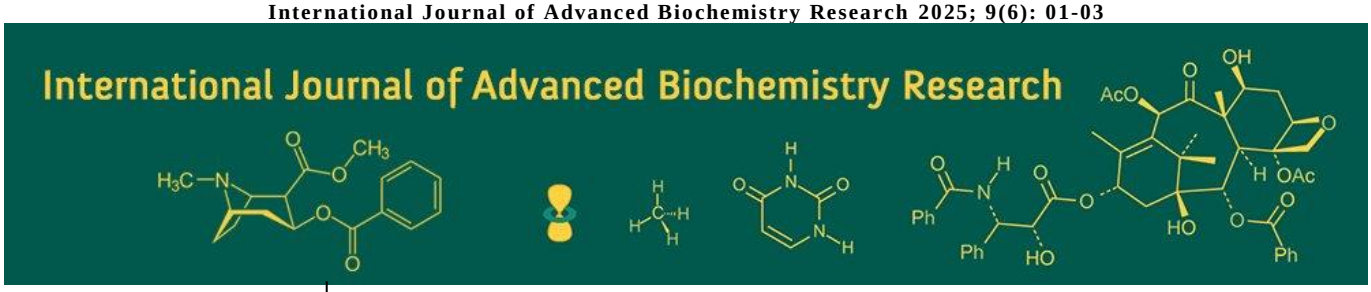

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Effect of biofertilizer with micronutrients as soil application on growth and yield of foxtail millet (*Setaria italica* L.)

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Abstract
A field experiment was conducted during *Zaid* season of 2024 at Crop Research Farm, Department of Agronomy, SHUATS, Prayagraj, Uttar Pradesh, India. The treatment consisted of seed inoculation of either *Azotobacter* or *Azospirillum* in combination with soil application of Boron at 0.5 and 1 kg/ha and Zinc at 10 and 15 kg/ha including control. The experiment was laid out in Randomized block design with nine treatments and replicated thrice. Seed inoculation with *Azospirillum* in combination with boron 1 kg/ha as soil application recorded significantly maximum growth attributes namely plant height (83.80 cm), plant dry weight (9.35 g), number of tillers/plant (3.40) and yield attributes namely seeds/panicle (286.0), panicle length (12.16 cm), test weight (3.76 g), grain yield (1.54 t/ha) and benefit cost ratio (1.68).

Keywords: *Azotobacter*, *Azospirillum*, boron, RBD, soil application, zinc

Introduction
Foxtail millet (*Setaria italica* L.) is a hardy, short-duration, and nutrient-rich cereal crop well suited to arid and semi-arid regions. Globally it is cultivated on approximately 23 million hectares, in India the crop is grown over an estimated area of 0.65 million hectares, which produce around 0.47 million tonnes annually (DACFW 2020) [2]. Despite its potential for contributing to food and nutritional security, its yield remains low due to imbalanced nutrient management and declining soil fertility. One of the major constraints affecting millet growth and yield is the deficiency of essential micronutrients particularly boron and zinc, which are critical for various physiological and biochemical functions in plants. These micronutrients are either low or unavailable due to intensive cultivation, poor organic matter content, and high soil pH (Tiwari *et al.*, 2006; Singh *et al.*, 2018) [12, 10]. Chemical fertilizers alone are insufficient to sustain soil health and crop productivity in the long term. Biofertilizers, such as nitrogen-fixing microorganisms, play a significant role in enhancing nutrient availability and uptake, improving soil microbial activity, and promoting sustainable crop production (Reddy and Reddy 2023) [7]. The integration of biofertilizers with micronutrient amendments may offer a synergistic effect, leading to improve the growth, nutrient use efficiency, and yield in foxtail millet.

Materials and Methods
A field experiment was conducted during *Zaid* season of 2024 at Crop research farm of Department of Agronomy at SHUATS, Prayagraj, Uttar Pradesh, India. The soil was neutral in pH, and a sandy loam texture. The experiment was laid out in a Randomized block design with nine treatments and replicated thrice. The experiment consisted of seed inoculation with either *Azotobacter* or *Azospirillum* in combination with Boron at 0.5 and 1 kg/ha and Zinc at 10 and 15 kg/ha including control. The work covers treatment combination as *Azotobecter* + soil application of boron 0.5 kg/ha, *Azotobacter* + soil application of boron 1 kg/ha, *Azotobecter* + soil application of Zinc 10 kg/ha, *Azotobecter* + soil application of Zinc 15 kg/ha *Azospirillum* + soil application of Boron 0.5 kg/ha, *Azopirillum* + soil application of Boron 1 kg/ha, *Azopirillum* + soil application of Zinc 10 kg/ha, *Azopirillum* + soil application of Zinc 15 kg/ha and Control N-P-K 50-30-20 kg/ha.

Results and Discussion

Result indicated in table 1 shows that application of *Azospirillum* along with soil application of boron significantly affected the different growth and yield attributes of the crop as compared to other treatments. Significantly maximum plant height was observed by the application of *Azospirillum* with soil application of boron 1 kg/ha, and was found to be at par with *Azotobacter* with zinc 15 kg/ha. The increase in plant height was due to the complementary functions of *Azospirillum* and boron, as *Azospirillum* is well known for its role as plant growth-promoting rhizobacterium, specially to fix atmospheric nitrogen and produce phytohormones like IAA, which stimulate root elongation and lateral root formation, leading to enhanced nutrient and water absorption. Similar result was reported in maize by Braccini *et al.* (2012) [1] in maize. Boron plays a critical role in cell division, cell formation, and improved auxin activity enhances cell elongation. These results confirm the findings of Das *et al.* (2022) [4] in sorghum.

It was observed that, maximum plant dry weight was recorded by the application of *Azospirillum* with soil application of boron 1 kg/ha, and was found to be at par with *Azotobacter* with zinc 10 kg/ha. The observed increase in plant dry weight may be attributed to improved physiological efficiency resulting from enhanced nutrient uptake and translocation. As *Azospirillum* stimulate root growth, increasing the surface area for nutrient absorption. Similar result was reported by Puente *et al*. (2009) [5], while boron ensured proper cell expansion, sugar transport to growing tissues, improve photosynthetic efficiency, the primary contributors to dry weight. These results confirm the findings of Singh *et al.* (2025) [11] in maize.

The maximum number of tillers per plant was observed by the application of *Azospirillum* with soil application of boron 1 kg/ha, and was found to be at par with *Azospirillum* with boron 0.5 kg/ha. The positive response in tiller production may be also associated with boron role in meristematic activity specially in the initiation and outgrowth of axillary buds. It supports better hormonal balance such as auxin and cytokinin, which influence tiller bud activation. These results confirm the findings of Shukla *et al*. (2020) [9] in rice.

Application of *Azospirillum* with soil application of boron 1 kg/ha, recorded maximum seeds per panicle, and it was found at par with *Azotobacter* with zinc 10 kg/ha. The result increase in number of seeds per panicle suggests that boron application enhanced pollen viability and fertilization efficiency, leading to better grain set and panicle filling. These results confirm the findings of Das *et al.* (2022) [4] in sorghum.

Highest panicle length was observed by the application of *Azospirillum* with soil application of boron 1 kg/ha, and was found to be at par with *Azotobacter* with zinc 15 kg/ha. In the present study, the improved panicle length could be attributed to better nutrient translocation and hormonal balance. Boron enhanced vascular tissue development, facilitating efficient movement of carbohydrates to the growing panicle. This promotes cell division and elongation during panicle formation. These results confirm the findings of Shukla *et al*. (2020) [9] in rice.

Maximum test weight (3.76 g) was recorded by the application of *Azospirillum* with soil application of boron 1 kg/ha. The increase in test weight may also refelect boron role in improving overall plant vigor and more effective translocation of photosynthates to reproductive organs. Similar result was reported by Daemo *et al.* (2024) [3] in maize.

Table 1: Effect of bio-fertilizer with micronutrients as soil application on growth and yield of foxtail millet.

S. No.	Treatment	Plant height	Plant Dry Weight	Tillers/ Plant	Seeds /panicle	Panicle length	Test weight	Grain yield	Benefit Cost Ratio
		(cm)	(g)	(No.)	(No.)	(cm)	(g)	(t/ha)	
1.	*Azotobacter* + Soil application of Boron 0.5 kg/ha	78.36	8.83	2.43	262.63	9.65	3.63	1.38	1.52
2.	*Azotobacter* + Soil application of Boron 1 kg/ha	80.57	9.12	2.56	274.60	10.70	3.56	1.49	1.62
3.	*Azotobacter* + Soil application of Zinc 10 kg/ha	75.43	8.64	3.35	268.40	12.11	3.67	1.32	1.38
4.	*Azotobacter* + Soil application of Zinc 15 kg/ha	77.54	8.26	2.36	251.13	11.17	3.27	1.29	1.29
5.	*Azospirillum* + Soil application of Boron 0.5 kg/ha	78.51	8.91	3.00	264.46	10.06	3.31	1.42	1.56
6.	*Azospirillum* + Soil application of Boron 1 kg/ha	83.80	9.35	3.40	286.0	12.16	3.76	1.54	1.68
7.	*Azospirillum* + Soil application of Zinc 10 kg/ha	76.85	7.98	3.11	267.93	11.67	3.62	1.26	1.31
8.	*Azospirillum* + Soil application of Zinc 15 kg/ha	72.58	7.70	2.71	250.60	12.04	3.58	1.17	1.17
9.	Control (N-P-K 50-30-20 kg/ha)	70.97	7.55	2.93	248.01	11.18	3.41	0.91	1.02
	F Test	S	S	S	S	S	NS	S	
	SEm (±)	2.19	0.29	0.15	5.99	0.47	0.15	0.10	
	CD (p=0.05)	6.55	0.87	0.45	17.94	1.41	-	0.29	

The application of *Azospirillum* with soil appliaction boron 1 kg/ha recorded maximum grain yield, and was found to be at par with *Azospirillum* with zinc 10 kg/ha. *Azospirillum* enhances root growth and nutrient acquisition. Similar result was reported by Rafi *et al.* (2012) [6] in foxtail millet. Boron facilitates pollen grain development, germination, and pollen tube elongation. It enhances floret development, promotes carbohydrates translocation to grains. The combined application results better panicle development, higher seeds count, and better panicle development, higher seeds count, and improved grain filling. These results confirm the findings of Shankar *et al.* (2017) [8] in finger millet.

Economics

Maximum Benefit Cost ratio (1.68) was recorded with the treatment receiving seed inoculation of *Azospirillum* with soil application of boron 1 kg/ha. This results align with the finding of Shankar *et al.* (2017) [10].

Conclusion

It is concluded that seed inoculation with *Azospirillum* in combination with soil application of Boron 1 kg/ha in foxtail millet recorded highest yield and benefit cost ratio.

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