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Response of growth and yield attributes of sorghum to foliar nano-nitrogen fertilization

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Abstract

A field experiment was conducted during *kharif* 2024 at the Agronomy Farm, School of Agriculture, Suresh Gyan Vihar University, Jaipur, to study the effect of foliar application of nano nitrogen fertilizer on growth and yield of sorghum (*Sorghum bicolor* L.). The experiment was laid out in a randomized block design with three replications, comprising nine treatments *viz.*, T_1 (Control), T_2 (75% RDN with commercial urea in two equal splits), T_3 (75% RDN + nano urea foliar spray in two equal splits at 20 and 40 DAS), T_4 (75% RDN + nano urea foliar spray in three equal splits at 15, 30 and 45 DAS), T_5 (100% RDN with commercial urea in two equal splits), T_6 (100% RDN + nano urea foliar spray in two equal splits), T_7 (100% RDN + nano urea foliar spray in three equal splits), T_8 (125% RDN + nano urea foliar spray in two equal splits) and T_9 (125% RDN + nano urea foliar spray in three equal splits). The sorghum variety 'Parbhani Shakti' was sown at a spacing of 45 cm × 15 cm using a seed rate of 15 kg ha^{-1} with a recommended dose of fertilizer (80:40:40 NPK kg ha^{-1}). The results revealed that growth attributes such as plant height, dry matter accumulation, leaf area index and tiller number improved significantly with higher nitrogen application and nano urea sprays. The maximum plant height (197.3 cm) and dry matter accumulation (162.5 g plant^{-1}) were observed under T_5, whereas the highest leaf area index (5.7) was recorded under T_9, highlighting the efficiency of nano urea in sustaining photosynthetic activity. Yield attributes also showed significant variation, the highest grain yield (2768 kg ha^{-1}), straw yield (6203 kg ha^{-1}) and biological yield (8971 kg ha^{-1}) were obtained with T_5, closely followed by T_9 (2683, 6074 and 8757 kg ha^{-1}, respectively).

Keywords: Nano urea, foliar fertilization, nitrogen management, sorghum, foliar spray, yield.

Introduction

Sorghum (*Sorghum bicolor* L. Moench), a member of the family *Poaceae* and subfamily Panicoideae, is an important *kharif* and *rabi* season crop cultivated worldwide to meet both green and dry fodder demands of livestock. Commonly known as jowar, sorghum originated in Africa around 5,000 years ago and subsequently spread across continents, becoming a vital food, feed and industrial crop. Globally, sorghum is grown extensively in the United States, India, Nigeria, Mexico and Sudan owing to its resilience and adaptability to diverse climatic conditions. Its inherent characteristics, including efficient C4 photosynthesis, high water- and nitrogen-use efficiency, drought tolerance and lodging resistance, make it one of the most sustainable cereals in semi-arid and tropical regions.Globally, sorghum ranks fifth among cereal crops after wheat, maize, rice

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and barley, serving as a staple dietary source of calories in many parts of Africa and Asia. In addition to being consumed as grain, sorghum plays a pivotal role as a source of fodder, cattle feed and raw material for brewing and other industries. In India, sorghum ranks third in area and production among cereals. During 2022-23, global sorghum production reached 60.06 million tonnes, with Nigeria leading production (7 million tonnes) followed by Ethiopia, Sudan and the United States (FAOSTAT, 2023). India ranked fifth, with 4.03 million tonnes produced on 3.64 million hectares in 2023-24, reflecting its importance in national food and fodder security. In Rajasthan, sorghum occupies about 0.50 million hectares annually, producing 0.52 million tonnes with an average productivity of 1,036 kg ha^{-1} (APEDA, 2023–24). Districts such as Ajmer, Kota, Sawai Madhopur and Jaipur are notable contributors to the state's sorghum area and production.

The nutritional value of sorghum further strengthens its significance. It has high energy content and provides ample levels of protein, making it particularly suitable for ruminant animals like cattle, sheep and goats. It comprises 72.6% carbohydrates, 10-12% protein, 1.6% mineral and 1.9% fat. Sorghum also provides a essential nutrients, including amino acids *viz.*, lysine, thiamine, riboflavin, folic acid and vitamin-B complex, notably niacin (vitamin B6). Sorghum is also gaining recognition as a "health food" owing to its high fiber and amino acid profile, making it valuable for both human and animal consumption. Despite its importance, sorghum productivity is constrained by nutrient management, particularly nitrogen (N). Nitrogen is a key macronutrient influencing plant growth, tillering, chlorophyll formation, photosynthesis, yield and grain protein content (Grant, 2000; Assefa, 2018). However, nitrogen-use efficiency under conventional practices remains low, leading to excessive application, higher costs of cultivation and environmental concerns such as leaching and gaseous emissions. Thus, efficient and sustainable nitrogen management strategies are crucial to enhancing sorghum yield and profitability.

Nano-fertilizers have emerged as an innovative approach to overcome these challenges. The nano-urea liquid has an effectiveness of more than 80%. This fulfils the plant nutrient requirement as a fertilizer.However, nano urea is available to plants because of its desirable particle size of about 20-50 nm and more surface area (10,000 times over 1 mm urea prill) and number of particles (55,000 nitrogen particles over 1 mm urea prill). This enhances leaf absorption, nutrient use efficiency and reduces nutrient losses (IFFCO, 2024). Foliar application of nano urea not only ensures direct and rapid nutrient availability but also minimizes environmental hazards while lowering fertilizer costs. Studies have reported significant improvements in plant height, leaf area index, dry matter accumulation, chlorophyll synthesis and photosynthetic efficiency under nano urea application compared with conventional urea (Rahman *et al.*, 2014).

Materials and Methods

The field experiment was conducted during the *kharif* season of 2024 at the Agronomy Farm, School of Agriculture, Suresh Gyan Vihar University, Jaipur, Rajasthan, situated at 26°92′ N latitude and 75°77′E longitude under semi-arid climatic conditions characterized by hot summers (up to 48°C), cold winters and an average annual rainfall of 400–500 mm, mostly received during July-August. The soil of the experimental site was sandy loam, slightly alkaline in reaction (7.7 pH), low in available nitrogen (138.5), medium in phosphorus (16.4) and high in potassium (250.15). The experiment was laid out in a Randomized Block Design with three replications, comprising nine treatments *viz.*, T_1 (control), T_2 (75% RDN with commercial urea in two equal splits at sowing and 30 DAS), T_3 (75% RDN + nano urea foliar spray in two equal splits at 20 and 40 DAS), T_4 (75% RDN + nano urea foliar spray in three equal splits at 15, 30 and 45 DAS), T_5 (100% RDN with commercial urea in two equal splits at sowing and 30 DAS), T_6 (100% RDN + nano urea foliar spray in two equal splits at 20 and 40 DAS), T_7 (100% RDN + nano urea foliar spray in three equal splits at 15, 30 and 45 DAS), T_8 (125% RDN + nano urea foliar spray in two equal splits at 20 and 40 DAS) and T_9 (125% RDN + nano urea foliar spray in three equal splits at 15, 30 and 45 DAS). The recommended fertilizer dose was 80:40:40 NPK kg ha^{-1}, supplied through urea, single superphosphate and muriate of potash, with nano urea applied as per IFFCO standards (500 ml equivalent to one bag of conventional urea). The sorghum variety 'Parbhani Shakti' was sown by dibbling at a spacing of 45 × 15 cm using a seed rate of 15 kg ha^{-1} in plots of 4.0 cm × 3.6 m (gross) and 3.0 × 2.4 m (net). Standard agronomic practices such as gap filling, thinning, weeding and plant protection measures were carried out as required. Plant height was recorded from five randomly selected and permanently tagged plants within the net plot area, measured from the ground surface to the tip of the main shoot at 45 DAS and at harvest and the mean value was expressed in cm. Dry matter accumulation was determined from five randomly sampled plants per plot at the same intervals. The sampled plants were cut into small pieces, oven-dried at 65 °C until a constant weight was achieved and the average dry weight was expressed as g plant^{-1}. Five randomly selected plants per plot, initially tagged for height measurement, were also used to record the total number of tillers at harvest and the mean value was expressed as tillers plant^{-1}. Yield attributes (Grain, Straw, Biological and Harvest index) was obtained by manually harvesting the net plot area using a sickle, bundling the biomass and recording its fresh weight in kg plot^{-1}. Data were statistically analyzed using ANOVA for RBD (Fisher, 1950) and treatment means were compared at 5% significance level.

Results and Discussion

Growth attribute

Growth and yield parameters of sorghum were significantly influenced by different fertility levels and methods of nitrogen application. Plant height showed a steady increase with progressive nitrogen doses and improved methods of application. An assessment of data (Table 1) indicates that the maximum plant height (197.3 cm) at harvest was obtained under treatment T_5 (100% RDN applied through commercial urea in two equal splits), which recorded a 14.4% improvement over control. This superiority in plant stature can be attributed to the direct role of nitrogen in cell elongation, protein synthesis and chlorophyll development. These results are con-

Table 1. Influence of foliar application of nano N fertilizer on growth attributes of sorghum

S. No.	Treatments	Plant height(cm)		DMA (g plant^{-1})		Leaf area index	Number of Tillers	
		45 DAS	Harvest	45 DAS	Harvest	Harvest	45 DAS	Harvest
1.	Control	54.7	144.8	48.9	106.5	3.2	2.4	2.9
2.	75% RDN with commercial urea in 2 equal splits - at sowing & 30 DAS	65.7	163.2	69.3	136.4	4.5	3.2	3.7
3.	Foliar spray of 75% RDN with nano urea in 2 equal splits - 20 & 40 DAS	61.2	159.2	66.4	133.1	3.4	2.6	3.0
4.	Foliar spray of 75% RDN with nano urea in 3 equal splits - 15, 30 & 45 DAS.	63.4	160.6	68.6	135.3	3.8	2.9	3.6
5.	100% RDN with commercial urea in 2 equal splits - at sowing & 30 DAS.	83.3	197.3	85.8	162.5	5.2	4.3	4.8
6.	Foliar spray of 100% RDN with nano urea in 2 equal splits - 20 & 40 DAS.	62.3	164.9	70.8	138.6	4.7	3.5	3.8
7.	Foliar spray of 100% RDN with nano urea in 3 equal splits - 15, 30 & 45 DAS.	66.0	167.9	72.7	140.4	5.0	3.6	4.0
8.	Foliar spray of 125% RDN with nano urea in 2 equal splits - 20 & 40 DAS.	79.2	177.2	79.7	153.9	5.1	3.9	4.6
9.	Foliar spray of 125% RDN with nano urea in 3 equal splits - 15, 30 & 45 DAS.	80.0	186.4	81.2	157.2	5.7	4.0	4.7
	SEm±	3.14	8.61	4.12	6.24	0.19	0.20	0.29
	CD (P=0.05)	10.4	26.4	12.1	20.1	0.6	0.6	0.9
	CV (%)	8.6	8.2	8.8	8.0	8.2	9.7	9.2

sistent with the findings of Singh *et al.* (2022), who also reported taller plants in sorghum and maize with higher nitrogen supply. Dry matter accumulation (DMA) followed a similar trend, with significant improvement under nitrogen-fertilized treatments compared to control. At harvest, the highest DMA (162.5 g plant^{-1}) was obtained with T_5, representing a 30.8% increase over unfertilized control. Treatments involving nano urea sprays, particularly at 125% RDN in three splits (T_9), also showed comparable performance, indicating that foliar-applied nano urea enhanced nitrogen use efficiency by ensuring timely supply of nutrients during critical growth stages. The increased dry matter can be explained by the role of nano urea in boosting enzymatic activity, chlorophyll synthesis and photosynthetic rate, which ultimately enhanced assimilate production. These findings corroborate earlier reports by Yasser *et al.* (2020) and Abdel-Aziz *et al.* (2016). Leaf area index (LAI) exhibited significant variation across treatments. The maximum LAI (5.7 at harvest) was recorded with T_9, where 125% RDN was supplied through nano urea in three equal splits. A higher LAI under nano urea treatments indicates greater expansion of photosynthetic surface, which is essential for efficient interception and utilization of solar radiation. This enhancement in LAI can be attributed to improved nutrient penetration through leaf stomata, a unique advantage of nano fertilizers over conventional urea. Similar results were also reported by Rajput *et al.* (2022), who observed higher LAI and sustained greenness in cereals with nano-fertilizer sprays. The number of tillers plant^{-1} was also markedly influenced by fertility levels. The maximum tiller number (4.8 plant^{-1}) was recorded in T_5, whereas the lowest was noted in control plots. Adequate nitrogen nutrition promotes tiller initiation and survival, thereby increasing the effective tiller count, which ultimately contributes to higher yield. These results are in line with the findings of Alam *et al.* (2012), who reported a direct relationship between nitrogen availability and tillering in cereals.

Yield attributes

The analysis of yield attributes (Table 2) demonstrated that the application of 100% RDN with commercial urea in two equal splits at sowing and 30 DAS (T_5) resulted in the maximum grain yield (2768 kg ha^{-1}), straw yield (6203 kg ha^{-1}) and biological yield (8971 kg ha^{-1}) with a harvest index of 30.9% reflecting a strong improvement in both source and sink capacity. In contrast, the unfertilized control produced the lowest values, recording grain yield (1351 kg ha^{-1}), straw yield (3798 kg ha^{-1}) and biological yield (5149 kg ha^{-1}), with a harvest index of 26.2%. Such improvement may be attributed to enhanced chlorophyll synthesis, prolonged photosynthetic activity and efficient translocation of assimilates to reproductive sinks, which collectively improved source–sink dynamics. Similarly, the rise in yield from using nano fertilizers in a foliar spray can be attributed to their rapid absorption by plants and this leads to improved growth, higher biomass and greater resil-

Table 2. Influence of foliar application of nano-N fertilizer on yield of sorghum

S. No.	Treatments	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Biological yield (kg ha^{-1})	Harvest Index (%)
1.	Control	1351	3798	5149	26.2
2.	75% RDN with commercial urea in 2 equal splits - at sowing & 30 DAS	2057	5157	7214	28.5
3.	Foliar spray of 75% RDN with nano urea in 2 equal splits - 20 & 40 DAS	1894	4599	6493	29.6
4.	Foliar spray of 75% RDN with nano urea in 3 equal splits - 15, 30 & 45 DAS.	1979	4907	6886	28.7
5.	100% RDN with commercial urea in 2 equal splits - at sowing & 30 DAS.	2768	6203	8971	30.9
6.	Foliar spray of 100% RDN with nano urea in 2 equal splits - 20 & 40 DAS.	2346	5326	7836	30.4
7.	Foliar spray of 100% RDN with nano urea in 3 equal splits - 15, 30 & 45 DAS.	2379	5412	7917	29.3
8.	Foliar spray of 125% RDN with nano urea in 2 equal splits - 20 & 40 DAS.	2631	5543	7995	33.0
9.	Foliar spray of 125% RDN with nano urea in 3 equal splits - 15, 30 & 45 DAS.	2683	6074	8757	30.6
	SEm±	**118**	**232**	**306**	**2**
	CD (P=0.05)	320	741	1001	NS
	CV (%)	**8.3**	**8.2**	**9.8**	**8.4**

ience, ultimately boosting yield. This aligns with the findings of Mallikarjuna (2021). Similar findings were reported by Sharma et al. (2022), who emphasized the efficiency of nano urea in sustaining crop yields while reducing environmental losses of nitrogen.

Conclusion

The findings clearly demonstrated that nitrogen management plays a vital role in improving the growth and yield of sorghum. Among the treatments, 100% RDN through commercial urea proved most effective, while foliar application of nano urea at 125% RDN in three splits performed nearly at par, reflecting its efficiency in nutrient use. Thus, nano urea offers a sustainable alternative to conventional fertilizers, supporting higher productivity while minimizing nutrient losses to the environment.

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