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Effect of Biofertilizers and Zinc Micronutrients on yield and Economics of Maize (*Zea mays* L.)

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The research work was done out during *Kharif* season of 2023 at the Crop Research Farm, Department of Agronomy, Naini Agricultural Institute, Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj U.P(India), to study the effect of biofertilizers and zinc sulphate on growth and yield of Maize. The treatments consist of Bio-fertilizers PSB, *Azotobacter*,(PSB) + *Azotobacter* and ZnSO4 (20, 25, 30 kg/ha) done under RBD with ten treatments and replicated three times. The soil of research trial plot was sandy loamy in texture, nearly neutral in soil reaction (pH 7.8), low in organic carbon (0.35%). The outcomes showed that the taller plants (159.03 cm), higher plant dry weight (162.70 g/plant), maximum crop growth rate (26.250 g/m^2/day), number of cobs/plant (1.8), higher number of rows/cob (16.8), number of seeds per cob (553.4),were achieved by the application of PSB + *Azotobacter* + ZnSO4 30 kg/ha. Higher gross return (INR 1,49,119.5/ha), higher net return (INR 1,08,439.5.00/ha) and higher Benefit Cost ratio (2.66) were also obtained by the using of (Azotobacter 25 g/kg + PSB: 25 g/kg + 1% Zn+B 1 %).

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1. INTRODUCTION

Maize (*Zea mays*.L) otherwise called Maize or corn, is from the Poaceae family of grasses. Being one of the most used cereal crops worldwide, it is cultivated everywhere. Maize is a fundamental component as well as a significant source of human nutrition, animal feed and the raw materials used to make a variety of industry goods. Products from the fermentation sectors are also included, along with corn starch, corn oil, and corn syrup. Recently, it has also been utilized as biofuel. A crop with a wide range of agroclimatic zones is maize [1,2]. In actuality, no other crop comes close to matching maize's adaptability to many settings. It is grown between 58^{o}N and 40^{o}S, from sea level to elevations more than three thousand m, and in regions with annual rainfall in between range from from 250 mm to 5000 mm, with a growth cycle of 3 to13 months. The majority of the world's maize production, however, occurs in temperate zones. 70% of the world's output is produced in the United States, China, Brazil, and Mexico. India produces 2% of global production and 5% of the world's maize acreage [3,4].

In our country, maize is farmed in all three seasons. Nearly 90% of the output occurs during the kharif season, 7-8% during the rabi season (mostly from Bihar), and the final 1% occurs during the summer season. In addition to its applications as food for humans and as animal feed, maize is significant as a source of many industrial goods. The demand for maize has increased due to its numerous applications, including those for maize corn, the starch industry, corn oil manufacturing, baby corns, popcorn, etc., as well as its potential for export. To meet the rising needs, per hectare yield of maize is calculated to rise to 2.36 tons as against 1.7 tons currently by the end of 2020 [5].

Use of bio fertilizers is done based on a right response to increasing the process of fertilization so it can keep fertilizer costs low and use of labor. In this concept, the use of few nutrients required by plants can be carried out by rhizobacteria which have the capacity to fix N from the air and phosphate solubilizing microbes that can transfer P fixed in the soil into P-available for plant growth, thus saving the use of synthetic fertilizers". "Bio fertilizers can increase fertilization efficiency, fertility and soil health. Bacteria in the rhizosphere environment play an excellent role in maximum available nutrients and can maintain the macronutrient N cycle. Inoculation of bio fertilizers consisting of nitrogen fixing bacteria can be one solution to increase the population of nitrogen-fixing bacteria in the rhizosphere environment which is expected to maximise soil nutrients" [6,2]. The use of bio fertilizers will not leave residues on crop yields so that they are safe for human and the environment.

Zinc and Boron are most crucial amongst the micronutrients that take part in growth of the plant and development due to its catalytic action in metabolization of almost all types of crops". "Deficiency of Zn and B in soil causes deficiency in crops. "Trend of Zn and B deficiency have been detected in crop varieties in relation to previous ones. However, the better method of nutrient application can be another approach for better uptake and utilization of Zn and But the foliar spray of micronutrients is efficient for increase of crop productivity.

2. MATERIALS AND METHODS

The research was carried out at *Kharif* of 2023, Crop Research Farm, Department of Agronomy, Naini Agriculture Institute, Sam Higginbottom University of Agriculture Technology And Sciences, Prayagraj, Uttar Pradesh. which is located at 25.24' 42'' N latitude, 81·50' 56" E longitude and 98m altitude above the mean sea level (SL). The research was done in RBD Design with 10 treatments each replicated three times. The size of plot in each treatment was 3m x 3m.The various Factors are Bio-fertilizers (Phosphate solubilizing bacteria, *Azotobacter*, Phosphate solubilizing bacteria + *Azotobacter* and the Micronutrients levels (30,40,50). The Maize (crop) was sown on 17th November 2023. Harvesting was done by using 1m^{2} area from every plot. And there five plants were randomly selected for recording the growth and yield parameters. The treatment details are as followsT_1 -(Azotobacter 25 g/kg + 0.5 % Zinc + Boron 0.5 %), T_2 -(Azotobacter 25 g/kg + 0.75 % Zinc + Boron 0.75 %), T_3 – (Azotobacter 25 g/kg + 1 % Zinc + Boron: 1 %), T_4 -(PSB 25 g/kg +0.5 % Zinc + Boron 0.5 %), T_5 -(PSB 25 g/kg +0.75 % Zinc + Boron 0.75 %), T_6 -(PSB 25 g/kg + 1 % Zinc + Boron 1 %), T_7 -(Azotobacter 25 g/kg + PSB: 25 g/kg +0.5% Zinc+ Boron 0.5 %), T_8 -(

Azotobacter 25 g/kg + PSB: 25 g/kg +0.75% Zinc+Boron0.75 %), T_9 -(Azotobacter 25 g/kg + PSB: 25 g/kg + 1% Zinc+Boron 1 %), and Control Plot. The observations were recorded for height of plant, dry matter weight, CGR, Number of cobs/plant, Number of seeds/cob, No. of seed row/cob, Seed index, seed yield and stover yield.

3. RESULTS AND DISCUSSION

3.1 Yield Attributes

Number of Cobs/Plant: (Data) in Table 1 showed that significantly maximum number of Cobs/plant (1.8) was observed in treatment with the use of (PSB+ *Azotobacter* + ZnSO4 - 30 kg/ha), which was significantly superior as compared to other treatments. However, with the use of (Azotobacter 25 g/kg + PSB: 25 g/kg +0.75% Zinc+Boron0.75 %), was found to be statistically at par with the use of (PSB + *Azotobacter* + ZnSO4 - 30 kg/ha). increase in number of cobs per plant as a matter of seed inoculation with *Azotobacter* and PSB in the current research work is taken to an improvement in nutrition of the soil and creation of better surrounding for better root growth through passing of growth promoting substances such as Gibberellin, cytokinin and auxin and need of nitrogen used by the micro-organisms".

Number of Seeds/cob: Result provided in Table 1 showed that significantly higher number of Seeds/cob (553.4) were observed with the use of (Azotobacter 25 g/kg + PSB: 25 g/kg + 1% Zn+B 1 %), which was highly superior over rest of the various treatments [Table 1]. However, with use of (Azotobacter 25 g/kg + PSB: 25 g/kg +0.75% Zn+B0.75 %), was found to be statistically at par with the application of (Azotobacter 25 g/kg + PSB: 25 g/kg + 1% Zinc+Boron 1 %). The use of biofertilizers and zinc has maximized the number of seed kernel per cob (insignificantly) in this research experiment. The increase in number of kernel seed per cob might be due to the presence of magnesium in multi- nutrients solution as kernel number are direct index of pollen viability reported by Mahgoub et al. [7].

Number of Rows/cob: Research reveled that significantly higher number of Rows/cob (16.85) were observed with use of (Azotobacter 25 g/kg + PSB: 25 g/kg + 1% Zinc+Boron 1 %), which was significantly maximum as compared with the rest of the treatments [Table 1]. However, the use of (Azotobacter 25 g/kg + PSB: 25 g/kg +0.75% Zinc+Boron0.75 %), was found to be statistically at par with the use of (Azotobacter 25 g/kg + PSB: 25 g/kg + 1% Zinc+Boron 1 %). When compared to alternative treatments, zinc application raised the number of rows/cobs substantially. Positive response of maize yield components due to increased availability of zinc and metabolites for growth and development of reproductive structure, resulting in identification of better productivity of individual plant. The findings of present investigation are supported by those of Gupta et al. [8]

Seed Index (gm): In the research we observed that significantly Test weight (29.3 gm) were observed with the use of (Azotobacter 25 g/kg + PSB: 25 g/kg + 1% Zinc+Boron 1 %), which was significantly maximum as compared to others [Table 1]. However, the use of (Azotobacter 25 g/kg + PSB: 25 g/kg +0.75% Zinc+Boron0.75 %), was found to be statistically at par with the application of (Azotobacter 25 g/kg + PSB: 25 g/kg + 1% Zinc+Boron 1 %). The increased availability of nitrogen, which led to an increase in leaf area, may be the cause of the rise in yield components. The outcomes were consistent with those of Kader et al [9]. who found that Azotobacter, a bio-fertilizer, enhances nitrogen availability in the soil, which might increase the number of grains and 100-grain weight.

Grain Yield (t/ha): In research it is observed that significantly Seeds yield (6.5 t/ha) were observed with use of (Azotobacter 25 g/kg + PSB: 25 g/kg + 1% Zinc+Boron 1 %), which was significantly maximum in relation to other treatments [Table 1]. However, with use of Azotobacter 25 g/kg + PSB: 25 g/kg +0.75% Zinc+Boron0.75 %), was found to be statistically at par with the use of (Azotobacter 25 g/kg + PSB: 25 g/kg + 1% Zinc+Boron 1 %). Application of biofertilizer proved useful for formation of corn yield attributing characters mainly due to availability of nutrients in proper amount during reproductive phase of the crop. Application of zinc led to a increase in chlorophyll content, which increased yield attributes. The application of biofertilizers to seeds seems to have a good impact on photosynthetic activity, the production of metabolites and growth-regulating compounds, oxidative and metabolic activities, and increased crop growth and development, which showed in an improvement in baby corn yield parameters Naik et al. [10].

Table 1. Influence of bio-fertilizers and zinc sulphate on yield attributes of maize

S. No.	Treatments	No. of. Cobs/plant	No. of. Rows/Cobs	No. of. Seeds/Cob	Seed index (gm)	Grain yield(t/ha)	Stover yield(t/ha)	Harvest index (%)
1.	Azotobacter 25 g/kg + 0.5 % Zinc + Boron 0.5 %	1.3	12.1	332.6	26.0	3.6	7.4	32.1
2.	Azotobacter 25 g/kg + 0.75 % Zinc + Boron 0.75 %	1.4	14.1	351.5	26.8	3.8	8.9	30.4
3.	Azotobacter 25 g/kg + 1 % Zinc + Boron: 1 %	1.5	14.5	383.4	27.6	3.9	9.8	28.6
4.	PSB 25 g/kg +0.5 % Zinc + Boron 0.5 %	1.3	12.7	374.3	26.9	4.0	10.5	27.7
5.	PSB 25 g/kg +0.75 % Zinc + Boron 0.75 %	1.6	14.7	425.4	27.4	4.2	11.1	27.6
6.	PSB 25 g/kg + 1 % Zinc + Boron 1 %	1.7	14.9	463.7	27.9	4.5	11.4	29.3
7.	Azotobacter 25 g/kg + PSB: 25 g/kg +0.5% Zinc+ Boron 0.5 %	1.6	14.4	495.3	27.2	5.4	11.9	32.1
8.	Azotobacter 25 g/kg + PSB: 25 g/kg +0.75% Zinc+Boron0.75 %	1.7	16.1	519.7	28.4	6.3	12.3	33.4
9.	Azotobacter 25 g/kg + PSB: 25 g/kg + 1% Zinc+Boron 1 %	1.8	16.8	553.4	29.3	6.5	12.9	33.8
10.	Control (N-P-K 120-60-40 kg/ha)	1.4	12.4	336.4	26.7	4.3	9.9	30.7
	F-Test	S	S	S	NS	S	S	S
	S Em (+)	0.05	0.38	6.51	0.74	0.07	0.85	0.77
	CD (p=0.05)	0.14	1.13	19.34	---	0.22	2.52	2.28

Table 2. Influence of bio-fertilizers and zinc sulphate on economics of maize

S. No. Treatments	Cost of cultivation (INR/ha)	Gross return (INR/ha)	Net return (INR/ha)	B:C Ratio
1 . Azotobacter 25 g/kg + 0.5 % Zinc + Boron 0.5 %	39580.00	83345.00	43765.00	1.10
2. Azotobacter 25 g/kg + 0.75 % Zinc + Boron 0.75 %	40080.00	89519.00	49439.00	1.23
3. Azotobacter 25 g/kg + 1 % Zinc + Boron: 1 %	40580.00	92249.00	51669.00	1.27
4. PSB 25 g/kg +0.5 % Zinc + Boron 0.5 %	39780.00	96319.00	56539.00	1.42
5. PSB 25 g/kg +0.75 % Zinc + Boron 0.75 %	40280.00	100799.00	60519.00	1.50
6. PSB 25 g/kg + 1 % Zinc + Boron 1 %	40780.00	106969.00	66189.00	1.62
7. Azotobacter 25 g/kg + PSB: 25 g/kg +0.5% Zinc+ Boron 0.5 %	39680.00	125050.00	85370.00	2.15
8. Azotobacter 25 g/kg + PSB: 25 g/kg +0.75% Zinc+Boron0.75 %	40180.00	143590.00	103410.00	2.57
9.Azotobacter 25 g/kg + PSB: 25 g/kg + 1% Zinc+Boron 1 %	40680.00	149119.00	108439.00	2.66
10. Control RDF(120-60-40) kg/ha	37580.00	100764.00	63184.00	1.68

Stover Yield (t/ha) - Treatment No 9 recorded highest significant Stover yield recorded (12.9 t/ha) in Table 1, which was maximum over rest of the treatments [Table 1]. However, with use of (Azotobacter 25 g/kg + PSB: 25 g/kg +0.75% Zinc+Boron0.75 %), was found to be statistically at par with the use of (Azotobacter 25 g/kg + PSB: 25 g/kg + 1% Zinc+Boron 1 %). Zinc fertilization has beneficial effect on crop metabolism and crop growth, which leads to maximum yield. Increase in green cob and green fodder yield with use of zinc and biofertilizers such as *Azotobacter* and the results were supported by the findings of Tariq et al. [11], and Palai et al. [12].

Harvest Index (%): Treatment No.9 recorded highest significant harvest index (33.8%) in Table 1, which was significantly superior over [Table 1]. However, with use of (Azotobacter 25 g/kg + PSB: 25 g/kg +0.75% Zinc+Boron0.75 %), was found to be statistically at par with the use (Azotobacter 25 g/kg + PSB: 25 g/kg + 1% Zinc+Boron 1 %). positive effect of biofertilizer may resulted from its ability to maximise the availability of phosphorus and other nutrients especially under the use of the calcareous nature of the soil which cause least on the nutrients availability Afzal et al [13].

4. ECONOMIC ANLYSIS

4.1 Gross Returns

Maximum gross return (149119.00 INR/ha) was found with the application of (Azotobacter 25 g/kg + PSB: 25 g/kg + 1% Zinc+Boron 1 %) while the lowest as compared to other treatments (Table 2).

4.2 Net Returns

Net return (108439.00 INR /ha) was found to be maximum with application of (Azotobacter 25 g/kg + PSB: 25 g/kg + 1% Zinc+Boron 1 %) as compared to the lowest (Table 2).

4.3 Benefit Cost Ratio

Benefit Cost ratio (2.66) was found to be maximum with application of (Azotobacter 25 g/kg + PSB: 25 g/kg + 1% Zinc+Boron 1 %)while lowest as relation to other treatments (Table 2).

5. CONCLUSION

It was concluded that with the use of Azotobacter 25 g/kg + PSB: 25 g/kg + 1% Zinc+Boron 1 % , has performed nicey and improved growth and yields of Maize. Maximum grain yield, gross returns, net returns and benefit cost ratio were also recorded with application of Azotobacter 25 g/kg + PSB: 25 g/kg + 1% Zinc+Boron 1 %). These findings are based on one season.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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