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P Vijaya Mary
Department of Agronomy,
Professor Jayashankar Telangana
Agricultural University (PJTUA),
Hyderabad, Telangana, India

G Santhosh Kumar
Agriculture Research Station
(ARS), Tornala, Telangana, India

Swarna Ronanki
ICAR-Indian Institute of Millet
Research (IIMR), Rajendranagar,
Telangana, India

K Pavanchandra Reddy
Principal Scientist (SSAC) AICRP
on STCR, ISHM, ARI,
Rajendranagar, Telangana, India

Corresponding Author:
P Vijaya Mary
Department of Agronomy,
Professor Jayashankar Telangana
Agricultural University (PJTUA),
Hyderabad, Telangana, India

Impact of various sowing dates and levels of nitrogen on morpho-phenophysical characteristics of *Rabi* sorghum

P Vijaya Mary, G Santhosh Kumar, Swarna Ronanki and K Pavanchandra Reddy

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Abstract

A field trial took place in the *rabi* season of 2024-2025 at the Indian Institute of Millets Research in Rajendranagar, Hyderabad, to evaluate the effects of sowing dates and nitrogen levels on the morpho-phenological characteristics of *rabi* sorghum. The trial was arranged in a split plot design and conducted with three replications. Four sowing dates (M₁-1st FN of September, M₂-2nd FN of September, M₃-1st FN of October and M₄-2nd FN of October) were assigned to main plot and four nitrogen levels (S₁- Control, S₂-40 kg N/ha, S₃-80 kg N/ha and S₄-120 kg N/ha) were allocated to sub plot treatment. The findings showed that morpho-phenological characteristics such as plant height, leaf area index, dry matter accumulation, days to 50 percent flowering and days to maturity were significantly influenced by sowing dates and levels of nitrogen. Among the sowing dates, significantly highest plant height, leaf area index, dry matter accumulation, higher number of days to 50 per cent flowering and number of days to maturity was recorded under September 1st FN. Among different levels of N, application of nitrogen at 120 kg N/ha recorded the highest plant height, leaf area index, dry matter accumulation, days to 50 percent flowering, and days to maturity were all significantly greater than the other nitrogen levels. while remained at par with 80 kg N/ha.

Keywords: *Rabi* sorghum, nitrogen levels, sowing dates, FN, growth characteristics, kg/ha plant height and dry matter.

Introduction

Sorghum (*Sorghum bicolor* L) is widely grown in tropical and subtropical regions. It ranks as the fifth most significant cereal crop globally, following rice, wheat, maize, and barley, and is known for its nutritional benefits. In India, it is the third most extensively cultivated crop after rice and wheat. Nevertheless, it holds the title of the most essential crop in the semi-arid tropics (SAT) of India. Often referred to as the king of millets, it serves as a staple food for over 500 million people across approximately 30 countries. The sorghum harvested after the rainy season is mainly used for human consumption. India is positioned fifth in production, trailing behind the USA, Nigeria, Mexico, and Ethiopia. Within India, sorghum is cultivated across an area of 4.24 million hectares, yielding 4.78 million tonnes with a productivity rate of 1128 kg per hectare. *Rabi* sorghum stands out as the most significant cereal crop for the post-rainy season in peninsular India, primarily grown under rainfed conditions. In Telangana, it is planted over an area of 0.10 million hectares, producing 0.19 million tonnes with a productivity of 1407 kg per hectare (Agricultural statistics at a glance, 2023)^[1].

As a drought-resistant crop, jowar experiences low yields. The limitations in jowar productivity can be linked to inadequate agronomic practices. With climate change posing a significant threat to crop productivity, sorghum is expected to be crucial for food, feed, and fodder security in dryland economies. Therefore, improving grain sorghum production is essential in this scenario. Furthermore, gaining a deeper understanding of how sorghum reacts to various cultivation management techniques would help reduce the sorghum yield gap and secure food availability, especially in arid and semi-arid areas. Among contemporary agro-management practices, the timing of sowing and the appropriate amount of nitrogen are key factors in increasing crop yield per unit area. Enhanced grain yields in intensive agricultural systems have been attained through

sufficient nitrogen (N) supply (Mahama *et al.*, 2014; Bollam *et al.*, 2021) ^[13, 3]. Consequently, this study has examined four different sowing dates and four nitrogen levels to determine the most suitable planting time and nitrogen dosage for *rabi* sorghum.

Materials and Methods

The study was conducted at the ICAR-Indian Institute of Millet Research (IIMR) farm in Rajendranagar, Hyderabad, during the *rabi* season of 2024-25. This farm is situated at an elevation of 475.6 meters above the average sea level (MSL) at coordinates 17° 04' N latitude and 75° 54' E longitude. It lies within the Southern Telangana Agro-climatic Zone in the state of Telangana. The soil of the experimental area was fairly flat and of sandy loam texture, featuring a pH of 8.04, low levels of available nitrogen (174.7 kg/ha), medium phosphorus (31.9 kg/ha), and high potassium (339.8 kg/ha), along with low organic carbon content (0.38%). The experiment utilized a Split Plot Design, comprising four main plot treatments, four subplot treatments, and was replicated three times. The primary plot treatments consist of four sowing periods: the first fortnight of September (M1), the second fortnight of September (M2), the first fortnight of October (M3), and the second fortnight of October (M4). Sorghum variety M35-1 was planted with a spacing of 45×15 cm. During the cropping season of 2024-25, the average weekly maximum temperature recorded was 31.0°C. Likewise, the average weekly minimum temperatures were noted to be 17.9°C. The mean morning relative humidity (RH I) during the growing period of the crop averaged at 83%. Similarly, the mean relative humidity (RH II) varied, averaging at 43.4%. A half dose of nitrogen (according to the treatment) along with the full doses of phosphorus (60 kg/ha) and potassium (40 kg/ha) were applied at sowing, while the remaining nitrogen was applied at 30 DAS. All other agronomic practices were adhered to as per recommendations.

The morpho-phenological characteristics, including plant height, dry matter yield, leaf area index, days to 50 percent flowering, and days to maturity, were documented. For non-destructive sampling measurements such as plant height, five plants were randomly chosen and labelled from each experimental plot, while another five plants were harvested and dried in a hot air oven at 60 °C until they reached constant weight. The final weights were reported in kg/ha. The collected data underwent statistical analysis according to the methods recommended by the relevant guidelines, and the standard error (S.E.) of the means was calculated for each factor. When outcomes were statistically significant, the critical difference (C.D.) was determined at a 5 percent level of significance.

Results and Discussion

Impact of dates of sowing and levels of nitrogen on plant height (cm)

Information on the plant height of *rabi* sorghum measured at various growth stages, specifically at 30, 60, 90 DAS, and at harvest, is displayed in Table 1. The different sowing dates and nitrogen levels had a significant impact on plant height at all growth stages; however, the interaction effect between these two factors was not significant throughout all growth stages of *rabi* sorghum.

Among the various sowing dates, the tallest plants measured 221.12 cm during the harvest of the M1 treatment (sown on September 1st FN). The smallest height recorded was 181.28 cm in the M4 treatment (sown on October 2nd FN). Early planting generally enables the crop to benefit from optimal

environmental conditions such as adequate soil moisture, extended daylight, and moderate temperatures, all of which support robust growth. Havva *et al.* (2012) found that plant height and diameter decreased with later sowing dates. Comparable findings were noted by Shravankumar *et al.* (2015). The levels of nitrogen significantly influenced the height of sorghum plants. An increase in plant height was observed as nitrogen application rose from 0 to 120 kg N/ha across all stages of crop development. At the time of harvest, the tallest plants were recorded with the application of 120 kg N/ha (207.34 cm), which was significantly greater than those with 40 kg N/ha and 0 kg N/ha. However, the height recorded at 120 kg N/ha (S4) was statistically similar to that of 80 kg N/ha (S3) (204.32 cm). The shortest plant height was noted with 0 kg N/ha (190.63 cm). The plant height followed a similar pattern at 30 DAS, 60 DAS, and 90 DAS. The increase in nitrogen application led to taller plants at different growth phases, likely due to stimulated cell division and elongation, resulting in a greater number and length of internodes, thereby increasing the plant's height as reported by Swetha *et al.* (2022) ^[18]. These results align with the conclusions drawn by Hussain *et al.* (2021) ^[9], Kugbe *et al.* (2019) ^[11], and Naik *et al.* (2018) ^[14].

Impact of dates of sowing and levels of nitrogen on dry matter accumulation

The accumulation of dry matter in *rabi* sorghum at various growth stages, specifically at 30, 60, 90 DAS, and at harvest, is outlined in Table 1. The interaction between the timing of sowing and levels of nitrogen did not show any significant effects.

Looking at the data, the highest dry matter accumulation was found in early sowing (8816 kg/ha), which was significantly greater than that of delayed sowing (6028 kg/ha). The most substantial dry matter accumulation occurred with the first fertilizer application in September across all growth stages of the sorghum. According to Panda *et al.* (2004), sowing delayed past October 16th led to a notable decrease in both primary and secondary branches per plant as well as total dry matter production. These findings align with the observations made by Hulihali *et al.* (2016), Kalhapure, and Shete (2013) ^[10].

At the time of harvest, the highest dry matter accumulation was recorded with an application of 120 kg N/ha (8225 kg/ha). This amount was found to be significantly better than the control with 0 kg N/ha (6221 kg/ha), although it was statistically similar to the treatment with 80 kg N/ha (8108 kg/ha). Each increase in nitrogen dosage resulted in a consistent and significant rise in dry matter accumulation. Saini (2012) ^[15] observed that using 125% of the recommended nitrogen dose produced a significantly greater dry matter yield. These findings are in close agreement with those reported by Kugbe *et al.* (2019) ^[11].

Impact of dates of sowing and levels of nitrogen on leaf area index

The leaf area index (LAI) of sorghum was notably affected by varying sowing dates and nitrogen levels throughout different growth stages, particularly at 30, 60, 90 days post-sowing, as well as at harvest, as shown in Table 1. Nevertheless, the relationship between sowing dates and nitrogen levels did not show a statistically significant effect on LAI.

The peak Leaf Area Index (LAI) was observed during the first fortnight of September at harvest (2.62), which is significantly higher than the values for the second fortnight of September (2.43) and the first fortnight of October (2.21). This may be attributed to the favourable climatic conditions, particularly the

temperature. The lowest LAI was noted in the second fortnight of October (2.19). Early sown crops take advantage of favorable weather, leading to a higher germination rate and greater vigor, which results in the development of more leaves. Consequently, this is reflected in the enhanced leaf area index seen during the panicle initiation phase. Comparable results are reported by Verma *et al.* (2012)^[20].

The leaf area index (LAI) of sorghum at the time of harvest shows considerable variation based on nitrogen levels, with the highest LAI (2.54) recorded when 120 kg N/ha was applied, which was statistically similar to the 80 kg N/ha application (2.45), while the lowest LAI (2.04) was seen with no nitrogen application. These findings are consistent with those reported by Samuel *et al.* (2012)^[16].

Impact of dates of sowing and levels of nitrogen on days to 50% flowering

The data presented in Table 2 showed that the number of days required to achieve 50% flowering was significantly influenced by both sowing dates and nitrogen levels; however, the interaction between these two factors was found to be non-significant.

The sowing dates exhibited significant differences in the number of days taken to reach 50% flowering. The treatment M4 had the lowest mean days (56 days) for 50% flowering, followed by M3 (59 days) and the other treatments. The M1 treatment (1st FN of September) recorded the highest mean days (68 days) for 50% flowering. This can be attributed to the fact that sowing in October reduces the vegetative phase due to cooler temperatures and shorter day lengths, while sowing in September encourages extended vegetative growth, resulting in a delay in flowering. These findings align with those reported by Likitha (2023).

The data indicated that the fewest days until 50% flowering (58 days) occurred without nitrogen application (S1), followed by 40 kg N/ha (S2) and then 80 kg N/ha (S3). The application of 120 kg N/ha (S4) led to a significant delay (64 days) in reaching

50% flowering, which was nearly six days later than the control group. Increased nitrogen levels encourage denser canopies and ongoing growth of stems and leaves, redirecting resources toward vegetative growth and effectively delaying the onset of reproductive stages. Similar results were reported by Tajane *et al.* (2019)^[19], Ajeigbe *et al.* (2018)^[2], and Buah *et al.* (2012)^[5].

Impact of dates of sowing and levels of nitrogen on days to maturity

The impact of sowing dates and nitrogen levels on the duration until physiological maturity was analysed statistically, with the findings presented in Table 2. The interaction between sowing dates and nitrogen levels did not show any significant effect on the number of days needed to reach physiological maturity.

The quickest time to achieve physiological maturity (98 days) was noted for the M4 sowing date, which was significantly better than the other dates. In contrast, the M1 date took a much longer time to attain physiological maturity, requiring 116 days. Generally, earlier planting led to a postponement in phenological development and maturity. These observations align with the previous research conducted by Hadebe *et al.* (2017)^[7].

The data indicated that the shortest time to reach physiological maturity (100 days) was observed with no nitrogen application (S1), followed by applications of 40 kg N/ha (S2) and 80 kg N/ha (S3). The application of 120 kg N/ha (S4) resulted in a significantly longer duration (113 days) required for maturity compared to the control. Higher nitrogen levels in *rabi* sorghum appear to postpone both 50% flowering and the time to maturity. This delay is due to increased nitrogen extending the vegetative phase, promoting stay-green traits, and lengthening the grain filling period, thus shifting physiological maturity to a later date. Both the physiological responses driven by nutrients and the signalling pathways involving nitrate play a role in this delayed maturity. These findings align with the research conducted by Buah and Mwinkaara (2009)^[4].

Table 1: Plant height, Dry matter accumulation, Leaf area index of *rabi* sorghum at different stages as influenced by dates of sowing and levels of nitrogen

Treatments	Plant height				Dry matter accumulation				Leaf area index			
	30 DAS	60 DAS	90 DAS	At harvest	30 DAS	60 DAS	90 DAS	At harvest	30 DAS	60 DAS	90 DAS	At harvest
Main plots: Sowing dates												
M1: 1 st FN of Sep	59.87	120.28	205.28	221.12	1278	5040	7633	8816	1.94	2.68	2.78	2.62
M2: 2 nd FN of Sep	55.19	112.95	193.90	206.11	1191	4497	7078	7900	1.76	2.33	2.52	2.43
M3: 1 st FN of Oct	50.59	106.44	180.13	190.43	1101	4008	6507	6918	1.56	2.08	2.31	2.21
M4: 2 nd FN of Oct	45.60	98.93	165.29	181.28	1005	3608	5717	6028	1.44	1.80	2.09	2.03
S.Em±	0.79	1.84	3.06	1.51	19.0	113.3	136.0	59.5	0.03	0.07	0.04	0.04
CD (p=0.05)	2.74	6.36	10.58	5.22	65.7	392.2	470.6	205.9	0.09	0.24	0.15	0.14
C.V (%)	5.20	5.80	5.69	2.61	5.7	9.2	7.0	2.8	5.26	10.62	6.14	6.06
Sub plots: Nitrogen levels												
S1: Control	46.34	100.96	169.54	190.63	1024	2992	5492	6221	1.29	1.83	2.20	2.04
S2: 40 kg/ha	49.88	107.23	179.85	196.65	1083	3775	6541	7108	1.57	2.22	2.34	2.27
S3: 80 kg/ha	56.41	113.83	194.89	204.32	1214	5037	7374	8108	1.87	2.38	2.54	2.45
S4: 120 kg/ha	58.63	116.59	200.33	207.34	1254	5350	7528	8225	1.98	2.46	2.63	2.54
S.Em±	0.84	1.21	1.99	1.07	15.8	111.0	66.6	55.9	0.04	0.04	0.04	0.04
CD (p=0.05)	2.44	3.52	5.81	3.13	46.1	323.9	194.5	163.2	0.13	0.13	0.11	0.10
C.V. (%)	5.49	3.81	3.70	1.86	4.8	9.0	3.4	2.6	8.96	6.91	5.34	5.31
Sub treatment at same level of main treatment												
S.Em±	1.67	2.41	3.98	2.15	31.6	221.9	133.2	111.8	0.09	0.15	0.07	0.07
C.D. (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Main treatment at same level of sub treatment												
S.Em±	1.65	2.78	4.61	2.39	33.3	223.1	178.3	113.6	0.08	0.14	0.08	0.07
C.D. (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 2: Number of days to attain 50% flowering and maturity of *rabi* sorghum as influenced by dates of sowing and levels of nitrogen

Treatments	Days to 50 percent flowering	Days to maturity
Main plots: Sowing dates		
M1: 1 st FN of Sep	68	116
M2: 2 nd FN of Sep	63	110
M3: 1 st FN of Oct	59	105
M4: 2 nd FN of Oct	56	98
S.Em ($\pm$)	0.6	1.3
CD (p=0.05)	2.1	4.5
Sub plots: Nitrogen levels		
S1: Control	58	100
S2: 40 kg/ha	60	105
S3: 80 kg/ha	63	111
S4: 120 kg/ha	64	113
S.Em ($\pm$)	0.5	0.8
CD (p=0.05)	1.4	2.5
Interaction		
Sub treatment at same level of main treatment		
S.Em ($\pm$)	0.9	1.7
CD (p=0.05)	NS	NS
Main treatment at same level of sub treatment		
S.Em ($\pm$)	1.0	2.0
CD (p=0.05)	NS	NS

Conclusion

Based on the findings presented, it can be inferred that *rabi* sorghum planted during the first fortnight of September (M1) exhibited significantly superior growth and phenological characteristics. In terms of nitrogen applications, the crop treated with 120 kg N/ha (S4) demonstrated notably higher morpho-phenological attributes, although it was statistically comparable to the treatment with 80 kg N/ha. The enhanced plant growth traits in response to increased nitrogen application can be attributed to its crucial role in stimulating cell division, leaf expansion, and photosynthetic processes, ultimately leading to improved dry matter accumulation. Additionally, early planting ensured favourable temperature and moisture levels during both the vegetative and reproductive stages, facilitating better crop establishment and growth. Therefore, it can be concluded that the ideal sowing time for *rabi* sorghum is the first fortnight of September with an application of 120 kg N/ha.

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