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EFFECT OF SEED INOCULATION WITH BIO-FERTILIZERS AND FOLIAR APPLICATION OF MICRONUTRIENTS ON GROWTH, YIELD AND ECONOMICS OF KODO MILLET (*PASPALUM SCORBICULATUM* L.)

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ABSTRACT

A field experiment was conducted during zaid (Summer) season of 2024-25 at crop research farm, Department of Agronomy, Naini Agricultural Institute, SHUATS, Prayagraj (UP). The experiment was laid out in RBD with 9 treatment replicated thrice ,the treatment consists of *Azotobacter* or *Azospirillum* in combination with foliar application of Iron at 10g,Manganese at 1g, Boron and zinc at 5g per litre water, seed inoculation with *Azospirillum* along with foliar spray of iron 10g/l water recorded Highest plant height (42.55cm), more number of tillers (7.87), Maximum dry weight (6.69g), more number of ears per plant(11.23),more number of seeds per ear (123.67), test weight (3.64g), yield (1667.75kg/ha) and Benefit-cost ratio (2.51).
***Keywords*:** Azospirillum, Azotobacter, Boron, Iron, Manganese and Zinc.

Introduction

Kodo millet or (*Paspalum scrobiculatum)* belongs to the family Poaceae, it is also known as rice grass, ditch millet, cow grass, the origin of kodo millet is known to be tropical Africa, the domestication of kodo millet is believed to be around 3000 years ago. In India the area under cultivation is 1.96lakh hectare and produce 0.84 lakh tonnes and with productivity of 429 kg per hectare. In India, it is widely grown in Madhya Pradesh, Tamil Nadu, Karnataka, Gujarat and Chhattisgarh. Apart from India, it is cultivated in many other countries like Russia, Africa and Japan. kodo millets are packed with the goodness of carbohydrates, proteins, and dietary fibres. the protein content in grain is 8.3%,1.4% fat and it is carbohydrate rich which is 65.6% It also contains other vitamins like niacin and riboflavin and minerals like calcium, iron and phosphorus. (Chandrasekara and Shahidi, 2011). Kodo millet is very useful for postmenopausal females with indications of cardiovascular disease such as high blood pressure and high level of cholesterol. So, research on production of millet based products is emerging area to utilize its beneficial effect considering increasing population in developing countries. The phosphorus content in kodo millet is lower than any other millet and its antioxidant potential is much higher than any other millet and major cereals.

Zinc plays key role in synthesis of pyruvic decarboxylase and indole acetic acid as it is constituent of enzyme which causes or helps in synthesis of pyruvic decarboxylase and plant growth regulator like Indole acetic acid. Zinc act as catalyst for many metabolic processes in plants like it catalyses the process of oxidation in plant cells and is vital for transformation of carbohydrates, indirectly helps in chlorophyll production by increases source of energy to produce chlorophyll, regulates the consumption of sugar, aids in the formation of plant growth regulators like auxin in the form of IAA and promotes absorption of water (Marschner, 2011).

Iron is required in various metabolic processes as catalyst, its catalytic function is biological oxidation-reduction and oxidative photophosphorylation during cell respiration. foliar spray of Fe compound is commonly used as a means of controlling lime induced chlorosis of field crops grown on calcareous soil. Iron helps in synthesis of chlorophyll, and for the maintenance of chloroplast structure and function. (Bouis and Welch, 2010).

Boron is an important element which plays role in Protien synthesis, Increasing yield and the physiological process of plants, the physiological processes are cell elongation, cell maturation, meristematic tissue development. (Chowardy *et al.*, 2019) boron can be applied in soil as well as foliar, foliar application gives more best results than the soil application, also boron plays an important role in plant metabolism (Movali Dr and Donga, 2020).

Manganese (Mn) is an essential micronutrient with many functional roles in plant metabolism. Manganese acts as an activator and co-factor of hundreds of metalloenzymes in plants. Because of its ability to readily change oxidation state in biological systems, Mn plays and important role in a broad range of enzyme-catalyzed reactions, including redox reactions, phosphorylation, decarboxylation, and hydrolysis. (Schmidt and Husted, 2019).

The Azotobacter is a non-symbiotic microbe, contains living organisms which helps mainly in fixing N, it enhances mineral uptake helps in accelerating beneficial activities of other biofertilizers, if used in association of other bio-fertilizers. Currently, several reports of Azotobacter being usedwith other microbes gave more good results, among researchers as well as farmers (Maurya *et al.,* 2012).

Azospirilla are free-living rhizobacteria that are able to promote plant growth and increase yields in many crops of agronomic importance. It is assumed that the bacteria affect plant growth mainly by the production of plant growth promoting substances, which leads to an improvement in root development and an increase in the rate of water and mineral uptake (Dobbelaere and Croonenborghs, 2001).

Materials and Methods

In the summer season of 2024,the experiment was conducted at the crop research farm, Naini Agriculture Institute, Department of Agronomy, Sam Higginbottom University of Agriculture Technology and Sciences (SHUATS), Prayagraj (UP).the crop research farm is situated at 25”39”42”N latitude, 81”67”56”E longitude and 98m altitude above the Mean sea level (MSL).on the right side of river Yamuna, the site is situated All the facilities requires for crop cultivation are available. Experiment conducted using a randomized block design (RBD). It included nine treatment combinations, each replicated three times. Treatments were randomly distributed within each replication to ensure unbiased results. The soil in the experimental field was of sandy loam texture, slightly alkaline in nature (pH 6.8), and characterized by low organic carbon content (0.47%). It contained a relatively high level of available nitrogen (188.8 kg/ha), phosphorus (22.3 kg/ha), and potassium (217.1 kg/ha).

The treatment combinations incorporated either *Azospirillum* or *Azotobacter*, along with micronutrients applied at the following concentrations: iron at 10 g/l, manganese at 1 g/l, and both zinc and boron at 5 g/l of water. T1-*Azotobacter* + Boron at 5g/l, T2-*Azotobacter* + $FeSO_4$ at 10g/l , T3- *Azotobacter* + $ZnSO_4$ at 5g/l,T4- *Azotobacter* + $MnSO_4$ at 1g/l,T5-*Azospirillum* + Boron at 5g/l,T6- *Azospirillum*+ $FeSO_4$ at 10g/l,T7- *Azospirillum* +$ZnSO_4$ at 5g/l,T8-*Azospirillum* + $MnSO_4$ at 1g/l,T9- NPK-40:20:20Kg/ha (Control).

Observations were recorded at harvest, focusing on key growth and yield attributes such as ear length (cm), number of ears per plant, number of effective tillers per plant, number of grains per ear, test weight (g), grain yield (t/ha).

Randomly five plants were selected from each plot and they were tagged. Plant height was measured from the base up to the tip. The height was measured in cm.

For tillers randomly selected and plucked and tillers were counted carefully. those plucked plants were taken for dry weight. For dry weigh 5 plants from plot were uprooted at an interval of 20, 40, 60 & 80 DAS. the uprooted plants were first dried then wrapped with paper and then kept in oven for drying at 70^{o}C for 24-48 hours. The dry weight of samples were recorded, average were done and finally expressed as g/plant. Ears of tagged plants were picked up separately and then counted**.** For the length of ear, tagged plants selected and measured with scale in cm. Seeds per ear,5 plants selected during harvest and seeds are separated from ears and counting the seeds. One thousand grains were randomly counted from capsules obtained from each plot and weighed and recorded as test weight (g) at approximately 14% moisture. Ears which were collected from each plot were beaten and seeds were collected. After that were weighed to calculate the overall seed yield.

The benefit cost ratio was calculated using the following formula:

$$\text{Benefit cost ratio} = \frac{\text{Net return}}{\text{Cpst of cultivation}}$$

Results and Discussion

At 80 days after sowing (DAS), treatment T6 exhibited a significantly greater plant height of 42.55 cm, outperforming all other treatments. However, treatment T2, with a plant height of 38.69 cm, was statistically comparable to T6.

The enhanced height under T6 can be attributed to the role of *Azospirillum* in ensuring a continuous nitrogen supply, while iron contributes to its effective utilization in chlorophyll and protein synthesis, supporting cell elongation. Growth-promoting hormones such as auxins and gibberellins, produced by *Azospirillum*, in synergy with iron, likely stimulated internodal elongation through enhanced cell division and expansion (Surya *et al*., 2022).

Similarly, the highest plant dry weight at 80 DAS (6.69 g) was recorded under treatment T6, which was significantly superior to other treatments. Treatment T2 (6.13 g) was also statistically at par with T6.

The nitrogen-fixing capability of *Azospirillum* enhances nutrient uptake in the root zone, improving vegetative growth and dry matter accumulation. Additionally, iron supplied through ferrous sulfate ($FeSO_4$) supports chlorophyll synthesis and enzyme activation, both crucial for photosynthetic efficiency and biomass production (Divya *et al*., 2021).

Treatment T6 also led to the highest number of tillers per plant (7.87), followed closely by T2 (7.67), which was statistically similar.

The increased tiller number is likely due to *Azospirillum*'s ability to produce auxins that stimulate shoot branching and development, while $FeSO_4$ facilitates energy-intensive processes like tiller initiation by improving iron availability (Grace and Dawson, 2024).

Ear length was also significantly influenced by the treatments, with T6 recording the highest value (9.08 cm), and T2 (8.56 cm) being statistically on par.

Furthermore, the number of ears per spike was maximized in T6 (11.23), while T2 followed closely at 11.08 ears/spike.

The enhanced ear formation can be linked to the combined effect of *Azospirillum* and iron, which together optimize nutrient uptake, promote root development, and support efficient physiological functioning (Surya *et al.,* 2022).

In terms of reproductive performance, treatment T6 produced the highest number of seeds per ear (123.67), with T2 (120.89) again statistically comparable.

Grain development was further supported by the higher test weight observed under T6 (3.64 g), with T2 (3.46 g) showing similar results. Improved root structure and nutrient absorption under $FeSO_4$ treatment contribute to more balanced growth and better seed filling (Reddy *et al*., 2023).

Grain yield was highest in treatment T6 (1667.75 kg/ha), significantly outperforming all others, while T2 recorded 1509.97 kg/ha and was statistically at par with T6.

The improved yield performance can be credited to *Azospirillum*-mediated root and shoot development, increased panicle weight, and overall enhanced biomass. Foliar application of *Azospirillum* and $FeSO_4$ also improved grain quality, with better protein and micronutrient profiles (Grace *et al*., 2023).

Regarding economics, the lowest cost of cultivation was observed in treatment T9 (Rs. 50,800). Nevertheless, treatment T6 resulted in the highest gross return (Rs. 183,453/ha), net return (Rs. 131,589/ha), and benefit-cost ratio (2.54), highlighting its superior economic viability.

Conclusion

It is concluded the application of Azospirillum 20g/kg seeds with foliar spray Iron 10g/l(T6) was recorded higher yield and benefit cost ratio in summer kodo millet.

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Table 1: Effect of bio-fertilizers a micronutrient on growth, yield and economics of kodo milet

At Harvest									
S. No.	**Treatments**	**Plant height (cm)**	**Dry weight (cm)**	**No.of tillers /plant**	**No.of seeds /ear**	**No.of ear /plant**	**Test weight (g)**	**Grain yield (kg/ha)**	**B:C**
1	*Azotobacter* + Boron at 5g/l	37.52	4.44	6.13	110.33	10.39	2.89	1093.48	1.17
2	*Azotobacter* + $FeSO_4$ at 10g/l	38.69	6.13	7.67	120.89	11.08	3.46	1551.42	2.18
3	*Azotobacter* + $ZnSO_4$ at 5g/l	38.64	5.91	7.13	118.89	10.83	3.38	1435.01	1.90
4	*Azotobacter*+ $MnSO_4$ at 1g/l	35.45	4.05	5.93	108.44	9.80	2.56	906.09	0.86
5	*Azospirillum* + Boron at 5g/l	37.69	4.90	6.20	112.91	10.54	3.11	1223.60	1.42
6	*Azospirillum*+ $FeSO_4$ at 10g/l	42.55	6.69	7.87	123.67	11.23	3.64	1667.75	2.51
7	*Azospirillum* +$ZnSO_4$ at 5g/l	38.53	5.53	6.60	115.11	10.61	3.24	1304.58	1.64
8	*Azospirillum* +$MnSO_4$ at 1g/l	36.75	4.21	6.00	109.58	10.17	2.71	997.80	1.05
9	NPK-40:20:20Kg/ha (Control)	35.11	3.75	5.90	105.67	9.72	2.37	803.59	0.59
	F-test	S	S	S	S	S	NS	S	
	SEm±	0.69	0.49	0.10	2.11	0.22	0.01	43.76	
	CD (p=0.05)	2.06	1.46	0.29	6.33	0.65	-	131.19	

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