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

ABSTRACT

The field experiment was carried out 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%). The outcomes showed that the higher plant height (159.03 cm), higher plant dry weight (162.70 g/plant), higher 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), 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 No.9 (PSB + *Azotobacter* + ZnSO4 30 kg/ha).

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

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^oN and 40^oS, 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. 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 tons as against 1.7 tons 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 carried out 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 (Phosphate solubilizing bacteria, *Azotobacter*, Phosphate solubilizing bacteria + *Azotobacter* and the ZnSO4 levels (20,25,30 kg/ha). The Maize crop was sown on 17 November 2022. Harvesting was done by taking $1m^2$ area from each plot. And from it five plants were randomly selected for recording growth and yield parameters. The treatment details are as follows, T_1 -(PSB- + ZnZnSO4 -20 kg/ha), T_2 -(PSB + ZnSO4 - 25 kg/ha), T_3 – (PSB + ZnSO4 -30 kg/ha), T_4 -(*Azotobacter* + ZnSO4 - 20 kg/ha), T_5 -(*Azotobacter* + ZnSO4 - 25 kg/ha), T_6 -(*Azotobacter* + ZnSO4 -30 kg/ha), T_7 -(PSB + *Azotobacter* + ZnSO4 - 20 kg/ha), T_8 -(PSB + *Azotobacter* + ZnSO4 - 25 kg/ha), T_9 -(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 information was statistically analyzed using the analysis of variance approach (Gomez and Gomez, 1976).

Results and Discussion

YIELD ATTRIBUTES

Number of Cobs/plant - Data in Table (1) showed that significantly higher number of Cobs/plant (1.8) were observed in treatment No.9 with (PSB + *Azotobacter* + ZnSO4 - 30 kg/ha), which was significantly superior over rest of thetreatments. However, treatment No.8 (PSB + *Azotobacter* + ZnSO4 - 25 kg/ha), was found to be statistically at par with treatment No.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 innutrition 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 data provided in Table 1 showed that significantly number of Seeds/cob (553.4) were observed in treatment No.9 with (PSB + *Azotobacter* + ZnSO4 -30 kg/ha), which was significantly superior over rest of thetreatments [Table No.1]. However, treatment No.8 (PSB + *Azotobacter* + ZnSO4 - 25 kg/ha), was found to be statistically at par with treatment No.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).**

Number of Rows/cob

Data in Table (1) observed that significantly number of Rows/cob (16.85) were observed in treatment No.9 with (PSB+ *Azotobacter* + ZnSO4- 30 kg/ha), which was significantly superior over rest of thetreatments [Table No.1]. However, treatment No.8 (PSB + *Azotobacter* + ZnSO4 - 25 kg/ha), was found to be statistically at par with treatment No.9 (PSB + *Azotobacter* + ZnSO4 30 - kg/ha). When compared to alternative treatments, zinc application raised the number of rows/cob 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 **Gupta *et al.*, (2018).**

Seed Index (gm)

Data in Table (1) observed that significantly Test weight (29.3 gm) were observed in treatment No.9 with (PSB+ *Azotobacter* + ZnSO4- 30 kg/ha), which was significantly superior over rest of the treatments [Table No.1]. However, treatment No.8 (PSB + *Azotobacter* + ZnSO4 -25 kg/ha), was found to be statistically at par with treatment No.9 (PSB + *Azotobacter* + ZnSO4 - 30 kg/ha). 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. (2002) 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) - Data in Table (1) observed that significantly Seeds yield (6.5 t/ha) were observed in treatment No.9 with (PSB + *Azotobacter* + ZnSO4 - 30 kg/ha), which was significantly superior over rest of the treatments [Table No.1]. However, treatment No.8 (PSB + *Azotobacter* + ZnSO4 -25 kg/ha), was found to be statistically at par with treatment No.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. Application of zinc led to a rise in chlorophyll content, which boosted yield attributes. The application of biofertilizers to seeds appeared to have a good impact on photosynthetic activity, the production of metabolites and growth-regulating compounds, oxidative and metabolic activities, and ultimately enhanced crop growth and development, which resulted in an improvement in baby corn yield parameters. These results are in agreement with the findings of **Naik *et al.*, (2020).**

Stover Yield (t/ha) - Treatment No 9 recorded highest significant stover yield recorded (12.9 t/ha) in Table (1), which was significantly superior over rest of the treatments [Table

No.1]. However, treatment No.8 (PSB + *Azotobacter* + ZnSO4 - 25 kg/ha), was found to be statistically at par with treatment No.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 (%)

Treatment No.9 recorded highest significant harvest index (33.8%) in Table (1), which was significantly superior over rest of the treatments [Table No.1]. However, treatment No.8 (PSB + *Azotobacter* + ZnSO4- 25 kg/ha), was found to be statistically at par with treatment No.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 specialty of the calcareous nature of the soil which cause decreasing on the nutrients availability, this results agreement with **Afzal *et al.*2005.**

ECONOMIC ANLYSIS

Gross Returns

Highest gross return (149119.00 INR/ha) was obtained in treatment No.9 (PSB + *Azotobacter* + ZnSO4 -30 kg/ha) as compared to other treatments (Table 2).

Net Returns

Net return (108439.00 INR /ha) was found to be highest in treatment No.9 (PSB + *Azotobacter* + ZnSO4- 30 kg/ha) as compared to other treatments (Table 2).

Benefit Cost Ratio

Benefit Cost ratio (2.66) was found to be highest in treatment No.9 with (PSB + *Azotobacter* + ZnSO4 - 30 kg/ha) as compared to other treatments (Table 2).

CONCLUSION

It was concluded that with the application of (PSB + *Azotobacter* + ZnSO4 -30kg/ha) (Treatment No.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 No.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 + ZnSO4 - 20 kg/ha	1.3	12.1	332.6	26.0	3.6	7.4	32.1
2.	PSB + ZnSO4 - 25 kg/ha	1.4	14.1	351.5	26.8	3.8	8.9	30.4
3.	PSB + ZnSO4 -30 kg/ha	1.5	14.5	383.4	27.6	3.9	9.8	28.6
4.	*Azotobacter* + Zns04 -20kg/ha	1.3	12.7	374.3	26.9	4.0	10.5	27.7
5.	*Azotobacter* + ZnSO4 - 25kg/ha	1.6	14.7	425.4	27.4	4.2	11.1	27.6
6.	*Azotobacter* + ZnSO4 -30kg/ha	1.7	14.9	463.7	27.9	4.5	11.4	29.3
7.	PSB+ *Azotobacter* + ZnSO4 - 20 kg/ha	1.6	14.4	495.3	27.2	5.4	11.9	32.1
8.	PSB + *Azotobacter* + ZnSO4 - 25 kg/ha	1.7	16.1	519.7	28.4	6.3	12.3	33.4

9. PSB + *Azotobacter* + ZnSO4 - 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+ZnSO4 -20 kg/ha	39580.00	83345.00	43765.00	1.10
2. PSB + ZnSO4- 25 kg/ha	40080.00	89519.00	49439.00	1.23
3. PSB + ZnSO4 - 30 kg/ha	40580.00	92249.00	51669.00	1.27
4. *Azotobacter* + ZnSO4 - 20 kg/ha	39780.00	96319.00	56539.00	1.42
5. *Azotobacter* -+ ZnSO4 -25 kg/ha	40280.00	100799.00	60519.00	1.50
6. *Azotobacter* + ZnSO4 - 30 kg/ha	40780.00	106969.00	66189.00	1.62

7. PSB + *Azotobacter* - + ZnSO4- 20kg/ha	39680.00	125050.00	85370.00	2.15
8. PSB + *Azotobacter*- + ZnSO4 -25kg/ha	40180.00	143590.00	103410.00	2.57
9. PSB + *Azotobacter* + ZnSO4 - 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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