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Effect of organic sources and nutrients on growth parameters of Sorghum (*Sorghum Bicolor* L.) crop

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Abstract
The present study evaluated the influence of integrated application of organic and inorganic nutrient sources on key growth parameters of sorghum during two consecutive seasons (2023-24 and 2024-25). Treatments comprising chemical fertilizers, organic manures, and biofertilizers were assessed for their effects on plant height, number of branches, and leaf area at different growth stages. The results clearly indicated that integrated nutrient management significantly enhanced all growth attributes compared to the control. Among the treatments, application of 100% Recommended Dose of Fertilizers (RDF) along with Azotobacter and Phosphate-Solubilizing Bacteria (PSB) consistently recorded the maximum plant height, number of branches, and leaf area at all growth stages and at harvest during both years. The treatment integrating 75% RDF with vermicompost and biofertilizers emerged as the next best option. The control treatment recorded the lowest values for all growth parameters. Improved growth under integrated treatments was attributed to balanced nutrient availability, enhanced microbial activity, and improved nutrient uptake. Overall, the study highlights the effectiveness of integrating organic manures and biofertilizers with inorganic fertilizers in promoting vigorous vegetative growth of sorghum and sustaining crop productivity.

Keywords: Sorghum, growth parameters, organic and inorganic fertilizer.

Introduction
Sorghum (*Sorghum bicolor* L.) Moench) is one of the world's most important cereal crops, valued for its versatility, resilience, and critical role in global agriculture. As a staple food for millions, particularly in semi-arid regions of Africa and Asia, sorghum contributes significantly to food security, livestock feed, and industrial applications. Its ability to thrive in harsh environmental conditions, including drought and poor soils, makes it a cornerstone of sustainable agriculture in the face of climate change (Paterson *et al.*, 2009) [10]. This introduction explores the origin, botanical characteristics, agricultural significance, environmental adaptability, and socio-economic importance of sorghum, providing a foundation for understanding its role in modern agriculture and the rationale for further research.

Sorghum was domesticated approximately 5,000-8,000 years ago in the region now encompassing Sudan and Ethiopia (Winchell *et al.*, 2017) [13]. Archaeological evidence suggests that early farmers selected wild sorghum varieties for traits such as larger grain size and non-shattering heads, leading to the development of cultivated sorghum (Pal *et al.*, 2024) [9]. The crop spread across Africa, Asia, and eventually to the Americas and Australia through trade and migration. Today, sorghum is grown in over 100 countries, with major production centers in the United States, Nigeria, Sudan, and India (FAO, 2023). Its historical significance lies in its role as a reliable food source in regions prone to drought and famine, earning it the nickname ``camel of crops" due to its resilience (Taylor *et al.*, 2019) [12]. State-wise, Maharashtra led the production in the 2023-2024 period with approximately 1.4 million metric tonnes, followed by Karnataka and Rajasthan. In terms of yield, Andhra Pradesh recorded the highest annual yield in 2024, with about 3,493 kilograms per hectare, indicating the potential for enhanced productivity through improved agronomic practices. (Khalifa *et al.*, 2023) [6].

Sorghum (Sorghum bicolor L.), a vital cereal crop, is predominantly cultivated in arid and semi-arid regions due to its resilience to drought and adaptability to diverse agro-climatic conditions.

Globally, between 2001 and 2020, the average harvested area for sorghum was approximately 40.9 million hectares, with major contributions from countries like India, Sudan, and Nigeria. During this period, the global average production stood at nearly 58.7 million tonnes annually, and the average yield was about 2.5 tonnes per hectare. However, yields varied significantly across regions, with North America achieving higher averages compared to South Asia and sub-Saharan Africa, where yields were notably lower. In India, sorghum cultivation has seen a decline over the years. The area under sorghum reduced from 10.25 million hectares in 1999-2000 to 6.36 million hectares in 2022-23. Despite this reduction in area, certain regions have reported higher productivity. For instance, in the rice fallows of coastal Andhra Pradesh, sorghum cultivation under zero-tillage practices achieved a productivity of 5.32 tonnes per hectare in 2022-23, significantly surpassing the national average yield, which remains below 1.0 tonne per hectare.

Integrated nutrient management in sorghum refers to the judicious and combined application of organic manures, chemical fertilizers, and biofertilizers to supply balanced nutrients, improve soil fertility, enhance microbial activity, increase nutrient use efficiency, and achieve sustainable improvement in sorghum growth, productivity, and soil health (Kumari *et. al.*, 2024 and Shukla *et al.*, 2024) [7, 11].

Materials and Methods

This research entitled "Effect of organic sources and nutrients on yield, quality and nutrient uptake by Sorghum (*Sorghum bicolor* L.)" was strategically executed during the *Kharif* seasons of 2023-24 and 2024-25. Hanumangarh is a notable district located in the northern expanse of Rajasthan, India, geographically situated between 25°46′ to 29°57′ N latitude and 74°43′ to 75°31′ E longitude. It occupies a strategic position, sharing borders with Punjab to the north, Haryana to the east, Churu to the south, and Bikaner and Ganganagar to the west. In RBD design total 13 treatments with 3 replications was applied in this research. The treatments details like- T_1 (Control), T_2 (100% RDF (120:60:60:40: N:P:K:S, kg ha^{-1}), T_3 (100% RDF + Bio-fertilizers (Azotobacter + PSB), T_4 (75% RDF + FYM 5 t ha^{-1}), T_5 (75% RDF + FYM 5 t ha^{-1} + Bio-fertilizers), T_6(75% RDF+Vermicompost 2 t ha^{-1}), T_7 (75% RDF + Vermicompost 2 t ha^{-1} + Bio-fertilizers), T_8 (50% RDF + FYM 10 t ha^{-1}), T_9 (50% RDF + FYM 10 t ha^{-1} + Bio-fertilizers), T_{10} (50% RDF + Vermicompost 4 t ha^{-1}), T_{11} (50% RDF + Vermicompost 4 t ha^{-1} +Bio-fertilizers), T_{12} (50% RDF+ FYM 5 t ha^{-1} +Vermicompost 2 t ha^{-1}), T_{13} (50% RDF + FYM 5 t ha^{-1} + Vermicompost 2 t ha^{-1} +Bio-Fertilizers). The plant height was measured within each designated experimental plot, a total of five plants were randomly chosen to ensure unbiased sampling of the crop population. The number of branches per plant was counted in every experimental plot established for the study, five individual plants were carefully chosen using a randomized selection method to ensure unbiased sampling. Leaf area estimation was conducted by recording the total number of leaves from five randomly selected plants at three different intervals- specifically at 30, 60, and 90 days after planting.

Results and Discussion

Plant height

Table 1 presents the data on plant height as influenced by different organic and inorganic nutrient sources. A detailed assessment of the results shows that integrated applications of organic manures, chemical fertilizers, and biofertilizers significantly enhanced sorghum plant height. During the first year (2023-24), at 30 DAS, the tallest plants (88.34 cm) were produced under treatment T_3 (100% RDF + Azotobacter + PSB), followed closely by T_7 (75% RDF + 2 t/ha vermicompost + biofertilizers), which recorded 81.23 cm. Other integrated nutrient treatments also resulted in marked improvements, whereas the control (T_1) recorded the shortest plants. This trend continued at 60 DAS, with T_3 producing the highest plant height (130.35 cm), followed by T_7 (121.79 cm), while T_1 again recorded the minimum height (64.08 cm). At 90 and 120 DAS, treatment T_3 maintained its superiority with heights of 158.23 cm and 173.02 cm, respectively. At harvest, T_3 recorded the tallest plants (177.90 cm), followed by T_7 (169.30 cm), whereas the control treatment had the lowest height (111.50 cm).

A similar pattern was observed during the second year (2024-25). At 30 DAS, the maximum plant height (89.82 cm) was again achieved under T_3, with T_7 following at 82.04 cm. At 60 DAS, T_3 recorded 131.78 cm, while T_7 achieved 123.19 cm. Treatment T_3 continued to outperform all others at 90 DAS (161.03 cm), 120 DAS (174.87 cm), and at harvest (179.95 cm), whereas T_1 consistently recorded the minimum height (113.58 cm). Overall, the combined application of organic and inorganic nutrient inputs along with biofertilizers significantly enhanced sorghum plant height at every growth stage. The superior performance of T_3 can be attributed to the application of the full recommended dose of fertilizers, which ensured adequate nutrient availability, particularly nitrogen, a key component of chlorophyll essential for photosynthesis and subsequent plant growth. Likewise, the integration of 75% RDF with vermicompost and biofertilizers, as in T_7, supplied nutrients more steadily over time, thereby improving plant height compared to most other treatments. Previous studies also support these findings: Bijarnia *et al.*, (2020) [1] noted improved sunflower emergence with urea application, while Dharaviya *et al.*, (2023) [3] reported significant increases in forage sorghum height when FYM was combined with biofertilizer seed treatment.

Number of branches

Table 2 presents the data on the number of branches in sorghum as influenced by various organic and inorganic nutrient sources. A detailed evaluation of the results clearly shows that the integration of these nutrient inputs had a highly significant effect on the branching behavior of the crop. During the 2023-24 growing season, observations at 30 DAS revealed that treatment T_3 consisting of 100% RDF along with biofertilizers (Azotobacter and PSB) produced the highest number of branches (4.52). This was closely followed by treatment T_7 (75% RDF + 2 t/ha vermicompost + biofertilizers), which recorded 4.32 branches.

Similar trends continued at later growth stages (60, 90, and 120 DAS), with T_7 performing prominently among the integrated nutrient treatments. At harvest, the maximum number of branches (7.83) was again observed under T_3, with T_7 remaining a close second. In every observation period, the lowest branch counts were consistently recorded in the control plot (T_1), which received no nutrient inputs. A comparable pattern was noted during 2024-25. Throughout all growth stages 30, 60, 90, and 120 DAS, treatment T_3 maintained its superiority, producing 4.82, 7.63, 7.87, and 8.05 branches, respectively, while T_7 consistently followed. At harvest, the maximum branch number (8.22) was again recorded under T_3, whereas the control (T_1) remained lowest.

The increase in the number of shoots per square meter with FYM combined with biofertilizers can be attributed to improved nutrient availability, especially nitrogen, within the root zone, enabling better nutrient uptake by the plants (Gudadhe *et al.*, 2020) [5]. Biofertilizers further contribute to the soil's nitrogen pool, enhancing vegetative growth and ultimately promoting greater shoot and branch development in sorghum. Such integrated nutrient management practices ensure a continuous supply of nutrients that foster robust crop architecture (Maharana and Singh, 2021) [8]. Supporting this, earlier studies have reported the positive influence of vermicompost on shoot proliferation, demonstrating its considerable role in enhancing overall plant growth.

Leaf area (cm^{-2})

Table 3 provides detailed information on the impact of organic and inorganic nutrient sources on leaf area development in sorghum. A thorough analysis of the data clearly indicates that integrated nutrient management combining organic fertilizers, inorganic fertilizers, and biofertilizers, significantly and positively influenced leaf area expansion in the crop. In the first year (2023-24), measurements taken at 30 DAS showed that treatment T_3, which consisted of 100% RDF along with Azotobacter and PSB, produced the largest leaf area (146.23 cm²). This value was statistically comparable to treatment T_7 (75% RDF + 2 t/ha vermicompost + biofertilizers), which recorded 142.63 cm². Other integrated nutrient treatments also resulted in markedly higher leaf area than the control (T_1), which consistently exhibited the smallest leaf area throughout all growth stages. At 60 DAS, T_3 again achieved the highest leaf area (172.28 cm²), with T_7 close behind at 168.78 cm², while the control treatment recorded only 88.51 cm². A similar pattern continued at 90 DAS, where T_3 reached the maximum leaf area of 183.23 cm², followed by T_7 (179.35 cm²), whereas T_1 remained significantly lower.

Results from the second experimental year (2024-25) mirrored these findings. At 30 DAS, the highest leaf area was again recorded in T_3 (147.52 cm²), statistically on par with T_7 (143.93 cm²). At 60 DAS, T_3 maintained its lead with 173.39 cm², while T_7 followed closely at 169.93 cm². The control treatment, once more, produced the lowest leaf area across all measurement periods. At 90 DAS, T_3 registered the highest leaf area (184.19 cm²), with T_7 remaining the second-best performer at 180.71 cm². Throughout both years of study, T_1 consistently produced the lowest leaf area values, highlighting the substantial limitations in vegetative growth under nutrient-deficient conditions. The combined findings from both years conclusively demonstrate that integrating organic manures such as vermicompost with recommended levels of inorganic fertilizers and biofertilizers markedly enhances leaf area development in sorghum (Gudadhe *et al.*, 2020) [5]. Improved leaf area is indicative of stronger vegetative growth and increased photosynthetic potential, which can ultimately translate into higher yield. The consistent superiority of integrated nutrient treatments across two consecutive seasons underscores the effectiveness of such nutrient management practices in promoting vigorous sorghum growth under field conditions (Maharana and Singh, 2021) [8].

Table 1: Effect of organic and inorganic sources of nutrients on different growth stages of plant height (cm).

Treatments	Plant height (cm)								
	30 DAS			60 DAS			90 DAS		
	2023-24	2024-25	Pooled	2023-24	2024-25	Pooled	2023-24	2024-25	Pooled
T_1	22.02	23.52	22.77	64.08	65.45	64.77	91.89	93.02	92.46
T_2	77.14	78.62	77.88	119.03	120.37	119.70	147.02	149.62	148.32
T_3	88.34	89.82	89.08	130.35	131.78	131.07	158.23	161.03	159.63
T_4	33.61	34.75	34.18	75.18	76.64	75.91	103.04	105.75	104.40
T_5	36.73	38.04	37.39	78.32	79.69	79.01	106.18	109.02	107.60
T_6	72.54	73.83	73.19	114.17	115.58	114.88	142.09	144.83	143.46
T_7	81.23	82.04	81.64	121.79	123.19	122.49	149.67	152.42	151.05
T_8	31.57	32.52	32.05	73.24	74.65	73.95	101.05	103.84	102.45
T_9	51.72	53.09	52.41	93.39	94.82	94.11	121.31	124.05	122.68
T_{10}	63.39	64.64	64.02	105.08	106.39	105.74	133.09	135.65	134.37
T_{11}	66.85	68.16	67.51	108.47	110.01	109.24	136.41	139.13	137.77
T_{12}	56.66	57.99	57.33	98.32	99.67	99.00	126.22	128.89	127.56
T_{13}	58.19	59.42	58.81	100.01	101.18	100.60	127.72	129.86	128.79
S.Em (±)	0.85	0.75	0.80	1.20	1.25	1.23	2.06	2.29	2.18
C.D. at 5%	2.49	2.20	2.35	3.54	3.68	3.61	6.05	6.73	6.39

Table 1.1: Effect of organic and inorganic sources of nutrients on different growth stages of plant height (cm).

Treatments	Plant height (cm)					
	120 DAS			At harvest		
	2023-24	2024-25	Pooled	2023-24	2024-25	Pooled
T_1	106.42	108.51	107.47	111.50	113.58	112.54
T_2	161.52	163.46	162.49	165.70	168.56	167.13
T_3	173.02	174.87	173.95	177.90	179.95	178.93
T_4	117.67	119.69	118.68	121.78	124.76	123.27
T_5	120.75	122.77	121.76	125.80	127.89	126.85
T_6	156.68	158.69	157.69	161.70	163.75	162.73
T_7	164.29	166.30	165.30	169.30	171.39	170.35
T_8	115.73	117.66	116.70	120.62	122.76	121.69
T_9	136.02	137.87	136.95	140.81	142.99	141.90
T_{10}	147.48	148.44	147.96	152.42	154.58	153.50
T_{11}	151.03	151.92	151.48	155.93	158.09	157.01
T_{12}	140.78	142.76	141.77	145.69	147.89	146.79
T_{13}	142.34	144.31	143.33	147.23	149.35	148.29
S.Em (±)	2.39	2.11	2.25	2.47	2.36	2.42
C.D. at 5%	7.04	6.19	6.62	7.25	6.93	7.09

Table 2: Effect of organic and inorganic sources of nutrients on different growth stages of number of branches per plant.

Treatment	Number of branches per plant								
	30 DAS			60 DAS			90 DAS		
	2023-24	2024-25	Pooled	2023-24	2024-25	Pooled	2023-24	2024-25	Pooled
T_1	3.12	3.41	3.27	4.91	5.41	5.16	5.32	5.68	5.50
T_2	4.23	4.54	4.39	6.42	6.92	6.67	7.13	7.47	7.30
T_3	4.52	4.82	4.67	7.13	7.63	7.38	7.52	7.87	7.70
T_4	3.63	3.90	3.77	5.61	6.12	5.87	5.93	6.26	6.10
T_5	3.64	3.91	3.78	5.42	5.91	5.67	6.03	6.35	6.19
T_6	4.21	4.52	4.37	6.63	7.14	6.89	6.92	7.24	7.08
T_7	4.32	4.61	4.47	7.11	7.63	7.37	7.53	7.82	7.68
T_8	3.34	3.63	3.49	5.32	5.82	5.57	5.74	6.04	5.89
T_9	3.82	4.12	3.97	5.93	6.41	6.17	6.25	6.54	6.40
T_{10}	4.14	4.44	4.29	6.33	6.82	6.58	6.75	7.03	6.89
T_{11}	4.21	4.51	4.36	6.42	6.93	6.68	7.05	7.32	7.19
T_{12}	3.91	4.22	4.07	6.04	6.52	6.28	6.41	6.71	6.56
T_{13}	3.92	4.23	4.08	5.93	6.41	6.17	6.42	6.74	6.58
S.Em (±)	0.07	0.06	0.07	0.08	0.07	0.08	0.11	0.07	0.09
C.D. at 5%	0.21	0.19	0.20	0.23	0.22	0.23	0.34	0.20	0.27

Table 2.1: Effect of organic and inorganic sources of nutrients on different growth stages of number of branches per plant.

Treatment	Number of branches per plant					
	120 DAS			At harvest		
	2023-24	2024-25	Pooled	2023-24	2024-25	Pooled
T_1	5.44	5.65	5.55	5.48	5.92	7.52
T_2	7.21	7.55	7.38	7.32	7.71	8.03
T_3	7.72	8.05	7.89	7.83	8.22	6.34
T_4	6.03	6.35	6.19	6.14	6.53	6.53
T_5	6.24	6.55	6.40	6.32	6.74	7.44
T_6	7.12	7.45	7.29	7.25	7.62	7.90
T_7	7.63	7.85	7.74	7.66	8.14	6.16
T_8	5.84	6.15	6.00	5.97	6.34	6.67
T_9	6.34	6.75	6.55	6.51	6.82	7.24
T_{10}	6.82	7.35	7.09	7.14	7.33	7.43
T_{11}	7.13	7.45	7.29	7.23	7.62	6.92
T_{12}	6.51	6.95	6.73	6.78	7.06	6.98
T_{13}	6.62	7.05	6.84	6.82	7.14	0.10
S.Em (±)	0.11	0.11	0.11	0.10	0.10	0.31
C.D. at 5%	0.32	0.33	0.33	0.31	0.30	7.52

Table 3: Effect of organic and inorganic sources of nutrients on different growth stages of Leaf area (cm^{-2}).

Treatments	Leaf area (cm^{-2})								
	30 DAS			60 DAS			90 DAS		
	2023-24	2024-25	Pooled	2023-24	2024-25	Pooled	2023-24	2024-25	Pooled
T_1	62.41	63.71	63.06	88.51	89.62	89.07	99.23	100.38	99.81
T_2	141.23	142.74	141.99	167.60	168.63	168.12	178.29	179.52	178.91
T_3	146.23	147.52	146.88	172.28	173.39	172.84	183.23	184.19	183.71
T_4	85.41	86.69	86.05	115.54	112.63	114.09	122.41	123.45	122.93
T_5	91.71	94.03	92.87	118.86	119.94	119.40	129.62	130.78	130.20
T_6	127.32	128.62	127.97	153.42	154.40	153.91	164.42	165.31	164.87
T_7	142.63	143.93	143.28	168.78	169.93	169.36	179.35	180.71	180.03
T_8	83.03	83.38	83.21	108.29	109.27	108.78	118.94	120.23	119.59
T_9	101.62	102.95	102.29	127.68	128.85	128.27	138.48	139.72	139.10
T_{10}	114.63	115.89	115.26	140.74	141.91	141.33	151.37	152.59	151.98
T_{11}	116.71	118.05	117.38	142.93	143.94	143.44	153.61	154.81	154.21
T_{12}	104.37	105.49	104.93	130.32	131.38	130.85	141.18	142.28	141.73
T_{13}	107.92	109.31	108.62	134.08	135.17	134.63	144.81	145.96	145.39
S.Em (±)	1.99	1.43	1.71	1.80	1.52	1.66	2.32	2.66	2.49
C.D. at 5%	5.83	4.21	5.02	5.28	4.46	4.87	6.81	7.83	7.32

Conclusion

The present study clearly demonstrates that the integrated use of organic and inorganic nutrient sources plays a significant role in enhancing the growth, development, and productivity of the sorghum crop. The combined application of these nutrient inputs ensured a balanced and continuous supply of essential nutrients throughout the crop growth period, leading to improved nutrient uptake and utilization. As a result, key vegetative growth parameters such as plant height, leaf area, and total biomass accumulation showed marked improvement. Enhanced plant height reflected better vigor, while increased leaf area promoted higher photosynthetic activity. Overall, integrated nutrient management proved to be an effective and sustainable approach for promoting vigorous growth and improving the productivity potential of sorghum.

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