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Research Article

Soil Health and Yield Dynamics under Nitrogen Substitution and Microbial Inoculants of Sorghum (*Sorghum bicolor* L.)

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Abstract

Sorghum (*Sorghum bicolor* L.) is a vital cereal crop cultivated in semi-arid regions due to its resilience to drought and adaptability to marginal soils. Efficient nutrient management is essential to enhance its productivity. This study evaluated the effect of integrated nitrogen management and biofertilizers on growth parameters, yield attributes, and yield of sorghum. The experiment included five nitrogen treatments combining inorganic nitrogen (urea) with organic sources such as farmyard manure (FYM) and castor cake, along with three biofertilizer treatments (control, Azotobacter, and Azospirillum). The results indicated that integrated nitrogen application significantly improved plant height, leaf area index, tiller number, dry matter accumulation, and chlorophyll content compared to sole chemical fertilization. Among nitrogen treatments, 50% RDN through urea + 50% RDN through FYM recorded the highest growth and yield parameters, including grain yield (2145.67 kg/ha), number of grains per head (1494.67), and harvest index (29.98%). Biofertilizer application, particularly Azospirillum, significantly enhanced growth and yield attributes over control. Interaction effects were non-significant. The study concludes that integrated nutrient management combined with biofertilizers is an effective strategy for sustainable sorghum production.

Keywords: Sorghum, Integrated Nutrient Management (INM), Nitrogen Fertilization, Azospirillum, Grain Yield

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Introduction

Sorghum (*Sorghum bicolor* L.) is the fifth most important cereal crop globally and a staple food in many developing countries. It plays a crucial role in ensuring food security, particularly in arid and semi-arid regions where other cereals fail to perform adequately [1]. In India, sorghum is widely cultivated due to its adaptability to drought-prone areas and low-input conditions. However, sorghum productivity remains relatively low due to poor soil fertility and imbalanced fertilizer use. Nitrogen (N) is one of the most limiting nutrients influencing plant growth, photosynthesis, and yield formation. Excessive use of chemical fertilizers, particularly nitrogenous fertilizers, can lead to soil degradation, environmental pollution, and reduced nutrient use efficiency [2]. Integrated nutrient management (INM), which combines chemical fertilizers with organic manures, offers a sustainable approach to maintaining soil fertility and enhancing crop productivity. Organic sources such as farmyard manure (FYM) and castor cake improve soil structure, microbial activity, and nutrient availability [3]. Biofertilizers such as Azotobacter and Azospirillum further enhance nutrient availability by fixing atmospheric nitrogen and promoting plant growth through phytohormone production [4]. Their integration with chemical fertilizers can reduce dependency on synthetic inputs and improve crop yield sustainably.

Despite several studies on nutrient management in cereals, limited research exists on the combined effect of organic, inorganic, and biological nitrogen sources on sorghum. Therefore, the present study was undertaken to evaluate the effect of integrated nitrogen management and biofertilizers on growth and yield of sorghum.

Materials and Methods

Experimental Site

The experiment was conducted during the cropping season under field conditions typical of semi-arid regions. The soil was characterized as sandy loam with moderate fertility status. "The experiment was conducted during Kharif 2024 at the Research Farm, Vivekananda Global University, Jaipur (Rajasthan), located at 26°51′ N latitude and 75°47′ E longitude at an altitude of 390 m above mean sea level. The crop variety used was 'CSH 14' (*Sorghum bicolor* L.).

Experimental Design

The experiment was laid out in a factorial randomized block design (FRBD) with three replications. Treatments included:

Nitrogen Treatments

1. RDN (100 kg N/ha)
2. 75% RDN (Urea) + 25% RDN (Castor cake)
3. 75% RDN (Urea) + 25% RDN (FYM)
4. 50% RDN (Urea) + 50% RDN (Castor cake)
5. 50% RDN (Urea) + 50% RDN (FYM)

Biofertilizer Treatments

1. Control
2. Azotobacter
3. Azospirillum

Crop Management

Sorghum seeds were sown at recommended spacing. Organic manures were incorporated before sowing, while urea was applied in split doses. Biofertilizers were applied as seed inoculation treatments. The initial soil was sandy loam in texture with pH 7.8, electrical conductivity 0.32 dS m^{-1}, organic carbon 0.42%, available nitrogen 245 kg ha^{-1}, available phosphorus 18.6 kg ha^{-1}, and available potassium 210 kg ha^{-1}."

Observations Recorded

Growth parameters were recorded at 45 days after sowing (DAS) and at harvest:

- Plant height (cm)
- Leaf area index
- Number of tillers
- Dry matter accumulation (g/plant)
- Chlorophyll content (SPAD units)

Yield attributes recorded:

- Grain yield (kg/ha)
- Number of grains per head
- Panicle weight (g)
- 1000 grain weight (g)
- Grain filling duration
- Harvest index (%)
- Number of heads per plant

Statistical Analysis

Data were analyzed using analysis of variance (ANOVA) at 5% level of significance. Standard error of mean (S.Em) and critical difference (CD) were calculated.

Results & Discussion

Effect on Growth Parameters

Nitrogen treatments significantly influenced plant growth. The highest plant height at harvest (184.9 cm) was recorded under 50% RDN (urea) + 50% RDN (FYM), followed by 50% RDN (urea) + 50% RDN (castor cake) (177.38 cm). The lowest plant height (147.51 cm) was observed under 100% RDN. Leaf area index (LAI) increased significantly with integrated nutrient management. The maximum LAI at harvest (5.34) was recorded in 50% urea + 50% FYM treatment, indicating better canopy development. Number of tillers and dry matter accumulation also followed a similar trend. The highest dry matter accumulation (136.7 g/plant) was recorded under integrated nitrogen application with FYM. Chlorophyll content was significantly higher in integrated treatments, with the maximum value (64.07 SPAD units) under 50% urea + 50% FYM.

Table 1 Effect of nitrogen and bio fertilizer on growth, yield attributes and yields of sorghum

Treatments	Plant height (cm)		Leaf area index		Number of tillers		Dry matter accumulation (g/plant)		Chlorophyll Content (SPAD units)
	45 DAS	At harvest	45 DAS	At harvest	45 DAS	At harvest	At 45 DAS	At harvest	
Nitrogen									
RDN (100 kg N/ha)	32.05	147.51	2.65	3.39	2.66	3.89	4.72	103.89	56.59
75 % RDN (Urea) + 25 % RDN (Castor cake)	35.09	156.56	2.89	3.98	3.07	4.3	5.3	113.32	59.59
75 % RDN (Urea) + 25 % (FYM)	34.14	166.22	3.02	4.75	3.63	4.86	6.14	120.12	61.17
50 % RDN (Urea) + 50 % RDN (Castor cake)	37.79	177.38	3.1	5.04	4.12	5.35	7.13	126.43	62.4
50 % RDN (Urea) + 50 % RDN (FYM)	37.93	184.9	3.32	5.34	4.49	5.73	8.79	136.7	64.07
S.Em±	0.38	1.66	0.03	0.04	0.03	0.04	0.06	1.07	0.50
CD (P=0.05)	1.10	4.80	0.08	0.11	0.09	0.12	0.17	3.09	1.44
Biofertilizer									
Control	34.31	162.74	2.92	4.32	3.44	4.67	3.44	4.67	59.7
Azotobacter	35.34	167.21	3	4.5	3.59	4.82	3.59	4.82	61.11
Azospirillum	36.56	169.6	3.05	4.65	3.75	4.97	3.75	4.97	61.49
S.Em±	0.29	1.28	0.02	0.03	0.02	0.05	0.05	0.83	0.39
CD (P=0.05)	0.85	3.72	0.06	0.08	0.07	0.16	0.13	2.39	1.12
CV (%)	7.85	7.56	8.05	7.56	8.18	7.50	9.27	8.29	8.23
Interaction	NS	NS	NS	NS	NS	NS	NS	NS	NS

Biofertilizer application significantly improved growth parameters. Azospirillum recorded the highest plant height (169.6 cm), LAI (4.65), and chlorophyll content (61.49 SPAD units). Azotobacter also showed improvement over control.

Yield Attributes and Yield

Grain yield was significantly influenced by nitrogen treatments. The highest grain yield (2145.67 kg/ha) was recorded under 50% RDN (urea) + 50% RDN (FYM), followed by 50% urea + 50% castor cake (1939.33 kg/ha).
Number of grains per head, panicle weight, and 1000 grain weight were significantly higher in integrated treatments. Maximum grains per head (1494.67) and panicle weight (50.11 g) were observed under FYM-based integrated treatment.

Harvest index was also improved with integrated nutrient management, indicating better partitioning of assimilates. Among biofertilizers, Azospirillum recorded the highest grain yield (1828.00 kg/ha), followed by Azotobacter (1764.40 kg/ha) and control (1691.60 kg/ha).

Interaction Effects

Interaction between nitrogen and biofertilizers was found to be non-significant for all parameters.

Table 2 Effect of nitrogen and bio fertilizer on Yield attributes and yield of sorghum

Treatments	Grain yield (kg/ha)	No. grains per head	Panicle/head weight (g)	1000 Grain weight (g)	Grain filling Duration	Harvest index (%)	No. of heads per plant
Nitrogen							
RDN (100 kg N/ha)	1416.33	1126.00	33.50	20.24	31.30	26.49	32.57
75 % RDN (Urea) + 25 % RDN (Castor cake)	1583.67	1243.67	37.83	21.37	33.75	27.64	35.67
75 % RDN (Urea) + 25 % (FYM)	1722.00	1322.00	42.50	22.22	35.61	28.23	34.70
50 % RDN (Urea) + 50 % RDN (Castor cake)	1939.33	1382.33	46.10	22.94	37.56	28.87	38.42
50 % RDN (Urea) + 50 % RDN (FYM)	2145.67	1494.67	50.11	23.53	39.73	29.98	38.57
S.Em±	18.04	9.86	0.38	0.21	0.26	0.26	0.38
CD (P=0.05)	52.26	28.57	1.11	0.60	0.76	0.74	1.10
Biofertilizer							
Control	1691.60	1274.00	40.00	21.76	34.84	27.94	34.87
Azotobacter	1764.40	1300.00	41.60	22.04	35.63	28.18	35.92
Azospirillum	1828.00	1363.60	43.00	22.38	36.30	28.61	37.17
S.Em±	13.98	7.64	0.30	0.16	0.20	0.20	0.29
CD (P=0.05)	40.48	22.13	0.86	0.46	0.59	0.57	0.85
CV (%)	12.36	7.63	8.48	8.28	9.26	6.23	11.86
Interaction	NS	NS	NS	NS	NS	NS	NS

Discussion

The superior performance of integrated nitrogen treatments can be attributed to the synergistic effect of organic and inorganic nutrient sources. Organic manures such as FYM improve soil physical properties, water retention, and microbial activity, leading to better nutrient availability [3].

The gradual release of nutrients from organic sources ensures sustained nutrient supply throughout the crop growth period. This results in enhanced vegetative growth, higher chlorophyll content, and increased photosynthetic efficiency. Higher leaf area index and chlorophyll content under integrated treatments indicate improved photosynthetic capacity, which ultimately contributes to higher biomass and yield.

The increased number of tillers and dry matter accumulation may be due to improved nutrient uptake and hormonal stimulation caused by organic amendments.

Biofertilizers such as Azospirillum enhance plant growth through biological nitrogen fixation and production of growth-promoting substances like auxins and gibberellins [4]. This explains the improved growth and yield parameters observed under biofertilizer treatments.

The highest yield under 50% urea + 50% FYM suggests that partial substitution of chemical nitrogen with organic sources can improve nutrient use efficiency and crop productivity. The grain yield recorded in the present study (2145.67 kg ha^{-1}) was higher than the yields reported by Kumar and Sharma (2017) [5], who observed 1800–2000 kg ha^{-1} under integrated nutrient management in sorghum. Similarly, Yadav and Meena (2009) [6] also reported enhanced yield with combined application of organic and inorganic nitrogen sources.

The non-significant interaction effect indicates that nitrogen management and biofertilizers act independently, although both contribute positively to crop performance.

Conclusion

The study clearly demonstrates that integrated nitrogen management significantly enhances growth, yield attributes, and yield of sorghum compared to sole chemical fertilization. Application of 50% RDN through urea combined with 50% RDN through FYM proved to be the most effective treatment, resulting in maximum growth and yield. Biofertilizers, particularly Azospirillum, further improved crop performance and can be recommended as a sustainable input. Thus, the integration of chemical fertilizers, organic manures, and biofertilizers is an effective strategy for sustainable sorghum production, improving soil health and reducing environmental impacts.

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