

Effect on growth and yield of sorghum (*Sorghum bicolor* L.) as influenced by nitrogen management

Tarachand Prajapati¹ O.P. Sharma², Omprakash Mawaliya³ and R.S. Saini

Department of Agronomy, School of Agriculture, Suresh Gyan Vihar University, Jaipur, Rajasthan India
Corresponding Author's Email: tarachandprajapati: taruprajapati28@gmail.com

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ABSTRACT

A field experiment entitled “Effect on Growth and Yield of Sorghum (*Sorghum bicolor* L.) as Influenced by Nitrogen Management” was conducted at the Agronomy Research Farm, School of Agriculture, Suresh Gyan Vihar University, Jaipur, Rajasthan during *kharif* 2024. The trial was laid out in a Split Plot Design with 15 treatment combinations of nitrogen sources (urea, castor cake, FYM) and biofertilizers (no inoculation, *Azotobacter*, *Azospirillum*), replicated thrice. Results revealed that nitrogen management and biofertilizer inoculation significantly influenced growth, yield attributes, and yield of sorghum. Plant height and dry matter accumulation were maximum under N₃ and B₃, with the highest dry matter (119.67 g/plant) recorded under N₃ + B₃ at harvest. Yield attributes such as grain number per ear head (1223), panicle weight (71.93 g), and 1000-grain weight (25.08 g) were highest in N₃, while B₃ significantly outperformed other biofertilizers, producing the maximum grain number (1355), panicle weight (72.60 g), and test weight (26.14 g). The interaction effect was significant for grain number, with N₃ / B₃ producing the maximum (1603.37). In terms of yield, N₃ recorded the highest grain yield (3103 kg/ha), straw yield (5930 kg/ha), and biological yield (9033 kg/ha), with a harvest index of 34.17%. Among biofertilizers, B₃ produced the maximum grain yield (3299 kg/ha), straw yield (6136 kg/ha), biological yield (9436 kg/ha), and harvest index (34.85%). The interaction effect was significant, with N₃ / B₃ producing the highest grain yield (3752 kg/ha), straw yield (6542 kg/ha), and biological yield (10294 kg/ha).

Keywords: Sorghum, nitrogen management, biofertilizers, *Azospirillum*, integrated nutrient management, yield

INTRODUCTION

Sorghum [*Sorghum bicolor* L. Moench], commonly known as “Jowar,” is a major cereal crop in India, particularly valued for its drought tolerance and adaptability to arid and semi-arid regions. It serves as a staple food, livestock fodder,

and industrial raw material, making it a versatile crop in rural farming systems. Nutritionally, sorghum grains are rich in carbohydrates, protein, minerals, and vitamins, while its stalks and leaves provide quality fodder, contributing to food and livestock security. In India, sorghum is primarily cultivated in semi-arid regions, with Rajasthan being a key producer. Despite extensive cultivation, productivity remains low due to poor nutrient management, sandy soils, and high nitrogen leaching. Nitrogen plays a critical role in plant growth, yield, and fodder quality, influencing parameters like plant height, leaf area, chlorophyll content, and protein concentration. Proper nitro-

MSc. Scholar^{1,3}, Department of Agronomy, School of Agriculture, Suresh Gyan Vihar University, Jaipur, Rajasthan India

Professor², Department of Agronomy, School of Agriculture, Suresh Gyan Vihar University, Jaipur, Rajasthan, India

Professor⁴, Department of Genetics & Plant Breeding, Suresh Gyan Vihar University, Jaipur, Rajasthan, India

gen management, including split application and integration with biofertilizers, can enhance yield, improve fodder quality, and promote sustainable farming practices. Given the challenges of soil fertility and resource constraints in Rajasthan, optimizing nitrogen use in sorghum is vital for improving productivity, farm profitability, and environmental sustainability. This study focuses on evaluating nitrogen management practices to develop efficient and economically viable sorghum-based production systems in the region.

MATERIALS AND METHODS

A field experiment entitled *Influence on Nitrogen Management on Yield and Quality of Sorghum* (*Sorghum bicolor* L.) was carried out during the *kharif* season of 2024 at the Agronomy Research Farm, School of Agriculture, Suresh Gyan Vihar University, Jaipur, Rajasthan. The experiment was laid out in a Split Plot Design with 15 treatments and three replications to minimize experimental error (Panse and Sukhatme, 1985). The sorghum variety used for the study was 'CSV-15, sown at a spacing of 45 cm × 10 cm using a seed rate of 15 kg ha⁻¹. The experimental layout followed the random allocation of treatments as per the method of Fisher and Yates (1963). The treatments *viz.*, N₁-

100 kg N/ha through urea, N₂ - 75 kg N through urea + 25 kg N/ha through castor cake, N₃- 75 kg N through urea + 25 kg N/ha through FYM, N₄- 50 kgN through urea + 50 kgN/ha through castor cake and N₅- 50kg N through urea + 50 kg N/ha through FYM and biofertilizer *viz.*, B₁- No inoculation, B₂ - *Azotobacter* and B₃- *Azospirillum* used during experiment. Biometric observations were recorded from five randomly selected and permanently tagged plants in each plot. Growth parameters such as initial and final plant stand per metre row length were assessed. Plant height (cm) and dry matter accumulation (g plant⁻¹) were recorded at 35 DAS, 70 DAS, and harvest. Dry matter was measured by oven-drying samples at 70°C until constant weight. For yield estimation, seed yield was recorded from the net plot and converted to kg ha⁻¹. Straw yield was calculated by subtracting the seed yield from the biological yield. All collected data were subjected to appropriate statistical analysis to interpret treatment effects.

RESULTS AND DISCUSSION

Growth Parameters

Data in Table 1 revealed that nitrogen man-

Table 1. Effect of nitrogen management and biofertilizer inoculation on growth attributes of sorghum (*Sorghum bicolor*)

Treatment	Plant stand (plants/m ²)		Plant height (cm)			Dry matter accumulation (g/plant)		
	Initial stand	Final stand	35 DAS	70 DAS	At harvest	35 DAS	70 DAS	At harvest
<i>A. Main factor- Nitrogen</i>								
N ₁	21.9	16.7	56.63	128.83	195.13	10.07	60.43	108.57
N ₂	21.6	18.4	61.31	140.09	204.76	11.16	64.35	114.14
N ₃	22.0	19.0	62.08	145.07	206.43	11.36	64.56	114.68
N ₄	21.9	18.3	60.48	139.19	202.05	10.80	62.97	112.61
N ₅	21.4	18.7	61.85	143.85	206.06	11.27	64.55	114.41
SEm±	0.24	0.59	0.91	2.98	2.06	0.25	1.62	1.47
C.D. @ 5%	NS	NS	2.96	9.72	6.73	0.83	5.29	4.78
<i>B. Sub factor- Biofertilizer</i>								
B ₁	21.9	17.0	58.37	130.86	196.06	10.01	60.47	108.66
B ₂	21.5	18.4	60.73	141.03	204.32	11.10	63.81	113.60
B ₃	21.9	19.2	62.31	146.33	208.28	11.68	65.84	116.39
SEm±	0.28	0.65	1.42	1.76	2.85	0.13	0.95	1.92
C.D. @ 5%	NS	NS	NS	5.18	8.42	0.39	2.81	5.68

Note: N₁-100 kg N/ha through urea; N₂-75 kg N through urea + 25 kg N/ha through FYM; N₃-75 kg N through urea + 25 kg N/ha through castor cake; N₄-50 kg N through urea + 50 kg N/ha, through FYM and N₅-50 kg N through urea + 50 kg N/ha through castor cake; B₁-No inoculation; B₂-*Azotobacter* and B₃-*Azospirillum*

agement and biofertilizer inoculation had no significant effect on sorghum plant stand at either stage, nor did their interaction. Among nitrogen practices, the highest initial (22.0 plants m⁻²) and final (19.0 plants m⁻²) stands were recorded under N₃ (75 kg N through urea + 25 kg N/ha through castor cake), while the lowest were under N₅ and N₁, respectively. For biofertilizers, B₃ (*Azospirillum*) maintained the highest final stand (19.2 plants m⁻²), whereas B₁ (no inoculation) recorded the lowest (17.0 plants m⁻²). These results are in line with Abrol *et al.* (2020) in wheat and Munagilwar *et al.* (2020) in sorghum, indicating that plant population is generally unaffected by fertility treatments.

Plant height of sorghum was significantly in-

fluenced by nitrogen management at all stages of crop growth, whereas biofertilizer inoculation and the interaction effect were significant at 70 DAS and harvest (Table 2a, 2b). Among nitrogen practices, N₃ (75 kg N through urea + 25 kg N/ha through castor cake) consistently recorded the tallest plants (62.08 cm at 35 DAS, 145.07 cm at 70 DAS, and 206.43 cm at harvest), followed by N₅, while the lowest height was observed under N₁ (100 kg N/ha through urea). With respect to biofertilizers, B₃ (*Azospirillum*) gave the maximum height (62.31, 146.33, and 208.28 cm), significantly superior to B₁ (no inoculation) at 70 DAS and harvest, but at par with B₂ (*Azotobacter*). The superiority of N₃ may be attributed to the combined ef-

Table 2a. Effect of nitrogen management and biofertilizer inoculation on grain number per ear head, panicle weight, and 1000 grain weight of sorghum (*Sorghum bicolor* L.)

Treatment	Grain number per ear head	Panicle weight g/head	1000 Grain weight (g)
<i>A. Main factor- Nitrogen</i>			
N ₁	846	64.48	22.27
N ₂	1215	70.20	24.90
N ₃	1223	71.93	25.08
N ₄	1043	68.68	23.44
N ₅	1221	70.98	25.00
SEm±	63	1.58	0.58
C.D. @ 5%	206	5.16	1.89
<i>B. Sub factor- Biofertilizer</i>			
B ₁	828	65.30	22.06
B ₂	1145	69.86	24.21
B ₃	1355	72.60	26.14
SEm±	34	1.28	0.36
C.D. @ 5%	101	3.79	1.07
<i>Interaction A × B</i>			
SEm±	76	2.87	0.81
C.D. @ 5%	225	NS	NS
C.V. (%)	11.90	7.18	7.21

Note: N₁-100 kg N/ha through urea; N₂-75 kg N through urea + 25 kg N/ha through FYM; N₃-75 kg N through urea + 25 kg N/ha through castor cake; N₄-50 kg N through urea + 50 kg N/ha, through FYM and N₅-50 kg N through urea + 50 kg N/ha through castor cake ; B₁-No inoculation; B₂-*Azotobacter* and B₃-*Azospirillum*

Table 2b. Interactive effect of nitrogen management and biofertilizer inoculation on grain number per head of sorghum (*Sorghum bicolor* L.)

B. Sub factor- Biofertilizer	Grain number per ear head				
	A. Main factor- Nitrogen				
	N ₁	N ₂	N ₃	N ₄	N ₅
B ₁	607.87	740.88	893.30	863.53	1032.06
B ₂	834.34	1376.08	1172.17	1045.31	1297.51
B ₃	1094.32	1527.51	1603.37	1219.41	1332.74
SEm±	76.21				
C.D. @ 5%	224.83				

fect of readily available nitrogen from urea and slow-release nitrogen with organic matter from castor cake, which promoted sustained growth. *Azospirillum* further enhanced plant height by contributing biological nitrogen fixation and phytohormones like IAA, GA, and cytokinins that stimulate cell elongation. Similar findings were reported by Patel *et al.* (2018) and Munagilwar *et al.* (2020), confirming the synergistic role of integrated nitrogen and biofertilizer application in enhancing sorghum growth.

The influence of nitrogen management and biofertilizer inoculation on dry matter accumulation of sorghum is presented in Table 3a and 3b. The data revealed significant differences among treatments at all stages of crop growth, with nitrogen $\times$ biofertilizer interaction effects becoming evident at 70 DAS and at harvest. At 35 DAS, the highest dry matter was recorded under N_3 (11.36 g/plant), closely followed by N_5 (11.27 g/plant), while the lowest was in N_1 (10.07 g/plant). A similar trend continued at 70 DAS (N_3 : 64.56 g/plant; N_5 : 64.55 g/plant; N_1 : 60.43 g/plant) and at harvest (N_3 : 114.68 g/plant; N_5 : 114.41 g/plant; N_1 : 108.57 g/plant). Among biofertilizers, B_3 (*Azospirillum*) consistently outperformed others with 11.68, 65.84, and 116.39 g/plant at 35 DAS, 70 DAS, and harvest, respectively, followed by B_2 , while B_1 remained the lowest. Dry matter accu-

mulation is a result of photosynthetic carbon fixation and assimilate translocation (Liu *et al.*, 2020). N_3 consistently produced the highest biomass due to balanced nitrogen availability that supported higher chlorophyll content, LAI, and prolonged photosynthetic activity. *Azospirillum* (B_3) further improved biomass by increasing nitrogen fixation, root branching, and water-nutrient uptake efficiency (Jehani *et al.*, 2023). The highest dry matter in $N_3 + B_3$ (119.67 g/plant) demonstrates how nutrient assimilation and physiological efficiency act together. Ganapati and Guggari (2018) and Munagilwar *et al.* (2020) reported higher biomass production in cereals under integrated nutrient management with biofertilizers, corroborating these results.

Yield attributes and Yield

The data presented in Tables 2a and 2b revealed that yield attributes of sorghum were significantly influenced by nitrogen management and biofertilizer inoculation. Grain number per ear head, panicle weight, and 1000-grain weight varied significantly among treatments, while their interaction effect was significant only for grain number per ear head. Among nitrogen levels, the application of 75 kg N through urea + 25 kg N/ha through castor cake (N_3) recorded the maximum grain number per ear head (1223), panicle weight

Table 3a. Effect of nitrogen management and biofertilizer inoculation on yield and harvest index of sorghum (*Sorghum bicolor* L.)

Treatment	Grain yield (kg/ha)	Straw yield (kg/ha)	Biological yield (kg/ha)	Harvest index (%)
<i>A. Main factor- Nitrogen</i>				
N_1	2254	5139	7394	30.04
N_2	3052	5907	8959	33.66
N_3	3103	5930	9033	34.17
N_4	2768	5627	8395	32.79
N_5	3067	5918	8985	34.12
SEm $\pm$	79	140	203	0.47
C.D. @ 5%	258	456	661	1.53
<i>B. Sub factor- Biofertilizer</i>				
B_1	2302	5181	7484	30.43
B_2	2945	5795	8740	33.59
B_3	3299	6136	9436	34.85
SEm $\pm$	74	86	139	0.50
C.D. @ 5%	219	253	411	1.46

Note: N_1 -100 kg N/ha through urea; N_2 -75 kg N through urea + 25 kg N/ha through FYM; N_3 -75 kg N through urea + 25 kg N/ha through castor cake; N_4 -50 kg N through urea + 50 kg N/ha, through FYM and N_5 -50 kg N through urea + 50 kg N/ha through castor cake ; B_1 -No inoculation; B_2 -*Azotobacter* and B_3 -*Azospirillum*

(71.93 g), and 1000-grain weight (25.08 g), which was closely followed by N₅ and N₂, whereas the lowest values for these traits were noted under 100 kg N/ha through urea (N₁). With respect to biofertilizers, inoculation with *Azospirillum* (B₃) proved significantly superior, producing the maximum grain number per ear head (1355), panicle weight (72.60 g), and 1000-grain weight (26.14 g), followed by B₂, while the lowest values were recorded under B₁ (no inoculation). The interaction effect revealed that the highest grain number per ear head (1603.37) was obtained under N₃ + B₃, followed by N₂ + B₃ (1527.51), whereas the minimum (607.87) was recorded in N₁ + B₁. However, interaction effects for panicle weight and test weight remained non-significant.

The effect of nitrogen management and biofertilizer inoculation on grain yield, straw yield, biological yield, and harvest index of sorghum is presented in Table 3a and 3b. The results indicated significant variation among nitrogen and biofertilizer treatments for all yield attributes, whereas the harvest index was not influenced significantly by the interaction effect. The highest grain yield of 3103 kg/ha was obtained under N₃ (75 kg N through urea + 25 kg N/ha through castor cake), which was superior. This was followed by N₅ (3067 kg/ha) and N₂ (3052 kg/ha), both of

which were statistically at par with N₃. The lowest grain yield of 2254 kg/ha was recorded under N₁ (100 kg N/ha through urea). For straw yield, N₃ produced the maximum of 5930 kg/ha, which was comparable with N₅ (5918 kg/ha) and N₂ (5907 kg/ha). The minimum straw yield of 5139 kg/ha was recorded with N₁. In terms of biological yield, N₃ produced the highest of 9033 kg/ha, which was followed by N₅ (8985 kg/ha) and N₂ (8959 kg/ha). The lowest biological yield of 7394 kg/ha was observed under N₁. The harvest index was also improved with N₃, which recorded 34.17%, followed by N₅ (34.12%) and N₂ (33.66%). The lowest harvest index of 30.04% was obtained with N₁.

Among biofertilizer treatments, B₃ (*Azospirillum*) resulted in the highest grain yield of 3299 kg/ha, which was superior. This was followed by B₂ (2945 kg/ha), while the minimum grain yield of 2302 kg/ha was obtained under B₁ (no inoculation). For straw yield, B₃ produced the maximum of 6136 kg/ha, followed by B₂ (5795 kg/ha), whereas the lowest was recorded with B₁ (5181 kg/ha). The highest biological yield of 9436 kg/ha was produced under B₃, followed by B₂ (8740 kg/ha), while the minimum of 7484 kg/ha was recorded with B₁. B₃ also improved harvest index, producing the highest of 34.85%, followed by B₂ (33.59%). The lowest harvest index of 30.43%

Table 3b. Interactive effect of nitrogen management and biofertilizer inoculation on yield of sorghum (*Sorghum bicolor* L.)

B. Sub factor- Biofertilizer	Grain yield (kg/ha)				
	A. Main factor- Nitrogen				
	N ₁	N ₂	N ₃	N ₄	N ₅
B ₁	1541	2159	2594	2456	2762
B ₂	2380	3410	2964	2785	3188
B ₃	2842	3586	3752	3065	3252
SEm±	166				
C.D. @ 5%	490				
Straw yield (kg/ha)					
B ₁	4442	5109	5436	5336	5582
B ₂	5286	6218	5812	5626	6035
B ₃	5690	6395	6542	5919	6136
SEm±	191				
C.D. @ 5%	565				
Biological yield (kg/ha)					
B ₁	5984	7268	8030	7791	8344
B ₂	7666	9628	8776	8410	9223
B ₃	8532	9982	10294	8984	9389
SEm±	312				
C.D. @ 5%	920				

was obtained with B_1 .

The interaction effect was significant for grain yield, straw yield, and biological yield but not for harvest index. For grain yield, the highest of 3752 kg/ha was obtained with N_3/B_3 , which was superior and followed by N_2/B_3 (3586 kg/ha). The lowest grain yield of 1541 kg/ha was observed in N_1/B_1 . For straw yield, N_3/B_3 produced the maximum of 6542 kg/ha, followed by N_2/B_3 (6395 kg/ha). The lowest straw yield of 4442 kg/ha was obtained with N_1/B_1 . Biological yield was also highest in N_3/B_3 (10294 kg/ha), which was superior and followed by N_2/B_3 (9982 kg/ha). The minimum biological yield of 5984 kg/ha was obtained in N_1/B_1 . Grain and straw yield represent the cumulative outcome of photosynthetic assimilation, assimilate translocation, and partitioning efficiency (Zhang *et al.*, 2020). These results are in line with the findings of Rajalakshmi *et al.* (2019) in sorghum, Sutar *et al.* (2020) in pearl millet and Khaled *et al.* (2021) in wheat, who reported that integrated nitrogen management along with *Azospirillum* inoculation significantly enhanced grain yield and

harvest index.

CONCLUSION

The study revealed that integrated nitrogen management along with biofertilizer inoculation significantly improved the growth, dry matter accumulation, and yield of sorghum. Among the treatments, N_3 (75 kg N through urea + 25 kg N/ha through castor cake) consistently recorded superior performance in terms of plant height, biomass, and yield attributes, while *Azospirillum* (B_3) proved most effective among biofertilizers. The combination N_3/B_3 resulted in the highest grain, straw, and biological yield, highlighting the synergistic effect of chemical and biological sources of nitrogen. These findings confirm that balanced nutrient management coupled with biofertilizer application enhances nutrient assimilation, photosynthetic efficiency, and ultimately productivity of sorghum. Thus, integrated nitrogen management with *Azospirillum* offers a sustainable approach for higher sorghum yield and better resource use efficiency.

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