Original Research Article

"Effect of Bio fertilizer and zinc on growth and yield of Sorghum (*Sorghum bicolor* L.)"

ABSTRACT

A field experiment was conducted at crop research farm during kharif 2022 Department of Agronomy, SHUATS, Prayagraj (UP.) to study the "Effect of Bio fertilizer and zinc on growth and yield of Sorghum". The experiment consisting of 10 treatment which was replicated thrice and where laid out in Randomized Block Design. The results showed that Treatment 9 Azotobacter *chroococcum* (20 g/kg seed) and Zinc (25 kg/ha), found more productive as it attained the superior values of growth parameters and yield attributing traits *i.e*., plant height (214.23 cm), dry weight (120.23 g), length of ear head (25.44 cm), seed yield (4310.02 kg/ha), straw yield (6810.02 kg/ha) and harvest index (38.68 %) proved significantly superior over other treatment of different levels of Azotobacter *chroococcum* and Zinc and that treatment also fetched the maximum values of gross return (85752.38 INR/ha), net return (58302.38 INR/ha) and also found more remunerative dur to highest benefit cost ratio (2.12).

Keywords: Sorghum, Azotobacter *chroococcum*, Zinc, growth parameters, yield and economics.

INTRODUCTION:

Sorghum commonly known as the "king of millets', is a highly productive crop plant, which can be used for grains, livestock feed or industrial purposes. Sorghum is a cereal crop ranked the world's fifth most important cereal grain after wheat, maize, rice and barley. The most important food and fodder crop in dryland agriculture is sorghum. It is one of the few resilient crops that can respond well to the effects of climate change, especially drought, salinity in the soil, and high temperatures. Due to its short lifespan, rapid growth, and high biomass production, the crop is particularly significant in arid and semi-arid regions where grain is the main source of nutrition for the underprivileged and rural population. Sorghum and their products have high nutritional value and showed antioxidant, anti-obesity, antidiabetic, anti-cardiovascular, anti-inflammatory, antimicrobial, and anticancer activities.

Sorghum is also heat and drought resilient. Food, feed, and forage are all made from sorghum. It contains (10-12%) protein, (70%) carbohydrate, (3%) fats, 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 61m.t, while in India it occupies an area of about 12.8 m ha with a total production of about 12.5 m.t. 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).**

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 about 11.4 million metric tons of sorghum. In india production of sorghum in India is about 8.71 million tonnes. In Tamil Nadu it is cultivated in an area of 4.01 lakh hectare with a productivity of 612 kg/ha. 2021-22 Sorghum production amounts to about 4.6 lakh tonnes.

According to **Durgude *et al.,* (2019)** the soil application of nutrients farmers do not apply any fertilizer leading to deficiency of nutrients in soil and further resulted in lower yield with low nutritional quality of grain and fodder. Micronutrient (Zn and fe) helped to increase in leaf area, chlorophyll content in leaves, uptake of total Fe, Zn, availability of Zn, Fe in soil, agronomic efficiency, grain and stover yield of rabi sorghum under Vertic Inceptisol.

According to **Doifode *et al*., (2021)** The use of N-fertilizer not only spoils the groundwater, soil but also have deleterious effects by the emission of harmful gases. The chemical fertilizers should be replaced with natural and organic fertilizers which can play a key role in the conservation of the environment and they improve the proper application of biofertilizers can reduce the RDF dose of NPK up to a considerable extent thereby the cost of production and minimize soil stress but cannot replace the instant yield benefits due to chemical fertilizers. Integrated and judicious use of inorganic and organic sources of fertilizers is essential in modern agriculture.

Biofertilizers play a vital role in persuading the insoluble phosphatic compound such as rock phosphate, bone meal, basic slag and particularly the chemically fixed soil phosphorus into available form, PSB encourages early root development, produce organic acids like malic, succinic, fumaric, citric, tartaric and alpha ketoglutaric acid which hastens the maturity and thereby increases the ratio of grain to straw as well as the total yield, helps in rapid cell development in plants and consequently enhance diseases resistance towards pathogens, increase micro nutrient content in soil like (Mn, Mg, Fe, Mo, B, Zn,) and make them available to the plant parts stimulates formation of fats, convertible starches and healthy seeds. Inoculants of phosphate solubilizing bacteria as fertilizer increases P uptake by the plant and enhance crop yield. Among the several bio-agents, Azospirillum alone and in combination with PSB increases the yield of Sorghum **Rani *et al.*, (2019)**.

MATERIALS AND METHODS:

The field experiment was conducted during *kharif* 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 8), low level organic carbon (0.62%), medium available N (225 Kg/ha), high in available P (38.2 kg/ha) and low available K (240.7 kg/ha). The treatment consists of 3 levels of Azotobacter *chroococcum viz.* Azotobacter *chroococcum* (10 g/kg), Azotobacter *chroococcum* (15 g/kg) and Azotobacter *chroococcum* (20 g/kg) with combination of different levels of Zinc *viz.* Z (15 kg/ha), Z (20 kg/ha) and Z(20 kg/ha). The experiment was laid out in RBD with 10 treatments each replicated thrice. The treatment combinations are T_1 Azotobacter *chroococcum* (10 g/kg) + Zinc (15 kg/ha). T_2 Azotobacter *chroococcum* (10 g/kg) + Zinc (20 kg/ha), T_3 Azotobacter *chroococcum* (10 g/kg) + Zinc (25 kg/ha), T_4 Azotobacter *chroococcum* (15 g/kg) + Zinc (15 kg/ha), T_5 Azotobacter *chroococcum* (15 g/kg) + Zinc (20 kg/ha), T_6 Azotobacter *chroococcum* (15 g/kg) + Zinc (25 kg/ha), T_7 Azotobacter *chroococcum* (20 g/kg) + Zinc (15 kg/ha), T_8 Azotobacter *chroococcum* (20 g/kg) + Zinc (20 kg/ha), T_9 Azotobacter *chroococcum* (20 g/kg) + Zinc (25 kg/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.

RESULT AND DISSCUSSION:

Growth parameters

Plant height (cm)

Data revealed that significant and higher plant height (214.23 cm) 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 (20 kg/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 **(Ganapathy and Savalgi 2006).**

Dry Weight (g)

The results found that dry weight was recorded significantly higher (120.23g) was recorded in treatment 9 [Azotobacter *chroococcum* (20g/kg seed) + Zinc (25kg/ha)]. However, treatment 8 [Azotobacter *chroococcum* (20g/kg seed) + Zinc (20kg/ha)], treatment 7 [Azotobacter *chroococcum* (20g/kg seed) + Zinc (15kg/ha)], treatment 6 [Azotobacter *chroococcum* (15g/kg seed) + Zinc (25kg/ha)] were found to be statistically at par with treatment 9 [Azotobacter *chroococcum* (20g/kg seed) + 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 and Kumawat 2017)** in pearl millet. 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 **Singh *et al*. (2016).**

Crop growth rate (g/m^2 /day)

The data revealed that during 75-100 DAS, there was no significant difference among the treatments, However, highest crop growth rate (8.018 g/m2 /day) was recorded with the treatment 10 [Control Plot N:P: K (80:40:40kg/ha)].

Relative growth rate (RGR) (g/g/day)

The data recorded that during 75-100 DAS, there was no significant difference among the treatments, However, highest crop growth rate (0.0058 g/g/day) was recorded with the treatment 10 [Control Plot N:P: K (80:40:40kg/ha)].

Yield parameters:

Length of ear head (cm)

Data revealed that significant and highest length of the ear head (25.44 cm) was recorded in treatment 9 [Azotobacter *chroococcum* (20g/kg seed) + Zinc(25kg/ha)], which was significantly superior over rest of the treatment. However, treatment 8 [Azotobacter *chroococcum* (20g/kg seed) + Zinc (20kg/ha)], treatment 7 [Azotobacter *chroococcum* (20g/kg seed) + Zinc (15kg/ha)], treatment 6 [Azotobacter *chroococcum* (15g/kg seed) + Zinc (25kg/ha)], was found to be statistically at par with treatment 9 [Azotobacter *chroococcum* (20g/kg seed) + 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 microbial balance in the rhizosphere and producing metaboliter that stimulates plant development. **(Raghuwanshi *et al*., 1997)**. 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 in particular there was significant increase in number of ear head**. Ramegowda *et al*. (2016).**

Grain yield (kg/ha)

The data showed that significant and higher grain yield (4310.02 kg/ha) was observed in treatment 9 [Azotobacter *chroococcum* (20g/kg seed) + Zinc(25kg/ha)], which was significant superior over rest of the treatments. However, treatment 8 [Azotobacter *chroococcum* (20g/kg seed) + Zinc (20kg/ha)], treatment 7 [Azotobacter *chroococcum* (20g/kg seed) + Zinc (15kg/ha)], treatment 6 [Azotobacter *chroococcum* (15g/kg seed) + Zinc (25kg/ha)], was found to be statistically at par with treatment 9 [Azotobacter *chroococcum* (20g/kg seed) + Zinc(25kg/ha)].

Significant and maximum grain yield obtained with the application of zinc (25 kg/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)**. Further increase grain yield with the application of Azotobacter *chroococcum* might be due to also reported that the use of bio-fertilizers lead to higher availability of nitrogen and phosphorus that promoted growth and development and ultimately resulting in higher yields **Bhagchand *et al*, (2000)**.

Straw yield (kg/ha)

The data revealed that significant and higher stover yield (6810.02 kg/ha) was observed in treatment 9 [Azotobacter *chroococcum* (20g/kg seed) + Zinc(25kg/ha)], which was significant superior over rest of the treatments. However, treatment 8 [Azotobacter *chroococcum* (20g/kg seed) + Zinc (20kg/ha)], treatment 7 [Azotobacter *chroococcum* (20g/kg seed) + Zinc (15kg/ha)], treatment 6 [Azotobacter *chroococcum* (15g/kg seed) + Zinc (25kg/ha)], was found to be statistically at par with treatment 9 [Azotobacter *chroococcum* (20g/kg seed) + 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)**. 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).**

Test weight (g)

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

Harvest index (%)

The data showed that significant and higher harvest index (38.75%) was observed in treatment 9 [Azotobacter *chroococcum* (20 g/kg seed) + Zinc (25 kg/ha)], which was significant superior over rest of the treatments. However, treatment 8 [Azotobacter *chroococcum* (20g/kg seed) + Zinc (20kg/ha)], treatment 7 [Azotobacter *chroococcum* (20g/kg seed) + Zinc (15kg/ha)], treatment 6 [Azotobacter *chroococcum* (15g/kg seed) + Zinc (25kg/ha)], was found to be statistically at par with treatment 9 [Azotobacter *chroococcum* (20g/kg seed) + 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 **Sammuauria *et al,* 2010).**

Economics:

The result showed that Maximum gross return (INR 85752.38/ha), net return (INR 58302.38/ha) and B:C ratio (2.12) were 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* (20 g/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).**

CONCLUSION:

Based on the above findings. It can be concluded that in Sorghum with the application of Azotobacter c*hroococcum* 20 g/kg along with the application of Zinc 25 kg/ha (Treatment 9) was observed highest seed yield and benefit cost ratio.

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Table 1. Effect of bio-fertilizer and zinc on growth attributes of Sorghum.

S. No.	Treatment combination	At 100 DAS		At 75-100 DAS	
		Plant height (cm)	Dry weight (g)	CGR ($g/m^2/day$)	RGR (g/g/day)
1.	Azotobacter *chroococcum* (10 g/kg) + Zinc (15 kg/ha)	203.50	105.23	7.727	0.0054
2.	Azotobacter *chroococcum* (10 g/kg) + Zinc (20 kg/ha)	204.47	106.06	5.279	0.0035
3.	Azotobacter *chroococcum* (10 g/kg) + Zinc (25 kg/ha)	204.99	107.85	6.059	0.0040
4.	Azotobacter *chroococcum* (15 g/kg) + Zinc (15 kg/ha)	205.19	108.72	6.095	0.0040
5.	Azotobacter *chroococcum* (15 g/kg) + Zinc (20 kg/ha)	206.60	109.67	6.242	0.0041
6.	Azotobacter *chroococcum* (15 g/kg) + Zinc (25 kg/ha)	208.17	110.98	5.582	0.0036
7.	Azotobacter *chroococcum* (20 g/kg) + Zinc (15 kg/ha)	211.72	114.50	6.879	0.0044
8.	Azotobacter *chroococcum* (20 g/kg) + Zinc (20 kg/ha)	212.95	117.17	7.236	0.0044
9.	Azotobacter *chroococcum* (20 g/kg) + Zinc (25 kg/ha)	214.23	120.23	7.691	0.0047
10.	(Control) N:P: K 80:40:40 kg/ha	202.08	103.54	8.018	0.0058
	F-test	S	S	NS	NS
	SEm (±)	2.61	3.360	2.194	0.0015
	CD (p=0.05)	7.78	9.98	-	-

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

Table 2. Effect of bio-fertilizer and zinc on yield attributes of Sorghum.

S. No.	Treatment combination	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

Table 3. Effect of bio-fertilizer and zinc on Economics of Sorghum.