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Effect of nitrogen and zinc on growth and yield of sorghum (*Sorghum bicolor* L.)

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Abstract
A field experiment was conducted during *kharif* 2024 at the crop research farm, Department of Agronomy, SHUATS, Prayagraj (U.P.) to study the effect of nitrogen and zinc on growth and yield of sorghum (*Sorghum bicolor* L.). The experiment was laid out in a Randomized Block Design with three replications. Two factors was considered Nitrogen at three levels (60,80,100 kg/ha), and Zinc at three levels (10,20,30 kg/ha). The results revealed that the combined application of Nitrogen at 80 kg/ha and Zinc at 20 kg/ha significantly improved higher Plant height (147.47 cm), Length of ear head (26.40 cm), Grains/Ear head (923.62), Test weight (29.95 g), Grain yield (33 kg/ha 00.53), Harvest index (40.84%), were recorded. Higher gross returns (Rs. 1,48,295.14/ha), net return (Rs. 1,05,704.69/ha) and benefit cost ratio (2.48) were also recorded with this treatment combination.

Keywords: Sorghum, nitrogen, zinc, growth and yield

Introduction
Sorghum (*Sorghum bicolor* L.) is a vital cereal crop grown extensively across the globe, especially in arid and semi-arid regions, due to its inherent tolerance to drought, high temperature, and marginal soils. It belongs to the Poaceae family and is the fifth most important cereal crop worldwide after wheat, rice, maize, and barley. Sorghum is cultivated for diverse purposes, including grain, fodder, forage, and biofuel, and it is used in food preparations like roti, porridge, and fermented beverages. Its versatility and resilience make it particularly suitable for climate-resilient farming systems (Patil *et al*. 2010; ANGRAU, 2021) [11, 1]. India is one of the top producers of sorghum, locally known as jowar. It is cultivated mainly in Maharashtra, Karnataka, Madhya Pradesh, Telangana, and Rajasthan, thriving in both kharif (rainy) and rabi (post-rainy) seasons. Sorghum is especially valued in rainfed agriculture due to its low input requirements and adaptability to variable rainfall patterns. According to the Agricultural Market Intelligence Centre (ANGRAU, 2021) [1], India had around 4.39 million hectares under sorghum in 2020-21, with a total production of 4.78 million tonnes, and average productivity of 1,070 kg/ha. Maharashtra accounted for 37% of national production, followed by Karnataka (22%) and Tamil Nadu (10%) (ANGRAU, 2021) [1]. Despite a declining trend in acreage due to the expansion of high-yielding cereals, sorghum remains critical for dryland farmers, especially in central and southern India. It is ranked as the third most important cereal in India after rice and wheat in terms of area under cultivation and is known for sustaining livelihoods in drought-prone areas (Jadhav *et al*. 2016) [7]. Nitrogen is a primary macronutrient essential for plant growth and development. It is a major component of amino acids, nucleic acids, and chlorophyll, playing a central role in photosynthesis, cell division, and biomass accumulation. In sorghum, nitrogen is directly linked with increased plant height, leaf area, tiller number, grain size, and yield. A deficiency of nitrogen results in chlorosis, reduced vegetative growth, and poor grain formation (Kumar *et al*. 2014) [10]. Fertilizers play a pivotal rule in increasing yield and improving the quality of crops. For storage application around with nitrogen (N) has significant effect and increase the number of tillers, plant height, number of grains per spike, 1000 grain weight and grain yield (Ali *et al*. 2005) [2]. Zinc is a micronutrient that is indispensable for the proper functioning of several enzymes, auxin metabolism, and membrane integrity. It also facilitates protein synthesis, gene expression, and chlorophyll production.

In Indian soils, zinc deficiency is widespread, particularly in calcareous, alkaline, and intensively farmed regions. In sorghum, zinc deficiency manifests in the form of stunted growth, interveinal chlorosis, delayed maturity, and reduced grain size (Deshmukh *et al*. 2013; Jadhav *et al*. 2016) [5, 7]. The interaction between nitrogen and zinc is synergistic and highly beneficial in enhancing sorghum growth and productivity. Nitrogen improves root biomass and nutrient uptake, while zinc facilitates nitrogen assimilation and protein metabolism. Combined application of these nutrients has been found to significantly enhance parameters such as plant height, leaf chlorophyll content, grain yield, and dry matter accumulation (Jadhav *et al*. 2016, Kumar *et al*. 2014) [7, 10].

Materials and Methods

The experiment was carried out during Kharif season of 2024 at Crop Research Farm of Naini Agriculture Institute, Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj, which is located at 250 24' 42" N latitude, 810 50' 56" E longitude and 98 m altitude above the mean sea level. This area is situated on the right side of the river Yamuna by the side of Allahabad Rewa Road about 5 km away from Allahabad city. The soil was of sandy loam texture, slightly alkaline in nature (pH 6.8). The experiment was conducted in randomized block design with 10 treatments each replicated thrice. The plot size of each treatment was 3 m x 3 m. The factors are Nitrogen (60 kg/ha, 80 kg/ha, 100 kg/ha) and Ascorbic acid (10 kg/ha, 20 kg/ha, 30 kg/ha). The treatment combinations are T_1-Nitrogen 60 kg/ha + Zinc 10 kg/ha, T_2-Nitrogen 80 kg/ha + Zinc 10 kg/ha, T_3-Nitrogen 100 kg/ha + Zinc 10 kg/ha, T_4-Nitrogen 60 kg/ha + Zinc 20 kg/ha, T_5-Nitrogen 80 kg/ha + Zinc 20 kg/ha, T_6-Nitrogen 100 kg/ha + Zinc 20 kg/ha, T_7-Nitrogen 60 kg/ha + Zinc 30 kg/ha, T_8-Nitrogen 80 kg/ha + Zinc 30 kg/ha, T_9-Nitrogen 100 kg/ha + Zinc 30 kg/ha and T_{10}-Control N-P-k: 80-40-40 kg/ha. The Sorghum crop was sown on 18th July 2024. Harvesting was done by taking 1m^2 area from each plot, and from it some plants were randomly selected for recording growth and yield parameters. The observations were recorded for Plant height (cm), Plant dry weight (g), Length of ear head (cm), Grains/ear head (g), Weight of grains/plant (g), Weight of grains/plant (g), Seed yield (kg/ha), Stover yield (kg/ha).

Harvest index (%) The data was subjected to statistical analysis by analysis of variance method. Economics was calculated *viz*., cost of cultivation, gross return, net return, benefit cost ration were calculated.

Result and Discussion

Plant Height (cm): The effect of nitrogen and zinc on increasing plant height was observed among the treatments. The highest plant height (147.47cm) was recorded in Treatment 5 (Nitrogen at 80 kg/ha + zinc at 20 kg/ha). Treatments 2,3,4 and 6 were found to be statistically at par with Treatment 5. The minimum plant height (118.80cm) was recorded in Treatment 1. The results indicate that increasing nitrogen levels up to 80 kg/ha, especially when combined with 20 kg/ha zinc, significantly enhances Sorghum plant height. Nitrogen is essential for amino acid and protein synthesis, chlorophyll production and overall vegetative growth, leading to increased plant height. Increase in the plant height might be due to cell elongation, cell enlargement and more chlorophyll synthesis, resulting better plant growth and ultimately resulted in higher herbage yield of sorghum. These yield attributes increased with the increase in N application by Verma *et al*. (2004) [15] and (Singh, 1990) [14]. The significant and higher plant height was observed with the application of Zinc might be due to Zinc involves in biosynthesis of indole acetic acid (IAA) which helps in better development of growth attributes.

Plant dry weight (g/plant): The data related to plant dry weight is placed in table1. At harvest, there was a significant difference dry weight was observed among the treatments. The highest plant dry weight (87.47 g) was recorded in Treatment 3 (Nitrogen at 100 kg/ha + zinc at 10 kg/ha). Treatment 8 (79.87 g) was found to be statistically at par with Treatment 3. The minimum plant dry weight was recorded in Control (70.00 g).

Significant increase in plant dry weight with zinc application may be due to its catalytic role in enzymatic reactions, hormone production, and protein synthesis, all of which enhance growth. Similar observations were made by Shekhawat *et al*. (2017) [13]. Zinc and iron also contribute directly to photosynthesis (Photosystems I and II) and photosynthate translocation, as reported by Bandiwaddar (2015) [3] in wheat. Nitrogen application promotes taller plants and supporting greater photosynthetic dry matter production Patel *et al*. (2017) [12]. Zinc, a component of carbonic anhydrase, improves CO_2 assimilation and photosynthetic efficiency, further boosting dry matter yield. Kumar *et al*. (2022) [9].

Yield attributes and Yield

Length of ear head(cm): There was significant difference among different treatments. Significant maximum length of ear head (26.40cm) was recorded with the application of 5th treatment. Whereas 4th, 6th, 7th, 8th and 9th treatments are significantly at par with 5th treatment.

The significant increase in ear head length under the 5th treatment, along with statistically similar performance from the 4th, 6th, 7th, 8th, and 9th treatments, can be attributed to improved nutrient availability in the rhizosphere. This enhanced nutrient environment likely promoted key physiological processes such as increased metabolic activity, efficient photosynthate partitioning, and stimulated cell division and elongation. As reported by Meena *et al*. (2008), such favorable nutrient conditions facilitate better vegetative and reproductive growth, ultimately resulting in greater ear head development.

No. of grains/Ear Head: Significantly Maximum Grains/ear head (923.62) was recorded with the treatment with application of Nitrogen at 80 Kg/ha + Zinc at 20 kg/ha and minimum was recorded in control (80:40:40) (743.76). Where in Treatment 7 (Nitrogen 60 Kg/ha + Zinc at 30 Kg/ha) (892.22) was statistically at par with Treatment 5. Similar results are seen with Kumar *et al*. (2022) [9] & Dixit *et al*. (2005) [6].

Test Weight (g): The data reveals that there is no significant difference among the treatments on test weight. Highest value (29.95 g) with 5th treatment and minimum value (28.65 g) in 10th treatment.

Stover Yield (kg/ha): Significantly Maximum stover yield (5369.67) was recorded with the treatment 6 with application of Nitrogen at 100 Kg/ha + Zinc at 20 kg/ha and minimum was recorded in Treatment 1 Nitrogen 60 Kg/ha + Zinc at 10 Kg/ha (4519.33), whereas Treatment 4 was statistically at par with Treatment 6. The increase in yields attributed to the fact that because of favourable nutritional environment in rhizosphere and higher absorption of nutrients by plant leading to the increased photosynthetic efficiency and production of assimilates. Similar results were also reported by, Bhunwal *et al*. (2015) [4] and Amit Kumar *et al*. (2022) [9].

Grain yield (kg/ha): The data reveals that there was a significant difference among the different treatments. Significantly maximum seed yield (3300.53 kg) was recorded at 5th treatment. Whereas 6th treatments are significantly at par with the 5th treatment.

The application of micronutrient with NPK fertilizers provides a double benefit increasing grain yield and improving the nutritional quality of the grains, since micronutrient with NPK fertilizers also increase the concentration of nutrients in grain as well as stover and there by increased the uptake of nutrients. These results are in agreement with those recorded by Khalifa *et al*. 2011 and Kumar *et al*. 2022 [8, 9].

Harvest index (%): Significantly Maximum harvest index (40.84) was recorded with the treatment 5 with application of (Nitrogen at 80 Kg/ha + Zinc at 20 kg/ha) and minimum was recorded in control (26.26), whereas Treatment 6 (Nitrogen 100 Kg/ha + Zinc at 20 Kg/ha) (2679.83) was statistically at par with Treatment 5.

Economic analysis: The maximum benefit cost ratio (2.48) was recorded in 5th treatment and minimum in 1st treatment as compared to other treatments. May be the higher nitrogen level likely enhanced yield significantly, thereby increasing gross returns, while the cost of input remained justifiable in comparison to the output value. Similarly, the application of zinc contributed to better crop performance without substantially increasing production costs, leading to a higher net return.

Table 1: Effect of Nitrogen and Zinc on growth attributes, yield attributes and yield of Sorghum.

At harvest									
S. No	Treatments	Plant height (cm)	Plant dry weight (g/plant)	Length of Ear Head (Cm)	No. of Grains/Ear/ Head	Test weight (g)	Stover Yield (Kg/ha)	Grain yield (kg/ha)	Harvest index (%)
1	Nitrogen 60 kg/ha + Zinc 10 kg/ha	118.80	72.50	22.13	770.46	29.47	4519.33	1613.07	26.26
2	Nitrogen 80 kg/ha + Zinc 10 kg/ha	134.00	80.60	22.40	792.05	29.29	4819.67	1806.20	27.15
3	Nitrogen 100 kg/ha + Zinc 10 kg/ha	131.80	87.47	22.17	760.74	29.78	4039.67	2212.53	35.35
4	Nitrogen 60 kg/ha + Zinc 20 kg/ha	134.60	80.30	24.40	812.30	29.92	4778.33	2280.80	33.12
5	Nitrogen 80 kg/ha + Zinc 20 kg/ha	147.47	84.67	26.40	923.62	29.95	4575.00	3300.53	40.84
6	Nitrogen 100 kg/ha + Zinc 20 kg/ha	141.13	83.70	24.73	860.31	29.55	5369.67	2679.83	33.08
7	Nitrogen 60 kg/ha + Zinc 30 kg/ha	120.00	68.90	24.67	892.22	29.21	4431.33	1963.50	30.77
8	Nitrogen 80 kg/ha + Zinc 30 kg/ha	120.20	79.87	24.53	908.98	29.08	4726.00	1883.57	28.45
9	Nitrogen 100 kg/ha + Zinc 30 kg/ha	130.47	84.03	25.53	874.93	28.99	4570.00	1949.03	29.86
10	Control N-P-K-80:40:40 Kg/ha	118.47	70.00	20.70	743.76	28.65	4985.00	1729.43	25.72
	F-Test	S	S	S	S	NS	S	S	S
	SEm±	5.42	4.08	1.10	16.42	0.32	211.39	182.55	1.93
	CD (p=0.05)	16.10	12.12	3.28	48.80	-	628.08	542.38	5.75

Table 2: Effect of Nitrogen and Zinc on economic of production of Sorghum.

Economics					
S. No	Treatments	Total cost of cultivation (INR/ha)	Gross Return (INR/ha)	Net Return (INR/ha)	B:C ratio
1	Nitrogen 60 kg/ha + Zinc 10 kg/ha	41456.16	83893.31	42437.15	1.02
2	Nitrogen 80 kg/ha + Zinc 10 kg/ha	41760.45	92733.95	50973.5	1.22
3	Nitrogen 100 kg/ha + Zinc 10 kg/ha	42064.25	104274.49	62210.24	1.48
4	Nitrogen 60 kg/ha + Zinc 20 kg/ha	42286.16	110562.05	68275.89	1.61
5	Nitrogen 80 kg/ha + Zinc 20 kg/ha	42590.45	148295.14	105704.69	2.48
6	Nitrogen 100 kg/ha + Zinc 20 kg/ha	42590.45	128681.89	85787.64	2.00
7	Nitrogen 60 kg/ha + Zinc 30 kg/ha	43116.16	96769.65	53653.49	1.24
8	Nitrogen 80 kg/ha + Zinc 30 kg/ha	43420.45	95205.66	51785.21	1.19
9	Nitrogen 100 kg/ha + Zinc 30 kg/ha	43724.25	96913.14	53188.89	1.22
10	Control N-P-K-80:40:40 Kg/ha	40930.45	90643.34	49712.89	1.21

Conclusion

It is concluded that the application of Nitrogen 80 kg/ha + Zinc 20 kg/ha was recorded higher seed yield and benefit cost ratio in Sorghum.

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