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Influence of Biofertilizer and Zinc on Growth, Yield and Economics of Sorghum (*Sorghum bicolor* L.)

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

A field experiment was conducted during *kharif* 2022 at Crop Research Farm, Department of Agronomy, SHUATS, Prayagraj (U.P) to study the "Influence of Biofertilizer and Zinc on growth, yield and economics of Sorghum (*Sorghum bicolor* L.)". To Study treatment consisting of three levels of Azotobacter *chroococcum* viz. 10g/kg, 15g/kg and 20g/kg and three levels of Zinc viz. 15kg/ha, 20kg/ha and 25kg/ha. There were 10 treatments, each of which was replicated three times and laid out in randomized block design. The results showed that treatment 9 [Azotobacter *chroococcum* (20g/kg) + Zinc (25kg/ha)] recorded significant higher plant height (214.23 cm), higher dry weight (120.23 g), higher length of ear head (25.44 cm), higher seed yield (4310.02 kg/ha), higher straw yield (6810.02 kg/ha) and higher harvest index (38.75 %) was recorded in treatment 9 [Azotobacter *chroococcum* (20g/kg) + Zinc (25kg/ha)]. Similarly, maximum gross return (85752.38 INR/ha), maximum net return (58302.38 INR/ha) and highest benefit cost ratio (2.12) was also recorded in treatment 9 [Azotobacter *chroococcum* (20g/kg) + Zinc (25 kg/ha)] as compared to other treatments.

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1. INTRODUCTION

Sorghum (*Sorghum bicolor* L.) commonly known as the 'king of millets', is a highly productive crop plant, which can be used for grains, livestock feed or industrial purposes. It is the most important, widely adaptable and extensively grown as a fodder crop. It can withstand heat, drought and also tolerate water logging better than other forage crops. The yield potential of sorghum is much higher than other forage crops but the production is low Singh et al. 2016 [1]. Sorghum is highly nutrient exhaustive crop, therefore, to achieve sustainable higher productivity maintenance of native soil fertility and health is necessary. The balanced and conjugated use of inorganic fertilizer, biocompost and biofertilizer in order to maintenance or adjustment of soil fertility and plant nutrient supply to an optimum level for sustaining desired crop productivity Rakshit et al. 2008 [2]. It is the staple for large tribal populations across the country. The poor and vulnerable groups in the society depend upon sorghum for their calories and micronutrient requirement. The absence of access and affordability to nutrient-rich foods and fortification of sorghum help in enhancing in nutritional security Dambiwal et al. 2017 [3]. It contains protein (10-12%), carbohydrate (70%), fats (3%), vitamins and mineral salts which are essential for vigorous growth of human life. It is grown on an area of about 45 m/ha in the world with a production of about 61 m.t, while in India it occupies an area of about 12.8 m ha with a total production of about 12.5 million tonnes. Average productivity of sorghum in India is only (977 kg/ha) which is well below the world average of (1500 kg/ha) Akhila et al., 2021 [4].

"Sorghum can grow in a wide range of ecological conditions and can still yield well even under unfavorable conditions of drought stress and high temperatures. In 2021-22, the United States was the largest producer of sorghum worldwide, producing about 11.4 million metric tons of sorghum. Production of sorghum in India was about 8.71 million tonnes". (www.statista.com). [5]. In Uttar Pradesh it is cultivated in an area of 248.0 hectare with a productivity of 1348 kg/ha and Sorghum production 184.0 tonnes in 2021-22.

"Insufficient micronutrient availability in soils not only causes low crop productivity but also poor nutritional quality of the crops and consequently contributes to malnutrition in the human population" Kumssa et al. [6]. "Zinc is essential for several enzyme systems that regulate various metabolic activities in plants. It is involved in auxin production which is growth regulating substances in plants. Zinc is also vital for the oxidation processes in plant cells and helps in the transformation of carbohydrates and regulates sugar in plants". Tandon [7].

Durgude et al. [8]. "Micronutrient (Zinc) helped to increase in leaf area, chlorophyll content in leaves, uptake of total Zinc availability in soil agronomic efficiency, grain and stover yield of sorghum".

"Use of biofertilizer in sorghum crop not only fixes the biological nitrogen but also solubilizes the insoluble phosphates in soil and thus improves fertilizers-use efficiency" Gogoi [9].

"Biofertilizers improve the quantitative and qualitative features of many plants". Yosefi et al. [10]. "Sorghum Yield and soil properties were significantly improved by combined application of organics, inorganics and biofertilizer than the inorganic alone". Gawai et al. [11]. "Numbers of different bacteria promote plant growth, including Azotobacter sp., Azospirillum sp., Pseudomones sp., Bacillus sp. Acetobacter sp". Turan et al. [12].

"Azotobacter is a free living N_2 fixing bacterium. It can successfully grow in the rhizospheric zone of wheat, maize, rice, sorghum, sugarcane, cotton, potato and many others and fix 10-20kg N/ha cropping season. Besides nitrogen fixation, Azotobacter synthesizes and secretes considerable amounts of biologically active substances like vitamin B, nicotinic acid, pantothenic acid, biotin, heteroauxins, gibberellins, etc. which enhance root growth of plants. Another important characteristic of Azotobacter association with crop improvement is excretion of ammonia in the rhizosphere in the presence of root exudates; which helps in modification of nutrient uptake by the plants. Azotobacter can produce antifungal antibiotics and fungistatic compounds against pathogens like Fusarium, Alternaria, Trichoderma" [13,14].

Keeping in view the above facts, the present experiment was undertaken to find out "Influence of biofertilizer and zinc on growth, yield and economics of Sorghum (*Sorghum bicolor* L.)".

2. MATERIALS AND METHODS

The field experiment was conducted during kharif season 2022 at Crop Research Farm, Department of Agronomy, SHUATS, Prayagraj (U.P). The soil of the experimental field was sandy loam in texture, nearly neutral in soil reaction (pH 7.6), organic carbon level in medium condition (0.87%), medium available N (225 Kg/ha), high in available P (41.8 kg/ha) and medium available K (261.2 kg/ha). The treatment consisting of three levels of Azotobacter *chroococcum* viz. 10g/kg, 15g/kg and 20g/kg and three levels of Zinc viz. 15kg/ha, 20kg/ha and 25 kg/ha. The experiment was laid out in Randomized Block Design with 10 treatments each replicated thrice. The treatment combinations are T 1 – Azotobacter *chroococcum* (10g/kg) + Zinc (15kg/ha), T 2 - Azotobacter *chroococcum* (10g/kg) + Zinc (20kg/ha), T 3 - Azotobacter *chroococcum* (10g/kg) + Zinc (25kg/ha), T 4 – Azotobacter *chroococcum* (15g/kg) + Zinc (15kg/ha), T 5 - Azotobacter *chroococcum* (15g/kg) + Zinc (20kg/ha), T 6 - Azotobacter *chroococcum* (15g/kg) + Zinc (25kg/ha), T 7 – Azotobacter *chroococcum* (20g/kg) + Zinc (15kg/ha), T 8 - Azotobacter *chroococcum* (20g/kg) + Zinc (20kg/ha), T 9 - Azotobacter *chroococcum* (20g/kg) + Zinc (25kg/ha), T 10 - Control N:P:K (80:40:40 kg/ha). All agronomic practices are followed in order in the crop period. Experimental data collected was subjected to statistical analysis by adopting Fisher's method of analysis of variance (ANOVA) as outlined by Gomez and Gomez (1984). Critical Difference (CD) values were calculated wherever the 'F' test was found significant at 5 percent level. [15].

3. RESULTS AND DISCUSSION

3.1 Growth Parameters

3.1.1 Plant height (cm)

At 100 DAS the significantly and higher plant height (214.23 cm) [Table 1] was recorded in treatment 9 [Azotobacter *chroococcum* (20g/kg) + Zinc (25kg/ha)]. However, treatment 8 [Azotobacter *chroococcum* (20g/kg) + Zinc (20kg/ha)], treatment 7 [Azotobacter *chroococcum* (20g/kg) + Zinc (15kg/ha)], treatment 6 [Azotobacter *chroococcum* (15g/kg) + Zinc (25kg/ha)], treatment 5 [Azotobacter *chroococcum* (15g/kg) + Zinc (20kg/ha)] were found to be statistically at par with treatment 9 [Azotobacter *chroococcum* (20g/kg) + Zinc (25kg/ha)]. 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. Similar result was reported by Ganapathy et al. 2006. [16].

3.1.2 Plant dry weight (g/plant)

At 100 DAS, the significantly higher dry weight (120.23 g) [Table 1] was recorded in treatment 9 [Azotobacter *chroococcum* (20g/kg) + Zinc (25kg/ha)]. However, treatment 8 [Azotobacter *chroococcum* (20g/kg) + Zinc (20kg/ha)], treatment 7 [Azotobacter *chroococcum* (20g/kg) + Zinc (15kg/ha)], treatment 6 [Azotobacter *chroococcum* (15g/kg) + Zinc (25kg/ha)] were found to be statistically at par with treatment 9 [Azotobacter *chroococcum* (20g/kg) + Zinc (25kg/ha)]. The significant and higher plant dry weight was observed with the application of Zinc (20kg/ha) might be due to zinc in soil and its role in various enzymatic reactions and it acts as a catalyst in various growth processes and in hormone production and protein synthesis which results in increasing the growth. Similar results were reported by Shekhawat et al., 2017. [17]. Further increase in dry weight with the application of Azotobacter *chroococcum* might be due to it increased uptake of nitrogen and phosphorus by the plants, which was made available through nitrogen fixation and phosphate solubalization by the microorganisms. These results were in conformity with those of Singh et al. 2016. [18].

3.2 Yield Parameters

3.2.1 Length of ear head (cm)

Significant and highest length of the ear head (25.44 cm) [Table 2] was recorded in treatment 9 [Azotobacter *chroococcum* (20g/kg) + Zinc(25kg/ha)], which was significantly superior over rest of the treatment. However, treatment 8 [Azotobacter *chroococcum* (20g/kg) + Zinc (20kg/ha)], treatment 7 [Azotobacter *chroococcum* (20g/kg) + Zinc (15kg/ha)], treatment 6 [Azotobacter *chroococcum* (15g/kg) + Zinc (25kg/ha)], was found to be statistically at par with treatment 9 [Azotobacter *chroococcum* (20g/kg) + Zinc (25kg/ha)]. Significant and higher length of the ear head with the application of Azotobacter (20kg/ha) might be due to attributed to increased nitrogen availability by fixing appreciable amount of molecular nitrogen and made available for plant growth and to synthesis growth promoting enzyme like indole acetic acid (IAA), gibberellins, vitamins and also altered the

Table 1. Influence of biofertilizer and zinc on growth parameters of Sorghum

S. No.	Treatment	At 100 DAS	
		Plant height (cm)	Plant dry weight (g)
1.	Azotobacter *chroococcum* (10 g/kg) + Zinc (15 kg/ha)	203.50	105.23
2.	Azotobacter *chroococcum* (10 g/kg) + Zinc (20 kg/ha)	204.47	106.06
3.	Azotobacter *chroococcum* (10 g/kg) + Zinc (25 kg/ha)	204.99	107.85
4.	Azotobacter *chroococcum* (15 g/kg) + Zinc (15 kg/ha)	205.19	108.72
5.	Azotobacter *chroococcum* (15 g/kg) + Zinc (20 kg/ha)	206.60	109.67
6.	Azotobacter *chroococcum* (15 g/kg) + Zinc (25 kg/ha)	208.17	110.98
7.	Azotobacter *chroococcum* (20 g/kg) + Zinc (15 kg/ha)	211.72	114.50
8.	Azotobacter *chroococcum* (20 g/kg) + Zinc (20 kg/ha)	212.95	117.17
9.	Azotobacter *chroococcum* (20 g/kg) + Zinc (25 kg/ha)	214.23	120.23
10.	Control N:P:K (80:40:40 kg/ha)	202.08	103.54
	F-test	**S**	**S**
	SEm±	**2.61**	**3.36**
	CD (p=0.05)	**7.78**	**9.98**

Table 2. Influence of biofertilizer and zinc on yield attributes and yield of Sorghum

S. No.	Treatment	Length of ear head (cm)	Yield attribute and yield			
			Seed yield (kg/ha)	Straw yield (kg/ha)	Harvest index (%)	Test weight (g)
1.	Azotobacter *chroococcum* (10 g/kg) + Zinc (15 kg/ha)	20.44	3158.30	6256.28	33.50	29.22
2.	Azotobacter *chroococcum* (10 g/kg) + Zinc (20 kg/ha)	21.73	3382.06	6322.68	34.84	29.42
3.	Azotobacter *chroococcum* (10 g/kg) + Zinc (25 kg/ha)	22.63	3511.43	6337.42	35.64	29.79
4.	Azotobacter *chroococcum* (15 g/kg) + Zinc (15 kg/ha)	23.55	3717.97	6404.64	36.73	29.95
5.	Azotobacter *chroococcum* (15 g/kg) + Zinc (20 kg/ha)	23.22	3837.42	6556.73	36.95	30.24
6.	Azotobacter *chroococcum* (15 g/kg) + Zinc (25 kg/ha)	23.71	3904.64	6563.27	37.48	31.28
7.	Azotobacter *chroococcum* (20 g/kg) + Zinc (15 kg/ha)	24.82	4076.33	6609.77	38.15	31.75
8.	Azotobacter *chroococcum* (20 g/kg) + Zinc (20 kg/ha)	24.89	4274.66	6774.66	38.68	32.32
9.	Azotobacter *chroococcum* (20 g/kg) + Zinc (25 kg/ha)	25.44	4310.02	6810.02	38.75	32.84
10.	Control N:P:K (80:40:40 kg/ha)	20.16	2962.77	5340.71	35.46	28.05
	F-test	**S**	**S**	**S**	**S**	**NS**
	SEm±	**1.16**	**140.88**	**186.05**	**1.07**	**0.93**
	CD (p=0.05)	**3.46**	**418.60**	**552.78**	**3.19**	**-**

Table 3. Influence of biofertilizer and zinc on Economics of Sorghum

S. No.	Treatment	Economics			
		Cost of cultivation (INR/ha)	Gross return (INR/ha)	Net return (INR/ha)	B:C ratio
1.	Azotobacter *chroococcum* (10 g/kg) + Zinc (15 kg/ha)	26416.20	64356.94	37940.74	1.43
2.	Azotobacter *chroococcum* (10 g/kg) + Zinc (20 kg/ha)	27249.60	68464.30	41214.70	1.51
3.	Azotobacter *chroococcum* (10 g/kg) + Zinc (25 kg/ha)	28083.00	70810.59	42727.59	1.52
4.	Azotobacter *chroococcum* (15 g/kg) + Zinc (15 kg/ha)	26461.20	74609.09	48147.89	1.81
5.	Azotobacter *chroococcum* (15 g/kg) + Zinc (20 kg/ha)	27294.60	76941.70	49647.10	1.82
6.	Azotobacter *chroococcum* (15 g/kg) + Zinc (25 kg/ha)	28128.00	78159.45	50031.45	1.77
7.	Azotobacter *chroococcum* (20 g/kg) + Zinc (15 kg/ha)	26506.20	81305.72	54799.52	2.06
8.	Azotobacter *chroococcum* (20 g/kg) + Zinc (20 kg/ha)	27339.60	85073.47	57733.87	2.11
9.	Azotobacter *chroococcum* (20 g/kg) + Zinc (25 kg/ha)	27450.00	85752.38	58302.38	2.12
10.	Control N:P:K (80:40:40 kg/ha)	24626.60	59738.77	35112.17	1.42

microbial balance in the rhizosphere and producing metaboliter that stimulates plant development Raghuwanshi et al., 1997 [19]. Further increase length of the ear head with the application of zinc (25kg/ha) might be due to Significant increase in number of ear head was due to that external application of Zn resulted in improved Zn concentration in different plant parts there was significant increase in number of ear head. Similar result was reported by Ramegowda et al. 2016 [20].

3.2.2 Seed yield (kg/ha)

Significant and higher seed yield (4310.02 kg/ha) [Table 2] was observed in treatment 9 [Azotobacter *chroococcum* (20g/kg) + Zinc(25kg/ha)], which was significant superior over rest of the treatments. However, treatment 8 [Azotobacter *chroococcum* (20g/kg) + Zinc (20kg/ha)], treatment 7 [Azotobacter *chroococcum* (20g/kg) + Zinc (15kg/ha)], treatment 6 [Azotobacter *chroococcum* (15g/kg) + Zinc (25kg/ha)], was found to be statistically at par with treatment 9 [Azotobacter *chroococcum* (20g/kg) + Zinc (25kg/ha)]. Significant and higher seed yield obtained with the application of zinc (25kg/ha) might be due to zinc improves the source and sink relationship due to increased translocation of photosynthates towards reproductive system Sammuauria et al., 2010. [21]. Further increase seed yield with the application of Azotobacter *chroococcum* might be due to also reported that the use of biofertilizers leads to higher availability of nitrogen and phosphorus that promoted growth and development and ultimately resulting in higher yields. Similar result was reported by Bhagchand et al. 2000. [22].

3.2.3 Straw yield (kg/ha)

Significant and higher straw yield (6810.02 kg/ha) [Table 2] was observed in treatment 9 [Azotobacter *chroococcum* (20g/kg) + Zinc(25kg/ha)], which was significant superior over rest of the treatments. However, treatment 8 [Azotobacter *chroococcum* (20g/kg) + Zinc (20kg/ha)], treatment 7 [Azotobacter *chroococcum* (20g/kg) + Zinc (15kg/ha)], treatment 6 [Azotobacter *chroococcum* (15g/kg) + Zinc (25kg/ha)], was found to be statistically at par with treatment 9 [Azotobacter *chroococcum* (20g/kg) + Zinc (25kg/ha)]. Significant and higher Stover yield was obtained with the application of Zinc (25kg/ha) might be due to the Zinc 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 Khan et al., 2010. [23] Further maximum higher straw yield was observed by application Azotobactor (20g/kg) Significant Increased in straw yield was due to application of biofertilizer that helps in increasing grain and fodder yield of Sorghum. Similar results were reported by Patel et al. 2017. [24].

3.2.4 Test weight (g)

The highest test weight (32.84 g) [Table 2] was observed in treatment 9 [Azotobacter *chroococcum* (20g/kg) + Zinc (25kg/ha)], though it was found non-significant.

3.2.5 Harvest index (%)

Significant and higher harvest index (38.75%) [Table 2] was observed in treatment 9 [Azotobacter *chroococcum* (20 g/kg) + Zinc (25 kg/ha)], which was significant superior over rest of the treatments. However, treatment 8 [Azotobacter *chroococcum* (20g/kg) + Zinc (20kg/ha)], treatment 7 [Azotobacter *chroococcum* (20g/kg) + Zinc (15kg/ha)], treatment 6 [Azotobacter *chroococcum* (15g/kg) + Zinc (25kg/ha)], was found to be statistically at par with treatment 9 [Azotobacter *chroococcum* (20g/kg) + Zinc (25kg/ha)]. Significant and higher harvest index obtained with the application of Zinc (25kg/ha) might be due zinc improved photosynthates favourably leading to greater translocation of these towards sink that resulted in significant increase in yield parameters. Such positive effects also led to significant improvement in the harvest index which ultimately enhanced economic proportion in the total accumulated biomass. Similar results were reported by Sammauria et al., 2008. [25].

4. ECONOMICS

The result showed that [Table 3] the maximum gross return (85752.38 INR/ha), net return (58302.38 INR/ha) and B:C ratio (2:12) was recorded in treatment 9 [Azotobacter *chroococcum* (20 g/kg) + Zinc (25 kg/ha)] as compared to other treatment. Higher Gross return, Net return and Benefit cost ratio was recorded with application of Azotobacter *chroococcum* (20g/kg) might be due to better grain yield and Straw yield are essential in realizing the higher yield and reducing cost of cultivation bio fertilizers not only increase growth but helps in supplying the plant requirements and maintaining soil health. These results are in conformity with those observed by Pullicionoa et al., 2009. [26].

5. CONCLUSION

Based on the above findings it is concluded that with the application of Azotobacter *chroococcum* (20g/kg) along with Zinc (25kg/ha) performs positively and improves the growth parameters, yield attributes and economics of Sorghum. Since the findings are based on one season, further trails may be required for further confirmation.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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