matter production from the sample rows. The material was air-dried and then oven-dried at 80 ± 2°C until a constant weight was attained and expressed in kg ha^{-1}. For fodder purpose crop was harvested during the 50 % flowering stage.One square meter area of each net plot was selected, the plants were cut close to the ground level, and the fresh weight was recorded and expressed as green fodder yield in kg/ha.

Statistical analysis

The statistical analysis of data was done using the analysis of variance (ANOVA) technique for strip plot design at a 0.05 % probability level.

RESULTS AND DISCUSSION

Dry matter production

Sowing window and crop geometry significantly influenced the dry matter production of dual purpose sorghum at all the stages of observation except for 30 DAS. The data pertaining to the sowing window is presented in Table 1.

Among different sowing windows dry matter production was higher when crop was sown during the first fortnight of April, at 30 DAS though there no significant difference. Whereas at 60 DAS and harvest, dry matter production was significantly higher in April sown crop (11528 kg/ha and 17783.25 kg/ha) followed by March sown crop (10285 kg/ha and 16734 kg/ha), respectively. Similar results were reported by (Mishra *et al.,* 2017), *i.e.*, under early sown conditions, sorghum plants could not accumulate sufficient photosynthates, resulting in poor vegetative growth and ultimately low dry matter production.

Sorghum cultivar responded differently to varied crop geometry. In the spacing's closer spacing recorded the highest biomass production compared to the wider spacing. At 30 DAS S_6 (30 x 5 cm) recorded higher dry matter, followed by S_3 (45 x 5 cm) and S_5 (30 x 10 cm). Treatments S_2 (45 x 10 cm)and S_4 (30 x 15 cm) were

Table 1. Dry matter production (kg/ha) of dual-purpose sorghum at different stages of crop growth as affected by sowing window and crop geometry

Treatment Sowing Window	30 DAS	60 DAS	Harvest
D_1 - First FN of February	2535	8471	15660
D_2 - First FN of March	2816	10285	16734
D_3 - First FN of April	3030	11527	17783
Sed	133.84	95.09	206.67
CD (P= 0.05)	NS	264.00	573.82
Crop Geometry			
S_1 – 45 x 15 cm	1792	7681	12610
S_2 – 45 x 10 cm	2225	8643	13848
S_3 – 45 x 5 cm	3625	11266	18965
S_4 – 30 x 15 cm	2120	8205	13452
S_5 – 30 x 10 cm	2763	9435	16627
S_6 – 30 x 5 cm	4238	15336	24850
Sed	122.98	250.28	380.06
CD (P= 0.05)	274.04	557.68	846.84
D x S	NS	S	S

FN- Fort night, D- Date of sowing, S- Spacing, DAS-Days after sowing

statistically on par with each other. The same trend was followed at 60 DAS and harvest, except that at 60 DAS and harvest, treatments $S_{2,}$ S_4 and S_1 were statistically on par with the highest dry matter production in 45 x 10 cm spacing. This might be due to narrower spacing providing increasing stem density due to the increase in plant population. Cavalaris (2017) reported that narrow row spacing (NRS) of sweet sorghum at 0.375 m resulted in higher plant population and productivity in terms of dry matter compared to 0.75 m.

Yield attributes

The data regarding yield attributes (stem diameter, ear head length, ear head weight, grains per panicle and test weight) as influenced by sowing window and crop geometry presented in Table. 2 shows that stem diameter was not significantly (0.05 % level of significance) influenced by the time of planting in contrast, crop geometry had a significant effect on the diameter of the stem. Wider spaced crop stem diameter was higher compared to the closer spacing. 45 cm x 10 cm (S_1) spacing produced a higher diameter (5 cm) followed by S_2(4.8 cm), with the least diameter (3.6 cm) being S_6 (30 x 5 cm). This might be due to less competition for growth resources in wider spacing compared to narrow spacing. Kumar *et al.* (2012) reported that increased stem girth at lower plant density was due to increased individual plant size and leaf area in sweet sorghum.

Variation in ear head length, ear head weight, grain weight per panicle and test weight was significant during all the sampling dates due to adopted times of sowing. 1000 grain weight is an important yield contributing factor, which plays an important role in showing the potential of a variety. During the first fortnight (I FN) of April, sowing recorded the highest ear head weight, length, test weight and grain weight per panicle, followed by I FN of March. With regard to spacing S_1- 45 x 15 cm recorded maximum ear head length (25.0 cm), ear head weight(50.92 g), grain weight per panicle (38.92 g) and test weight (22.43 g) followed by S_2 - 45 x 10 cm with the values 23.20 cm, 45.91g, 33.16 g and 20.90 g respectively, which is on par with S_4 - 30 x 15 cm spacing. The lowest yield parameters were observed in closer spacing, *i.e.*30 x 5 cm. Low test weight, grain weight per panicle in 30 x 5 cm spacing might be due to higher plant population, which resulted in lesser photosynthetic rate availability and higher respiration rate because of mutual shading as reported by Eldie *et al*. (2017).

Grain yield and green fodder yield

The sowing window and crop geometry significantly influenced grain yield and green fodder yield. The data pertaining to this is presented in Table 3 and Fig 2. Grain yield was significantly higher when the crop was sown during I FN of April (2585 kg/ha) followed by I FN of March (2459 kg/ha). The same trend was observed regarding fodder yield. More favorable climatic conditions created at the grain filling stage of sorghum in treatment D_3 caused a better sink-source relationship and higher grain yield. Zander *et al.* (2021) reported that optimum grain yields of sorghum were found when planting in April or May and cooler soil temperatures can limit yield when grain sorghum is planted too early.

Table 2. Effect of sowing window and crop geometry on yield attributes of dual purpose sorghum

Treatment	Stem diameter (cm)	Ear head length (cm)	Ear head weight(g)	Grain weight panicle^{-1} (g)	Test weight (g)
Sowing Window					
D_1 - First FN of February	4.2	20.8	39.53	26.38	18.23
D_2 - First FN of March	4.3	22.8	42.15	28.34	19.30
D_3 - First FN of April	4.4	22.4	45.24	31.09	20.08
Sed	0.061	0.2	0.52	0.69	0.57
CD (P= 0.05)	NS	0.6	1.45	1.91	1.60
Crop Geometry					
S_1 - 45 x 15 cm	5.0	25.0	50.92	38.92	22.43
S_2 – 45 x 10 cm	4.8	23.5	45.91	33.16	20.90
S_3 – 45 x 5 cm	3.8	20.1	37.61	22.80	17.10
S_4 – 30 x 15 cm	4.6	23.1	44.98	32.06	20.50
S_5 – 30 x 10 cm	4.0	21.1	40.73	26.50	18.27
S_6 – 30 x 5 cm	3.6	19.2	33.69	18.18	16.03
Sed	0.063	0.3	1.684	1.28	0.78
CD (P= 0.05)	0.14	0.6	3.75	2.85	1.74
D x S	NS	NS	NS	NS	NS

FN- Fort night, D- Date of sowing, S- Spacing

Table 3. Grain yield and green fodder yield of dual purpose sorghum as affected by sowing window and crop geometry

Treatment	Grain Yield (kg/ha)	Green fodder Yield (t /ha)
Sowing Window		
D_1 - First FN of February	2338	28.9
D_2 - First FN of March	2459	32.7
D_3 - First FN of April	2585	35.5
Sed	36.96	0.45
CD (P= 0.05)	102.61	1.26
Crop Geometry		
S_1 - 45 x 15 cm	2950	24.0
S_2 – 45 x 10 cm	2670	26.8
S_3 – 45 x 5 cm	2195	39.1
S_4 – 30 x 15 cm	2551	27.6
S_5 – 30 x 10 cm	2354	33.2
S_6 – 30 x 5 cm	2042	43.6
Sed	67.57	1.42
CD (P= 0.05)	150.55	3.17
D x S	NS	NS

FN- Fort night, D- Date of sowing, S- Spacing

Grain yield is a product of the combined effects of cultivar genetics and environmental factors on the crop's yield components. The result of the intricate physiological and morphological processes that occur throughout a crop's growth and development is its grain yield and different plant spacing alters the growing circumstances (Zamir *et al*., 2011). The present data show that higher population density differed in grain yield significantly from others. The maximum grain yield was observed in S_1 (45 x 15 cm) (2950 Kg/ha) followed by which produced 2670 kg/ha yield which is on par with S_4 (2551 kg/ha) and the lowest yield was recorded in S_6(2042 kg/ha) treatment. In comparison, fodder yield was highest in S_6 (43.6 t/ha) followed by S_3 (39 t/ha). S_4 (30 x 15 cm) and S_2 are on par. Though the plant population was same in these treatments, *i.e.,* S_2 and S_4, 45 x 10 cm spacing (S_2) recorded higher yield than S_4 (30 x 15 cm) because of greater inter row spacing. Analysis of variance shown that interaction of planting date and crop geometry was not statistically significant for grain yield and fodder yield.

Andrade *et al*. (2002) reported that the narrow-row yield response was inversely proportional to the radiation interception achieved with wider rows. It has been reported by Fernandez *et al.* (2012) that the yield response to narrow rows in corn and grain sorghum is affected by many environmental, spatial, and temporal field interactions. In present study, fodder yield was

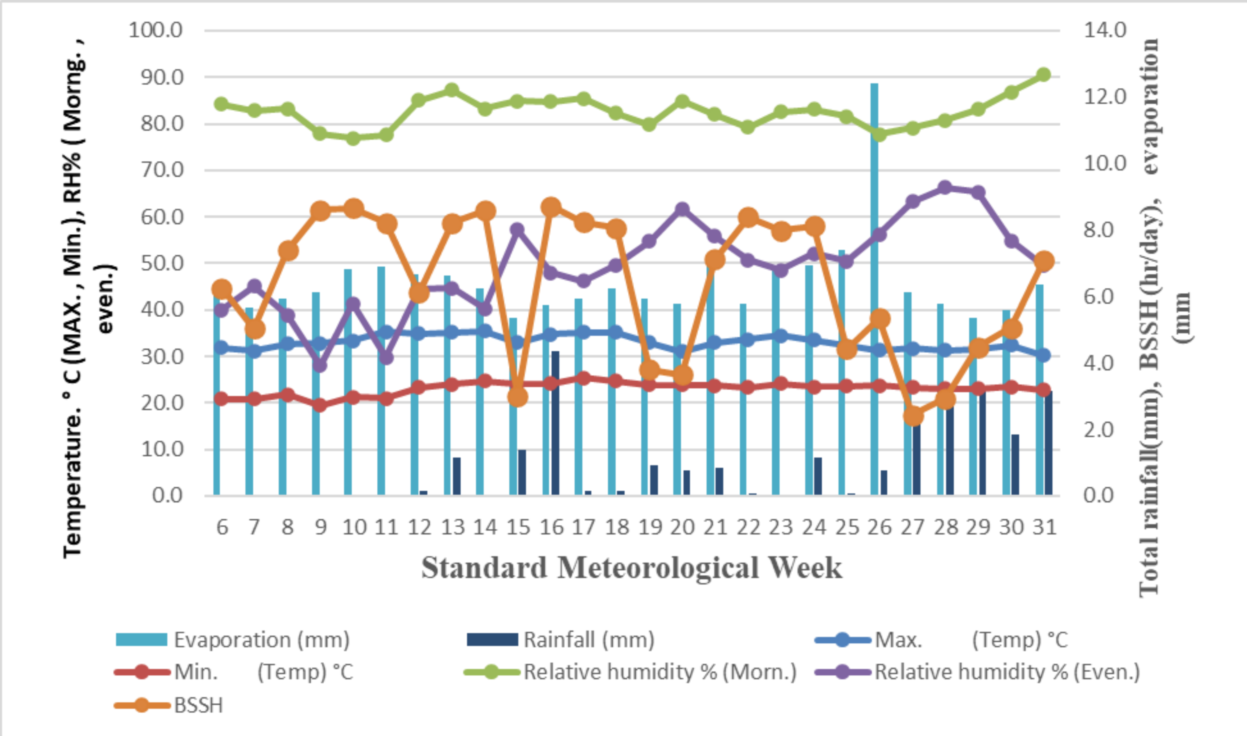

Fig 1. *Weather data of Standard meteorological weeks during the cropping period (February 2022- August 2022)*

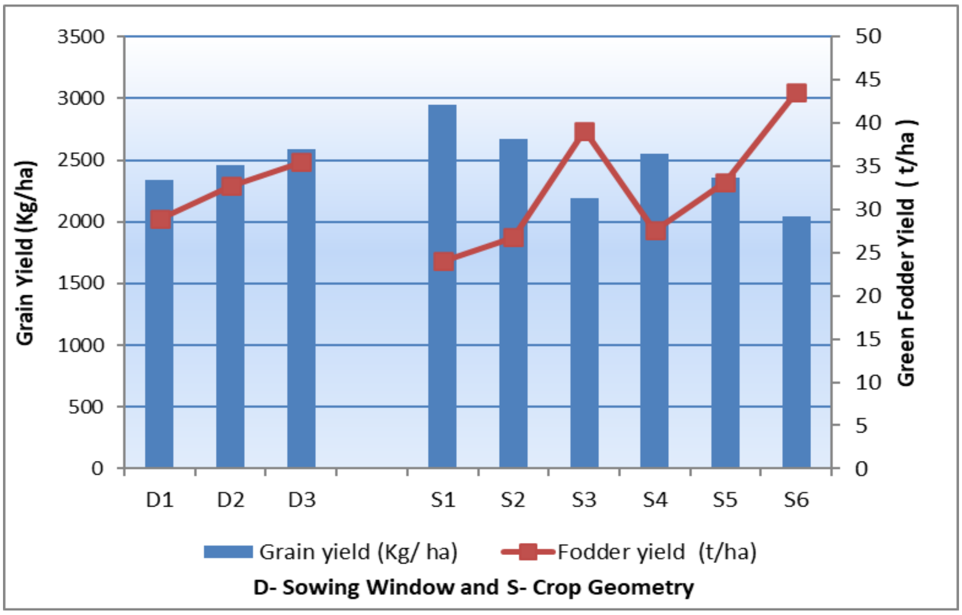

Fig 2. *Effect of Sowing window and varied crop geometry on grain yield and green fodder yield of sorghum*

better in S_6 because of increased stem densities compared to optimum spacing. Among different spacing's (30 x 10 cm, 30 x 15 cm, 30 x 20 cm and 30 x 25 cm), higher level of green forage yield of multicut sorghum were recorded under 30 x 10 cm spacing as reported by Sanmugapriya and Kalpana (2017).The present study focused on the influence of spacing dual-purpose sorghum variety CO-32, where importance is given to grain and fodder yield compared to other researchers with the expected outcome of good quality fodder with better palatability and optimum grain yield.

Conclusion

The present study concluded that sowing windows and crop geometry significantly affected sorghum yield (*S. bicolor*). The grain yield decreased significantly with decreasing inter and intra-row spacing. Among different sowing windows of the summer season, sorghum sowing during 1^{st} FN of April performed better than other sowing dates. Higher grain yield was obtained from 45 x15 cm (S_1), i.e., wider spacing in contrast for green fodder yield closer spacing of 30 x 5 cm was best. The population negatively affected the plant characteristics such as ear head length and stem diameter. Hence, when the sorghum crop is grown for fodder purposes, 30 x 5cm can be recommended; if the crop is grown for grain purposes, then 45 x 15 cm is best.

Conflict of interest

The authors declare that they have no conflict of interest.

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