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Influence of bio-fertilizers and zinc levels on growth and yield of finger millet (*Eleusine coracana* L.)

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Abstract
A field experiment was conducted during *Kharif* 2021 at Crop Research Farm, Department of Agronomy, SHUATS, Prayagraj, (U.P.). The treatments consist with foliar application of Zinc sulphate *viz.*, 0.2%, 0.4% and 0.6% and seed inoculation of azospirillum 20g/kg, azotobacter 20g/kg, azospirillum+ azotobacter 20g/kg whose effect is observed in finger millet (GPU-28). The experiment was laid out in Randomized Block Design with ten treatments replicated thrice. The result revealed that significant and higher plant height (80.78cm), maximum number of tillers/hill (7.76), higher plant dry weight (22.61g), maximum number of fingers/earhead (7.30), higher grain yield (2.83 t/ha) and higher straw yield (4.84 t/ha) was observed in the Treatment 9[(T_9-Azospirillum +Azotobactor (20g/kg) +Zinc sulphate (0.6%)]. Maximum gross returns (99283.00 INR/ha), net returns (68301.00 INR/ha) and B:C (2.20) was also recorded highest in the Treatment 9 [(Azospirillum + Azotobacter (20g/kg)+ZnSO4 (0.6%)] respectively.

Keywords: Finger millet, azotobacter, azospirillum, zinc, yield and economics

Introduction
Finger millet [*Eleusine coracana* L.] commonly known as ragi, the generic name Eleusine derived from greek goddess of cereals. Finger millet with regard to protein (6-8%) and fat (1-2%) it is comparable to rice and with respect to mineral and micronutrient contents it is superior to rice and wheat. Nutritionally; it has high content of calcium (344 mg/100g), dietary fiber (15-20%) and phenolic compounds (0.3-3%) (Amir *et al.* 2014) [1].

According to FAO, the world production of millets is 90.35 million metric tonnes from an area of 75.70 million ha (FAO Statistics, 2020). Out of the total In India, finger millet is cultivated over an area of 100.46 hectares with a production of 1755.06 million tonnes giving an average productivity of 1747.27 kg/ha (Ministry of Agriculture-DMD 2020). In Uttar Pradesh in India finger millet is cultivated over an area of 0.6 thousand ha with an production of 0.8 thousand tones and productivity 1333 kg/ha. (Ministry of Agriculture-DMD 2020).

Biofertilizer are essential in realizing the higher yield and reducing cost of production was reported by (Shekhawat *et al.* 2015). Bacteria include species of Azotobacter and *Azospirillum*, both of which provide direct and indirect effects on plant growth and pest resistance more numbers of different bacteria promote plant growth, including Azotobacter spp., *Azospirillum* spp., (Turan *et al.* 2006).

Foliar spray of Zinc plays a significant role in various enzymatic and physiological activities in plant system. Zinc plays important role in nitrogen metabolism and results in improving quality, it plays a major role in protein synthesis and photosynthesis (Cakmak, 2008). Foliar spraying of micronutrient is very helpful when the roots cannot provide necessary nutrient. Moreover, soil pollution would be a major problem by soil application of micronutrients as people are concerned about the environment and uptake of nutrients through plant leaves is better than soil application, foliar spraying was advised (Bozorgi *et al.* 2011).

One of the major limiting factors for production and productivity of finger millet crop is blast disease caused by *Magnaporthe grisea* (anamorph *Pyricularia grisea*). This disease has been identified as the highest priority constraint to finger millet production in Eastern Africa, and India since most of the genotypes are highly susceptible. The causal organism of blast disease *Magnaporthe grisea* is also a causative agent of rice blast. The average loss due to blast disease has been reported to be around 28-36% and in certain areas yield losses could be as high as 80-90%. The disease affects the crop at all growth stages however, neck blast and finger blast are the most destructive forms of disease. Biofertilizers like Azotobacter and Azospirillum help to give disease resistant seedlings when inoculated with seeds and zinc foliar spray helps to less attack of disease.

Materials and Methods

The experiment was conducted during *Kharif* season of 2020-2021. The experiment was conducted in Randomized Block Design consisting of nine treatment combinations with three replications and was laid out with the different treatments allocated randomly in each replication. The soil of the experimental field was sandy loam in texture, slightly alkaline reaction (pH 7.7) with low level of organic carbon (0.39%), available N (79.39 Kg/ha), P (19.30 kg/ha) and higher level of K (210.06 kg/ha). The treatment combinations are [(T1-Azospirillum (20g/kg) + Zinc sulphate (0.2%)] [(T_2-Azospirillum (20g/kg) + Zinc sulphate (0.4%)] T_3-Azospirillum (20g/kg) + Zinc sulphate (0.6%)] [(T_4-Azotobacter (20g/kg) + Zinc sulphate (0.2%)] [(T_5-Azotobacter (20g/kg) + Zinc sulphate (0.4%)] [(T_6-Azotobacter (20g/kg) + Zinc sulphate (0.6%)] [(T7-Azospirillum + Azotobactor (20g/kg) + Zinc sulphate (0.2%)] [(T_8-Azospirillum +Azotobactor (20g/kg) + Zinc sulphate (0.4%)] [(T_9-Azospirillum + Azotobactor (20g/kg) + Zinc sulphate (0.6%)] [(T_{10}-Control through RDF (60:30:30:: N:P:K)]. Variety: GPU-28. Sowing was carried out by line sowing with spacing of 22.5x8 cm^2. The seeds were covered immediately after sowing. Recommended dose of fertilizer i.e. 60: 30: 30 kg. N, P_2O_5 and K_2O per hectare were applied in splits as basal and N and P_2O_5 per hectare. Five plants from each net plot were randomly selected and labelled for taking biometric observations at every 15 days interval commencing from 15 days onwards after sowing. The same five plants were harvested separately for post-harvest studies. Plant height (cm), Root Nodules $plant^{-1}$, Plant dry weight (g/plant), Crop growth rate (g/m^2/day), Relative growth rate (g/g/day) Final plant count, Post-harvest studies is Number of Fingers/ear head, Pod yield (t/ha), Haulm yield (t/ha), Test weight (g), Harvest index(%).The data recorded on growth and yield parameters were tabulated and subjected to statistical analysis as per Gomez and Gomez, 1976.

Seed and soil inoculation

Seed and soil inoculation technique was used. 10% sugar solution was boiled and, then, cooled. This slurry was uniformly applied to the seed. Then the seed was coated with the powder of Azospirillum, Azotobacter and sown. For soil inoculation, Azospirillum Azotobacter powder was directly placed into the soil above which the Finger millet seeds were sown.

Results and Discussion

Growth parameters

Plant height

The data revealed that significant and higher plant height (80.78) of finger millet was observed in treatment 9 [(Azospirillum + Azotobactor (20 g/kg) + Zinc sulphate (0.6%)]. However, T_8 [(Azospirillum + Azotobactor (20g/kg) + Zinc sulphate (0.4%)] which was found to be statistically at par with treatment 9 (Table 1). Significant increased in plant height was with the application of Zinc sulphate (0.6%) may be due to Zinc probably activated the activity of carbonic anhydrase enzyme in leaves which had important role in cell elongation and cell division this led to increase in stem height. These results were in support with Malik *et al*., (2011). Further biofertilizers, Azospirillum, Azotobactor (20g/kg) might increased availability of nutrients in the soil through mineralization of organic sources could have triggered cell elongation and multiplication resulting in high growth rate of shoots in turn plant height of finger millet. Similar results were obtained by Sunitha *et al*., (2004) [19].

Number of Tillers/hill

The data recorded that significant and maximum number of tillers/ hill (7.76) of finger-millet was recorded in treatment 9 [(Azospirillum +Azotobactor (20g/kg) +Zinc sulphate (0.6%)] However, T_8 [(Azospirillum + Azotobactor (20g/kg) + Zinc sulphate 0.4%)] which was found to be statistically at par with treatment 9 [(Azospirillum + Azotobactor (20g/kg) + Zinc sulphate (0.6%)] (Table 1). Significantly increased in number of tillers was with the application Zinc sulphate (0.6%) may be due to increase in the uptake and availability of other essential nutrients which resulted in improvement of plant metabolic activities and crop growth finally increase in number of tillers. Similar results were found by Mustafa *et al*., (2011). Further biofertilizers Azospirillum, Azotobactor (20g/kg) seeds inoculated with nitrogen fixing bacteria like azotobacter, azospirillum increased number of tillers similar findings was reported by Saxena *et al*., (1997).

Plant dry weight(g)

The data recorded that significant and highest dry weight (22.61 g) of finger millet was found in treatment 9 [(Azospirillum + Azotobactor (20g/kg) + Zinc sulphate (0.6%)] However, T_8 [(Azospirillum + Azotobactor (20g/kg) + Zinc sulphate (0.4%)] which was observed statistically at par with treatment 9 [(Azospirillum + Azotobactor (20g/kg) + Zinc sulphate (0.6%)] (Table 1). Significant increased in dry weight was with the application of Azospirillum, Azotobactor (20g/kg) Zinc sulphate (0.6%) may be due to external zinc application has significantly increased dry weight shoot and grain this is due to zinc also interfered with translocation of Fe from roots to above ground parts. Similar results were found by Ambler *et al*. (1970). Further biofertilizers Azospirillum, Azotobactor (20g/kg) By inoculating nitrogen-fixing microorganisms Azotobacter, Azospirillum significantly improves the plant height, dry weight of finger millet. these results were in conformity with the findings of Swami *et al*. (2020).

Table 1: Effect of bio-fertilizers and zinc levels on growth parameters of finger millet

	At harvest		
Treatments	**Plant height (cm)**	**Number of tiller per plant**	**Dry weight (g)**
T1: Azospirillum (20g/kg) + Zinc sulphate (0.2%)	75.29	6.53	19.91
T2: Azospirillum (Seed inoculation @20g/kg) + Zinc sulphate 0.4% foliar spray	76.22	6.73	20.90
T3: Azospirillum (Seed inoculation @20g/kg) +Zinc sulphate 0.6% foliar spray	76.96	6.85	21.13
T4: Azotobactor (Seed inoculation @20g/kg) +Zinc sulphate 0.2% foliar spray	77.60	6.94	21.81
T5: Azotobactor (Seed inoculation @20g/kg) +Zinc sulphate 0.4%foliar spray	78.13	7.11	21.91
T6: Azotobactor (Seed inoculation @20g/kg) +Zinc sulphate 0.6%foliar spray	78.54	7.28	22.01
T7: Azospirillum + Azotobactor (Seed inoculation @20gm/kg) +Zinc sulphate	79.00	7.38	22.30

0.2% foliar spray			
T8: Azospirillum + Azotobactor (Seed inoculation @20g/kg) +Zinc sulphate 0.4% foliar spray	80.03	7.65	22.42
T9: Azospirillum + Azotobactor (Seed inoculation @20g/kg) +Zinc sulphate 0.6% foliar spray	80.78	7.76	22.61
T10: Control through RDF (60:30:30::NPK)	74.58	6.23	18.48
F Test	S	S	S
SEm(±)	0.11	0.04	0.18
CD (p=0.05)	0.32	0.13	053

Yield parameters

Numbers of fingers/earhead

The data revealed that significant was maximum Number of fingers/earhead of (7.76) was found in treatment 9 with the application of [(Azospirillum + Azotobactor (20g/kg) + Zinc sulphate (0.6%)]. However, treatment 8 [(Azospirillum + Azotobactor (20g/kg) + Zinc sulphate (0.4%)] recorded statistically at par with treatment 9 [(Azospirillum + Azotobactor (20g/kg) + Zinc sulphate (0.6%)] (Table 2). Zinc sulphate (0.6%) Significant increase in number of fingers/earhead 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 fingers/earhead similarly results also reported by Ramegowda *et al*. (2016) [17]. Further biofertilizers, Azospirillum, Azotobactor (20g/kg) Seed inoculation with Azotobacter, Azospirillum significantly increased effective number of fingers per earhead, ear head length, test weight This could mainly be ascribed to the increased availability of the nitrogen to the plants through biological nitrogen fixation in rhizosphere by biofertilizers. Thus, the greater availability of nitrogen might have helped in better root proliferation and vigorous plant growth, resulting in ear head development. These results were in conformity with the findings of Sushila and Giri *et al.* (2000) [23].

Grain yield(t/ha)

The data revealed that significant and higher seed yield (2.83t/ha) was found in treatment 9 with the application of [(Azospirillum + Azotobactor (20g/kg) + Zinc sulphate (0.6%)]. However, treatment 8 [(Azospirillum + Azotobactor (20g/kg) + Zinc sulphate (0.4%)] recorded statistically at par with treatment 9 [Azospirillum + Azotobactor (20g/kg) + Zinc sulphate (0.6%)] (Table 2). Zinc sulphate (0.6%) Foliar application of Zinc increased grain yield. The increase in the grain yield was attributable to the improved physiology of plants with the added Zn which consequently corrected the efficiency of different enzymes, chlorophyll content, IAA hormone and improved grain yield. these results were in conformity with the findings of Moghadam *et al.* (2012). Further biofertilizers Azospirillum, Azotobactor (20g/kg) increases yield by 0-30 percent and reduces the amount of chemical fertilizer required millet by 50 percent without reducing yield. By inoculating biofertilizers grain and stover yield increases in finger millet. Similar results also reported by Swami *et al*. (2020).

Straw yield(t/ha)

The data revealed that significant and maximum straw yield (4.84 t/ha) was found in treatment 9 with the application of [(Azospirillum + Azotobactor (20g/kg) + Zinc sulphate (0.6%)]. However, treatment 8 [(Azospirillum + Azotobactor (20g/kg) +Zinc sulphate (0.4%)] recorded statistically at par with treatment 9 [(Azospirillum + Azotobactor (20g/kg) + Zinc sulphate (0.6%)] (Table 2). Azospirillum, Azotobactor (20g/kg) Significant increased in straw yield was due to application of biofertilizer that helps in increasing grain and fodder yield of finger millet these findings were in support with Patel *et al*. (2017). and Zinc sulphate (0.6%) Foliar Application of zinc had positive effect on growth and yield of Finger millet Yadavi *et al.* (2014). Response of crop to Zn application may be due to deficiency of nutrients in soil which was improved by Zn application these results were also in support with Tabrizi *et al*. (2009).

Table 2: Effect of bio-fertilizers and zinc levels on yield attributes and yield of finger millet

Treatments	No of fingers	Test weight (gm)	Seed yield (t/ha)	Straw yield (t/ha)	Harvest Index (%)
T1: Azospirillum (Seed inoculation @20g/kg) + Zinc sulphate 0.2% foliar spray	5.98	3.39	2.27	4.30	34.62
T2: Azospirillum (Seed inoculation @20g/kg) + Zinc sulphate 0.4% foliar spray	6.48	3.44	2.36	4.38	35.00
T3: Azospirillum (Seed inoculation @20g/kg) + Zinc sulphate 0.6% foliar spray	6.53	3.51	2.44	4.44	35.48
T4: Azotobactor (Seed inoculation @20g/kg) + Zinc sulphate 0.2% foliar spray	6.69	3.57	2.52	4.52	35.81
T5: Azotobactor (Seed inoculation @20g/kg) + Zinc sulphate 0.4%foliar spray	6.75	3.63	2.59	4.59	36.13
T6: Azotobactor (Seed inoculation @20g/kg) + Zinc sulphate 0.6%foliar spray	6.81	3.69	2.65	4.65	36.30
T7: Azospirillum +Azotobactor (Seed inoculation @20gm/kg) +Zinc sulphate 0.2% foliar spray	7.05	3.74	2.72	4.72	36.58
T8: Azospirillum + Azotobactor (Seed inoculation @20g/kg) +Zinc sulphate 0.4% foliar spray	7.19	3.77	2.77	4.79	36.69
T9: Azospirillum + Azotobactor (Seed inoculation @20g/kg) +Zinc sulphate 0.6% foliar spray	7.30	3.81	2.83	4.84	36.93
T10: Control through RDF (60:30:30:: N:P:K)	5.80	3.49	2.25	4.19	34.98
F-Test S.Em (±)	S 0.08	S 0.06	S 33.59	S 25.88	NS 0.43
CD (P=0.05)	0.25	0.17	99.80	76.90	1.28

Harvest index (%)

The data revealed significant and maximum harvest index of 36.93 found to be significantly superior in treatment 9 with the application of [(Azospirillum + Azotobactor (20g/kg) +

Zinc sulphate (0.6%)]. However, Treatment 8 [(Azospirillum + Azotobactor (20g/kg) + Zinc sulphate (0.4%)] was observed to be statically at par with treatment 9 [(Azospirillum + Azotobactor (20g/kg) + Zinc sulphate (0.6%)].

Economics

The data revealed in (Table 3) significant and higher Gross Returns (99,283.00 INR/ha), Net Returns (68,301.00 INR/ha) and B:C Ratio (2.20) was obtained with treatment 9 [(Azospirillum + Azotobactor (20g/kg) + Zinc sulphate (0.6%)] Higher gross returns, net return and benefit cost ratio this may be due to application of bio fertilizers Azospirillum, Azotobactor (20g/kg) 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 findings are in support with Pullicionoa *et al.* (2009). Further foliar application of Zinc sulphate (0.6%). Might be attributed to the lower cost of cultivation, highest seed yield that influenced the economics. similar findings also reported by Arjun Sharma *et al.* (2007) [2].

Table 3: Effect of bio-fertilizers and zinc levels on economics of finger millet

Treatments	Cost of cultivation	Gross returns	Net returns	B:C Ratio
T1: Azospirillum (Seed inoculation @20g/kg) + Zinc sulphate 0.2% foliar spray	30889	79683	48794	1.58
T2: Azospirillum (Seed inoculation @20g/kg) + Zinc sulphate 0.4% foliar spray	30931	82600	51669	1.67
T3: Azospirillum (Seed inoculation @20g/kg) +Zinc sulphate 0.6% foliar spray	30973	85517	54544	1.76
T4: Azotobactor (Seed inoculation @20g/kg) +Zinc sulphate 0.2% foliar spray	30891	88317	57426	1.86
T5: Azotobactor (Seed inoculation @20g/kg) +Zinc sulphate 0.4% foliar spray	30933	90883	59950	1.94
T6: Azotobactor (Seed inoculation @20g/kg) +Zinc sulphate 0.6% foliar spray	30975	92750	61775	1.99
T7: Azospirillum +Azotobactor (Seed inoculation @20gm/kg) +Zinc sulphate 0.2% foliar spray	30898	95433	64535	2.09
T8: Azospirillum + Azotobactor (Seed inoculation @20g/kg) +Zinc sulphate 0.4% foliar spray	30940	97183	66243	2.14
T9: Azospirillum + Azotobactor (Seed inoculation @20g/kg) +Zinc sulphate 0.6% foliar spray	30982	99283	68301	2.20
T10: Control through RDF (60:30:30:: N:P:K)	28740	78983	50243	1.75

Conclusion

It can be concluded that for obtaining maximum yield with the application of Azospirillum, Azotobactor (20g/kg) and Zinc sulphate (0.6%) foliar spray improves growth and yield of Finger millet. The application of biofertilizer along with zinc resulted in achievement of maximum yield, net returns and benefit-cost ratio. These findings are based on one season therefore, further trial may be required for further confirmation.

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