

Original Research Article

Influence of Biofertilizers and zinc Sulphate on yield and economics of Maize (*Zea mays* L.)

ABSTRACT

The field experiment was conducted during *Rabi* season of 2022 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 Response of Bio- fertilizers 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)The soil of experimental plot was sandy loamy in texture, nearly neutral in soil reaction (pH 7.8), low in organic carbon (0.35%). Results revealed that the higher plant height (159.03 cm), higher plant dry weight (162.70 g/plant), higher crop growth rate (26.250 g/m²/day), number of cobs/plant (1.8), higher number of rows/cob (16.8), number of seeds per cob (553.4), higher 100 seed weight (29.3 gm), higher Grain yield (6.5 t/ha) higher straw yield (12.9 t/ha), and Harvest index (33.8) were significantly influenced with 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 B:C ratio (2.66) were also recorded in treatment-9 (PSB + *Azotobacter* + ZnSO₄ 30 kg/ha).

Keywords: *Maize, Bio-fertilizers, Zinc sulphate, yield attributes and Economics.*

Comment [A1]: Add background, problems, aims

INTRODUCTION

Maize (*Zea mays*.L) also known as Maize or corn, is a member of the Poaceae family of grasses. Being one of the most significant cereal crops worldwide, it is grown 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 industrial goods. Products from the fermentation and distillation sectors are also included, along with corn starch, maltodextrins, corn oil, and corn syrup. Recently, it has also been utilized as biofuel. A crop with a wide range of agroclimatic zones is maize. In actuality, no other crop comes close to matching maize's adaptability to many settings. It is grown between 58°N and 40°S, from sea level to elevations more than 3000 m, and in regions with annual rainfall ranging from 250 mm to 5000 mm, with a growth cycle of 3 to 13 months (Annual report, DMR, 2007-08). 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.

After rice and wheat, maize is becoming the third-most significant crop in India. India contributes 3% of the world's total production of maize, ranking sixth in the world. In India, maize is farmed in the kharif, rabi, and summer 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 growing demand, per hectare yield of maize is estimated to rise to 2.36 tonnes as against 1.7 tonnes currently by the end of 2020. **Kumar *et al.*, (2022).**

In an effort to increase crop yields, the continuous use of chemical fertilizers in the long term without being balanced with the use of organic matter will face serious obstacles and have an impact on soil damage. An alternative solution to this problem is the use of environmentally friendly fertilizers such as bio fertilizers to help increase soil fertility and provide nutrients that are not available to plants (**Nosheen *et al.*, 2021**). Utilization of bio fertilizers is carried out based on a positive response to increasing the efficiency of fertilization so that it can save fertilizer costs and use of labor. In this case, the supply of some of the nutrients needed by plants can be carried out by rhizobacteria which have the

ability to fix N from the air and phosphate solubilizing microbes that can convert P fixed in the soil into P-available for plant growth, thus saving the use of chemical fertilizers (Kalayu 2019). Bio fertilizers can improve fertilization efficiency, fertility and soil health. Bacteria in the rhizosphere environment play an important role in increasing available nutrients and can maintain the macronutrient N cycle. Inoculation of bio fertilizers consisting of nitrogenfixing bacteria can be one solution to increase the population of nitrogen-fixing bacteria in the rhizosphere environment which is expected to increase soil nutrients (Fasusi *et al.*, 2021). The use of bio fertilizers will not leave residues on crop yields so that they are safe for human health and the environment.

Zinc is most crucial amongst the micronutrients that take part in plant growth and development due to its catalytic action in metabolism of almost all crops (George and Schmitt, 2002). Deficiency of Zn in soil causes deficiency in crops and altogether this has become problem all over the world with acute zinc deficiency ranges in arid to semi-arid regions of the world (Rashid and Ryan, 2004). Trend of Zn deficiency have been detected in crop varieties as compared to old ones. The genetic differences among crop varieties and species for up taking Zn could be promising approach to Zn problem which invites the selection of proper genotypes. Moreover, the proper method of nutrient application can be another approach for better uptake and utilization of Zn. Amongst the different methods; the foliar spray of micronutrients is efficient for enhancement of crop productivity (Savithri *et al.*, 1999).

Materials and Methods

The experiment was conducted during *Rabi* of 2022, 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 experiment was conducted in Randomized Block Design with 10 treatments each replicated thrice. The plot size of each treatment was 3m x 3m. Factors are Bio-fertilizers (PSB , *Azotobacter*, PSB + *Azotobacter* and the ZnSO₄ levels (20,25,30 kg/ha). The Maize crop was sown on 17 November 2022. Harvesting was done by taking 1m² area from each plot. And from it five plants were randomly selected for recording growth and yield parameters. The treatment details are as follows, T₁-(PSB- + ZnSO₄ -20 kg/ha), T₂-(PSB + ZnSO₄ - 25 kg/ha), T₃- (PSB + ZnSO₄ -30 kg/ha), T₄-(*Azotobacter* + ZnSO₄ - 20 kg/ha), T₅-(*Azotobacter* + ZnSO₄ - 25 kg/ha), T₆-(*Azotobacter* + ZnSO₄ -30 kg/ha), T₇-(PSB +

Azotobacter + ZnSO₄ - 20 kg/ha), T₈-(PSB + *Azotobacter* + ZnSO₄ - 25 kg/ha), T₉-(PSB + *Azotobacter* + ZnSO₄ -30 kg/ha), and Control Plot. The observations were recorded for plant height, dry weight, Crop growth rate, number of No. of cobs/plant, No. of seeds/cob, No. of seed row/cob, Seed index, see yield and stover yield. The data was subjected to statistical analysis by analysis of variance method (**Gomez and Gomez, 1976**).

Results and Discussion

YIELD ATTRIBUTES

Comment [A2]: Add pictures for all parameters

Number of Cobs/plant - The significant and higher number of Cobs/plant (1.8) were observed in treatment-9 with (PSB + *Azotobacter* + ZnSO₄ - 30 kg/ha), which was significantly superior over rest of the treatments. However, treatment-8 (PSB + *Azotobacter* + ZnSO₄ - 25 kg/ha), was found to be statistically at par with treatment-9 (PSB + *Azotobacter* + ZnSO₄ - 30 kg/ha). A significant increase in number of cobs per plant as a consequence of seed inoculation with *Azotobacter* and PSB in the present investigation is attributed to an improvement in nutrition status of the soil and creation of congenial environment for better root growth through secretion of growth promoting substances such as Gibberellin, cytokinin and auxin and availability of nitrogen fixed by the micro-organisms (**Singh and Totawat, 2002**).

Number of Seeds/cob

The significant and higher number of Seeds/cob (553.4) were observed in treatment-9 with (PSB + *Azotobacter* + ZnSO₄ -30 kg/ha), which was significantly superior over rest of the treatments. However, treatment-8 (PSB + *Azotobacter* + ZnSO₄ - 25 kg/ha), was found to be statistically at par with treatment-9 (PSB + *Azotobacter* + ZnSO₄ -30 kg/ha). Combined application of biofertilizers and zinc has increased the number of grains per cob insignificantly in this field experiment. The increment in number of grains per cob might be due to the presence of magnesium in multi-nutrients solution as grains number are direct index of pollen viability and where magnesium is proved to increase fruit set and pollen viability and significant effect on pollen formation as reported by **Mahgoub et al., (2010)** and **Siam et al., (2008)**.

Number of Rows/cob

The significant and higher number of Rows/cob (16.85) were observed in treatment-9

with (PSB+ *Azotobacter* + ZnSO₄- 30 kg/ha), which was significantly superior over rest of the treatments. However, treatment-8 (PSB + *Azotobacter* + ZnSO₄ - 25 kg/ha), was found to be statistically at par with treatment-9 (PSB + *Azotobacter* + ZnSO₄ 30 - kg/ha). The significant and higher number of Rows/cob (15.5) were observed with the application of Zinc. The positive response of yield components of maize because of due to the greater availability of zinc and metabolites for growth and development of reproductive structure which ultimately led to recognition of higher productivity of individual plant. The findings of present investigation are supported by **Gupta et al., (2018)**.

Seed Index (gm)

The significant and higher Test weight (29.35 gm) were observed in treatment-9 with (PSB+ *Azotobacter* + ZnSO₄- 30 kg/ha), which was significantly superior over rest of the treatments. However, treatment-8 (PSB + *Azotobacter* + ZnSO₄ -25 kg/ha), was found to be statistically at par with treatment-9 (PSB + *Azotobacter* + ZnSO₄ - 30 kg/ha). The increase in the yield components might be due to the increased of the availability of nitrogen which resulted in the increase of the leaf area. The obtained results were in agreement with findings of (**Kader et al., 2002**) who reported that bio-fertilizer (*Azotobacter*) increases Nitrogen availability in the soil which could enhance the number of grains and 100-grain weight.

Seed Yield (t/ha) - The significant and higher Seeds yield (6.5 t/ha) were observed in treatment-9 with (PSB + *Azotobacter* + ZnSO₄ - 30 kg/ha), which was significantly superior over rest of the treatments. However, treatment-8 (PSB + *Azotobacter* + ZnSO₄ - 25 kg/ha), was found to be statistically at par with treatment-9 (PSB + *Azotobacter* + ZnSO₄ - 30 kg/ha). Application of biofertilizer proved beneficial for development of corn yield attributing characters mainly due to availability of nutrients in proper amount during reproductive phase of the crop. The increase in yield attributes due to application of zinc, which has increased chlorophyll content. Seed treatment with biofertilizers had apparently a positive effect on photosynthetic activity, synthesis of metabolites and growth regulating substances, oxidation and metabolic activities and ultimately better growth and development of crop, which led to increase in yield attributes of baby corn. These results are in agreement with the findings of **Chand et al., (2017) and Naik et al., (2020)**.

Stover Yield (t/ha) - The significant and higher Stover yield (12.9 t/ha) were observed in

treatment-9 with (PSB + *Azotobacter* + ZnSO₄ - 30 kg/ha), which was significantly superior over rest of the treatments. However, treatment-8 (PSB + *Azotobacter* + ZnSO₄ - 25 kg/ha), was found to be statistically at par with treatment-9 (PSB + *Azotobacter* + ZnSO₄-30 kg/ha). Zinc fertilization has beneficial effect on plant metabolism and plant growth, which leads to higher yield. Increase in green cob and green fodder yield with application of zinc and biofertilizers such as *Azotobacter* and the results were supported by the findings of **Tariq *et al.*, (2014) and Jnana Bharati Palai *et al.*, (2018).**

Harvest Index (%)

The significant and higher Harvest Index (33.8%) were observed in treatment-9 with (PSB+ *Azotobacter* + ZnSO₄ -30 kg/ha), which was significantly superior over rest of the treatments. However, treatment-8 (PSB + *Azotobacter* + ZnSO₄- 25 kg/ha), was found to be statistically at par with treatment-9 (PSB + *Azotobacter* + ZincSO₄ - 30 kg/ha). positive effect of biofertilizer may resulted from its ability to increase the availability of phosphorus and other nutrients especially under the speciality of the calcareous nature of the soil which cause decreasing on the nutrients availability, results agree with **Afzal *et al.*2005.**

ECONOMIC ANALYSIS

Gross Returns

Highest gross return (1,49,119 INR/ha) was obtained in treatment-9 (PSB + *Azotobacter* + ZnSO₄ -30 kg/ha) as compared to other treatments.

Net Returns

Net return (1,08,439.5 INR /ha) was found to be highest in treatment-9 (PSB + *Azotobacter* + ZnSO₄- 30 kg/ha) as compared to other treatments.

Benefit Cost Ratio

Benefit Cost ratio (2.66) was found to be highest in treatment-9 with (PSB + *Azotobacter* + ZnSO₄ - 30 kg/ha) as compared to other treatments.

Comment [A3]: Add discussion. Please explain this data

CONCLUSION

It was concluded that with the application of (PSB + *Azotobacter* + ZnSO₄ -30kg/ha) (Treatment-9), has performed positively and improved growth and yield parameters. Higher grain yield, gross returns, net returns and benefit cost ratio were also recorded with application of (PSB + *Azotobacter* + ZnSO₄ -30kg/ha) (Treatment-9). These findings are based on one season therefore; further trials may be required for further confirmation

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.	PSB + ZnSO ₄ - 20 kg/ha	1.3	12.1	332.6	26.0	3.6	7.4	32.1
2.	PSB + ZnSO ₄ - 25 kg/ha	1.4	14.1	351.5	26.8	3.8	8.9	30.4
3.	PSB + ZnSO ₄ -30 kg/ha	1.5	14.5	383.4	27.6	3.9	9.8	28.6
4.	<i>Azotobacter</i> + ZnSO ₄ -20kg/ha	1.3	12.7	374.3	26.9	4.0	10.5	27.7
5.	<i>Azotobacter</i> + ZnSO ₄ - 25kg/ha	1.6	14.7	425.4	27.4	4.2	11.1	27.6
6.	<i>Azotobacter</i> + ZnSO ₄ -30kg/ha	1.7	14.9	463.7	27.9	4.5	11.4	29.3
7.	PSB+ <i>Azotobacter</i> + ZnSO ₄ - 20 kg/ha	1.6	14.4	495.3	27.2	5.4	11.9	32.1
8.	PSB + <i>Azotobacter</i> + ZnSO ₄ - 25 kg/ha	1.7	16.1	519.7	28.4	6.3	12.3	33.4

9. PSB + <i>Azotobacter</i> + ZnSO ₄ - 30 kg/ha	1.8	16.8	553.4	29.3	6.5	12.9	33.8
10. Control RDF (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.

Treatments	Cost of cultivation (INR/ha)	Gross return (INR/ha)	Net return (INR/ha)	B:C Ratio
1.PSB+ZnSO ₄ -20 kg/ha	39580.00	83345.00	43765.00	1.10
2. PSB + ZnSO ₄ - 25 kg/ha	40080.00	89519.00	49439.00	1.23
3. PSB + ZnSO ₄ - 30 kg/ha	40580.00	92249.00	51669.00	1.27
4. <i>Azotobacter</i> + ZnSO ₄ - 20 kg/ha	39780.00	96319.00	56539.00	1.42
5. <i>Azotobacter</i> + ZnSO ₄ -25 kg/ha	40280.00	100799.00	60519.00	1.50
6. <i>Azotobacter</i> + ZnSO ₄ - 30 kg/ha	40780.00	106969.00	66189.00	1.62

7. PSB + <i>Azotobacter</i> - + ZnSO ₄ - 20kg/ha	39680.00	125050.00	85370.00	2.15
8. PSB + <i>Azotobacter</i> - + ZnSO ₄ -25kg/ha	40180.00	143590.00	103410.00	2.57
9. PSB + <i>Azotobacter</i> + ZnSO ₄ - 30kg/ha	40680.00	149119.00	108439.00	2.66
10. Control RDF(120-60-40) kg/ha	37580.00	100764.00	63184.00	1.68

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Comment [A4]: Add references using limited 5 years ago

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