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Influence of biofertilizers and foliar application of zinc on yield and economics of sorghum (*Sorghum bicolor* L.)

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Abstract
The field experiment was conducted during *kharif* season, 2021 at Crop Research Farm, Department of Agronomy, SHUATS, Prayagraj (UP). The experiment was laid out in Randomized Block Design with ten treatments including control, replicated thrice with the biofertilizers *viz. Azospirillum* 25 g/kg seed, PSB 25 g/kg seed and combination of *Azospirillum* 25 g/kg seed + PSB 25 g/kg seed and foliar application of 0.5% zinc at 30 DAS, 50 DAS and 30 + 50 DAS study revealed that Foliar application of zinc 0.5% at 50 DAS/ha along with seed inoculation by *Azospirillum* 25 g/kg Seeds + PSB 25 g/kg seeds significantly higher grain yield (4476.62 kg/ha) and stover yield (7458.57kg/ha) as compared to all the treatment combinations. The maximum gross return (₹ 144684.83), net return (₹ 109054.83) and B:C ratio (3.06) is recorded in treatment of seeds with dual inoculation *Azospirillum* 25 g/kg seeds + PSB 25 g/kg seeds along with 0.5% Zinc foliar spray 50 DAS.

Keywords: Sorghum, bio-fertilizers, zinc, *Azospirillum* SPS, PSB, yield, economics

Introduction
Sorghum is one of the most important cereals grown in India and consumed by the majority of Indians on a daily basis. After wheat, maize, rice, and barley, it ranks fifth in cereal production. It is also widely utilized in industry, as it is employed in malting, the production of high fructose syrup, starch, bakery, value-added products for diabetics, and animal feed, as well as in domestic products. Sorghum is also a drought-tolerant crop, which contributes to its popularity in areas where the weather is unpredictable. It can withstand both drought and water logging situations. It thrives in a variety of soil types, although sandy loam soil with adequate drainage is ideal for cultivation. a pH range of 6 to 7. is suitable for cultivation and improved growth of sorghum.

Sorghum has been discovered to be high in vitamins and minerals, as well as having a high protein content and accounting for a major amount of dietary fiber consumption. 100 g of grain has 10.4 g of protein, 1.9 g of fat, 72.6 g of carbohydrates, 1.6 g of crude fiber, and 25 g of calcium. Sorghum is abundant in vitamins and a good source of fiber. Sorghum is recognized to be high in phenolic chemicals, many of which function as antioxidants and aid in tumor reduction. Sorghum productivity is low due to its cultivation on marginal soils and constant use of macronutrients. Zinc insufficiency has become the most common micronutrient deficiency in soils and crops around the world, resulting in significant yield losses and nutritional quality degradation. Because the use of biofertilizers has increased in all types of crops, including cereal crops, integrated nutrient management is being implemented on many of them. Biofertilizers in cereal crops have been demonstrated advantageous in many ways for nitrogen fixation. The most effective strategy to maximize grain yield is to use a combination of biofertilizers and foliar zinc fertilizers. The use of an agronomic biofortification technique appears to be critical in maintaining adequate zinc levels in plants.

Materials and Methods
The experiment was carried out during *kharif* season of 2021 at Crop Research Farm, Department of Agronomy, Naini Agricultural Institute, SHUATS, Prayagraj. (U.P). which is located at 25° 39' 42" N latitude, 81° 67' 56" E longitude and 98 m altitude above the mean sea level. The soil of the experimental plot was sandy loam in texture, nearly neutral in soil reaction (pH 7.7), low in organic carbon (0.57%), available N (230 kg/ha), available P (32.10 kg/ha) and available K (346 kg/ha). The crop was sown on 19th July 2021 using variety NTJ-5.

The experiment was laid out in Randomized Block Design comprised of 3 replications and total 9 treatments *viz*., T1: Control- 80: 40:40 Kg NPK/ha (Farmer's Practice), T2: *Azospirillum* 25 g/kg seeds + 0.5% zinc foliar spray 30 DAS, T3: *Azospirillum* 25 g/kg seeds + 0.5% zinc foliar spray 50 DAS, T4: *Azospirillum* 25 g/kg seeds + 0.5% zinc foliar spray 30 + 50 DAS, T5: PSB 25 g/kg seeds + 0.5% zinc foliar spray 30 DAS, T6: PSB 25 g/kg seeds + 0.5% zinc foliar spray 50 DAS, T7: PSB 25 g/kg seeds + 0.5% zinc foliar spray 30 + 50 DAS, T8: *Azospirillum* + PSB: 25+25 g/kg seeds + 0.5% zinc foliar spray 30 DAS, T9: *Azospirillum* + PSB: 25+25 g/kg seeds + 0.5% zinc foliar spray 50 DAS, T10: *Azospirillum* 25 g/kg+ PSB 25 g/kg seeds + 0.5% zinc foliar spray 30 + 50 DAS. All nutrients were applied through soil as urea, single super phosphate (SSP) and muriate of potash (MOP). Half dose of nitrogen and total amount of phosphorus and potash should be applied at the time of sowing in respective plots. The remaining half quantity of nitrogen was top dressed at 30 days after sowing. The growth parameters were recorded at periodical intervals of 20,40,60,80 DAS and at harvest stage from the randomly selected five plants in each treatment. Statistically analysis was done and mean compared at 5% probability level of significant results.

Table 1: Details of treatment combinations

Treatment No.	Treatment Combinations
T1	Control (Farmer's Practice)
T2	*Azospirillum* 25gm/kg seeds + 0.5% zinc foliar spray 30 DAS
T3	*Azospirillum* 25gm/kg seeds + 0.5% zinc foliar spray 50 DAS
T4	*Azospirillum* 25gm/kg seeds + 0.5% zinc foliar spray 30 + 50 DAS
T5	PSB 25 gm/kg seeds + 0.5% zinc foliar spray 30 DAS
T6	PSB 25 gm/kg seeds + 0.5% zinc foliar spray 50 DAS
T7	PSB 25 gm/kg seeds + 0.5% zinc foliar spray 30 + 50 DAS
T8	*Azospirillum* + PSB 25+25 g/kg seeds + 0.5% zinc foliar spray 30 DAS
T9	*Azospirillum* + PSB 25+25 g/kg seeds + 0.5% zinc foliar spray 50 DAS
T10	*Azospirillum* + PSB 25+25 g/kg seeds + 0.5% zinc foliar spray 30 + 50 DAS

Results and Discussion

Influence of biofertilizer and foliar application of zinc on yield of sorghum

Influence of biofertilizers and foliar application of zinc on yield of sorghum are presented in Table 2. In the results revealed that dual inoculation of *Azospirillum* and PSB along with Foliar application of 0.5% zinc at 50 DAS/ha significantly increased the yield attributing parameters *viz*., grain yield (4476.62 kg/ha), stover yield (7458.57 kg/ha) over control. Higher seed yield and stover yield was due to the foliar application of zinc by the action of biofertilizers. Zinc is essential for several biochemical processes in plant, such as cytochrome and nucleotide synthesis, auxin metabolism, chlorophyll production, enzyme activation, and membrane integrity which helped in good foliage and grain development in panicle (Sutaria *et al*., 2013) [15], and better availability of nitrogen and phosphorus due to the action of biofertilizer lead in overall better development of the crop. The combined use of biofertilizer and foliar application of zinc just before flowering stage at 50 DAS helped in good foliage and good panicle development in the crop which resulted in improved growth parameters due to increased dry matter production, which in turn contributed to improved yield attributes. It may be due to increased nitrogen and phosphorus supply, which contributes to better vegetative growth and fruiting resulting into higher seed and stover yield of sorghum. These results are in close conformity with the findings of (Singh *et al*., 2015).

Influence of Biofertilizers and Foliar application of Zinc on economics of sorghum

Influence of biofertilizers and foliar application of zinc on economics of sorghum are presented in table 3. The highest gross returns (₹144684.83/ha), higher net returns (₹ 109054.83/ha) and maximum B:C ratio (3.06) recorded in dual inoculation of *Azospirillum* and PSB along with foliar application of 0.5% zinc at 50 DAS. This was mainly due to higher seed and stover yields compared to other treatment combinations. Similar findings were reported by Jaga and Sharma (2015) and A.K Roy *et al*., (2018).

Table 2: Influence of biofertilizers and foliar application of zinc on yield and economics of sorghum.

Treatment Combinations	Grain yield (kg/ha)	Stover yield (kg/ha)
1. Control 80:40:40 kg NPK/ha (Farmer's Practice)	3892.77	7157.83
2. *Azospirillum* 25gm/kg seeds + 0.5% zinc foliar spray 30 DAS	4121.69	7484.50
3. *Azospirillum* 25gm/kg seeds + 0.5% zinc foliar spray 50 DAS	4005.73	7419.90
4. *Azospirillum* 25gm/kg seeds + 0.5% zinc foliar spray 30 + 50 DAS	4254.42	7366.50
5. PSB 25 gm/kg seeds + 0.5% zinc foliar spray 30 DAS	4093.64	7326.83
6. PSB 25 gm/kg seeds + 0.5% zinc foliar spray 50 DAS	4132.91	7292.13
7. PSB 25 gm/kg seeds + 0.5% zinc foliar spray 30 + 50 DAS	4266.02	7358.60
8. *Azospirillum* + PSB 25+25 g/kg seeds + 0.5% zinc foliar spray 30 DAS	4203.98	7419.13
9. *Azospirillum* + PSB 25+25 g/kg seeds + 0.5% zinc foliar spray 50 DAS	4476.62	7458.57
10. *Azospirillum* + PSB 25+25 g/kg seeds + 0.5% zinc foliar spray 30 + 50 DAS	4187.74	7437.40
F test	S	S
S.Em(±)	10.75	14.81
CD (p=0.05)	33.42	44.01

Table 3: Influence of biofertilizers and foliar application of zinc on economics of sorghum

Treatment Combinations	Total cost of cultivation	Gross return	Net return	B: C ratio
1. Control 80:40:40 kg NPK/ha (Farmer's Practice)	33630.00	129214.78	95584.78	2.84
2. *Azospirillum* 25gm/kg seeds + 0.5% zinc foliar spray 30 DAS	35380.00	136865.70	101485.70	2.87
3. *Azospirillum* 25gm/kg seeds + 0.5% zinc foliar spray 50 DAS	35380.00	133231.50	97851.50	2.77
4. *Azospirillum* 25gm/kg seeds + 0.5% zinc foliar spray 30 + 50 DAS	36880.00	138958.90	102078.90	2.77
5. PSB 25 gm/kg seeds + 0.5% zinc foliar spray 30 DAS	35380.00	134888.57	99508.57	2.81
6. PSB 25 gm/kg seeds + 0.5% zinc foliar spray 50 DAS	35380.00	135631.87	100251.87	2.83
7. PSB 25 gm/kg seeds + 0.5% zinc foliar spray 30 + 50 DAS	36880.00	139140.20	102260.20	2.77
8. *Azospirillum* + PSB 25+25 g/kg seeds + 0.5% zinc foliar spray 30 DAS	35630.00	137966.07	102336.07	2.87
9. *Azospirillum* + PSB 25+25 g/kg seeds + 0.5% zinc foliar spray 50 DAS	35630.00	144684.83	109054.83	3.06
10. *Azospirillum* + PSB 25+25 g/kg seeds + 0.5% zinc foliar spray 30 + 50 DAS	37130.00	137659.00	100529.00	2.71

Conclusion

In eastern plain zones of Uttar Pradesh, under inceptisol soil order, cultivation of sorghum with the foliar application of 0.5% zinc at 50 DAS/ha along with co-inoculation of *Azospirillum* and phosphate solubilizing bacteria was found to be more desirable in terms of increasing yield. It also recorded the maximum gross return, net return and benefit cost ratio as compared to all treatments.

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