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Influence of Biofertilizers and Zinc Sulphate on Growth and Yield of Maize (*Zea mays* L.)

Kasidi Divakar Reddy [a++*], Rajesh Singh [a#] and Akankhya Pradhan [a†]

[a] *Department of Agronomy, Naini Agricultural Institute, Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj-211007, Uttar Pradesh, India.*

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 field study took place at the Crop Research Farm, Department of Agronomy, Naini Agricultural Institute, Sam Higginbottom University of Agriculture, Technology And Sciences, Prayagraj (U.P.), India, during the Rabi season of 2022. To research how Zinc Sulphate and Bio-fertilizers affect the production and growth of Maize. PSB, Azotobacter, PSB + Azotobacter, and Zinc Sulphate 20, 25, and 30 kg/ha make up the treatments. The soil on the experimental plot had a sandy loamy texture, had a pH of 7.8, and had little organic carbon (0.35%). The results showed that the greater plant height (159.03 cm), plant dry weight (162.70 g/plant), crop growth rate (64.12 $g/m^2/day$), number of cobs per plant (1.8), number of rows per 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 the application of PSB + *Azotobacter* + Zinc Sulphate 30 kg/ha.

[++] *M.Sc. Scholar;*
[#] *Associate Professor;*
[†] *Ph.D Scholar;*
**Corresponding author: E-mail: divakarreddykasidi953@gmail.com;*

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1. INTRODUCTION

Next to wheat and rice, maize (*Zea mays* L.) ranks third in importance as a grain both globally and in India (Paramasivan et al., 2010). It may flourish in humid, subtropical, warm temperate, and tropical climates, as well as warm temperate regions. It is also grown in the tropics. Production of maize occupies a unique position historically, economically, and agronomically. Due to its potential applications in the production of starch, plastic, rayon, dye, resins, boot polish, syrups, ethanol, etc., it is used as food, feed, and fodder and is also becoming extremely important. A maize grain's nutritional composition is around 70% carbohydrates, 10% protein, 4% oil, 2.3% crude fibre, 10% aluminium, and 1.4% ash. Due to its C4 plant type and excellent ability to transform solar energy into the creation of dry matter, maize has a very high productivity. Because it is a miracle crop, it is referred to as the "Queen of Cereals" [1]. From latitudes 50° N to 40° S, from sea level to elevations greater than 3000 m, and in regions with annual rainfall ranging from 250 to 500 mm, maize is grown in nearly every region of the nation [2].

Biofertilizer is a substance with microorganism(s) put to the soil to make specific nutrients directly or indirectly available to plants for sustenance. Nitrogen fixers, phytostimulants, phosphate-solubilizing bacteria, rhizobacteria that promote plant development, and other agents are examples of different sources of biofertilizers [3]. To achieve a high-quality output and prevent environmental damage, the use of biofertilizers has become more important [4]. Bio-fertilizer often comprises microorganisms with specialised functions, such as Azospirillum to fix N_2 and P solubilizing bacteria to solubilize P from the soil and fertiliser to be available to the plants [5]. Numerous researchers had carried out tests to assess the reactions of various plants, including juvenile Robusta coffee (Junaedi et al*.,* 1999), soybean and turfgrass [6] to the bio-fertilizer application, but the results were still inconsistent. Further research is still needed in this area.

The micronutrient zinc is most frequently found to be the factor limiting maize output in North America and across the world. With phosphate (P) or potassium (K) fertilisers, zinc is frequently administered physically to maize crops. According to Alloway (2009), zinc sulphate is the most used zinc source. Crops that lack zinc are more likely to be maize. Zinc insufficiency in the soil-crop system has developed over the past few decades due to the selective cultivation of high yielding maize varieties, greater purity of chemical fertilisers employed, and intensification of cropping [7]. According to Mengel and Kirkby [8], zinc is critical for the proper operation of several enzyme systems, the production of nucleic acids and auxins (a plant hormone), protein metabolism, and normal crop development and growth.Zinc and phosphorus, both necessary for plant growth, can be hostile to one another under certain conditions, such as when zinc absorption is sluggish or insufficient and phosphorus supply is excessive.

2. MATERIALS AND METHODS

At the Crop Research Farm, Department of Agronomy, Naini Agriculture Institute, Sam Higginbottom University of Agriculture Technology and Sciences, Prayagraj, Uttar Pradesh, the experiment was carried out during Rabi of 2022. It is situated 98m above mean sea level (SL) at 25.24' 42'' N latitude, 81.50' 56" E longitude. The experiment was conducted in Randomized Block Design with 10 treatments each replicated thrice. Each treatment's plot was 3m x 3m in size. Zinc sulphate levels (20,25,30 kg/ha) and bio-fertilizers (PSB, Azotobacter, PSB + Azotobacter/kg seed) are factors. The maize harvest was planted on November 17, 2022. Each plot was harvested by removing 1 m2 of land. Five plants were then at random chosen from it to record the yield and growth characteristics. The treatment details are as follows, T_1 -(PSB + $ZnSO_4$ - 20 kg/ha), T_2 -(PSB+ $ZnSO_4$-25 kg/ha), T_3 – (PSB+ $ZnSO_4$- 30 kg/ha), T_4 -(*Azotobacter* + $ZnSO_4$- 20 kg/ha), T_5 -(*Azotobacter* + $ZnSO_4$- 25 kg/ha), T_6 -(*Azotobacter* + $ZnSO_4$- 30 kg/ha), T_7 -(PSB + *Azotobacter* + $ZnSO_4$- 20 kg/ha), T_8 -(PSB + *Azotobacter* + $ZnSO_4$- 25 kg/ha), T_9 -(PSB + *Azotobacter* + $ZnSO_4$-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 [9].

3. RESULTS AND DISCUSSION

3.1 Growth Parameters

Plant Height – At Harvest, Treatment - 9 (PSB + Azotobacter + $ZnSO_4$– 30 kg/ha) had noticeably higher plant height (159.03 cm). Though statistically comparable to treatment-9 (PSB + Azotobacter + $ZnSO_4$– 30 kg/ha), treatment-8 (PSB + Azotobacter + $ZnSO_4$– 25 kg/ha) was not statistically superior. The availability of nutrients to the plant at critical growth phases in a timely manner causes a significant difference in plant height, and the administration of zinc stimulates the creation of IAA, which raises plant height. Azotobacter bacterialization of maize and foliar zinc administration induced a growth-stimulating rise in the lengths of the roots and shoots in the treated plants. Alka Jyoti Sharma et al. [10] and Garima Joshi and Aaradhana Chilwal [11] both reported findings that were similar.

Dry weight/plant-At Harvest, Treatment-9 (PSB + Azotobacter + $ZnSO_4$– 30 kg/ha) had noticeably taller plants (162.70 gramme). The statistical comparison between treatment-8 (PSB + Azotobacter + $ZnSO_4$– 25 kg/ha) and treatment-9 (PSB + Azotobacter + $ZnSO_4$– 30 kg/ha) was nonetheless equal. Interestingly, the fresh weight and dry weight of the plant were measured after Azotobacter inoculation. The microbial balance, inhibition of pathogenic microbes, metabolism of soil phosphate, and production of compounds that promote plant development after germination are all ways that Azotobacter might influence plant growth in addition to fixing nitrogen [12]. The impact of Azotobacter inoculation on plant dry weight is consistent with a previous study conducted on maize by Jarak et al*.* [13]. According to Ghodpage et al*.* [14], the increase in yield could be attributed to the proper supply of Zn in the soil up until the stages of harvesting, which may have resulted in increased photosynthetic activity for a longer period of time and their favourable effect on plant metabolism, ultimately increasing dry-matter accumulation.

Crop growth rate – At 60–80 DAS, Treatment-9 (PSB + Azotobacter + $ZnSO_4$– 30 kg/ha) showed considerably higher crop growth rate (64.12 g/m2/day). Treatment 8 (PSB + Azotobacter + $ZnSO_4$– 25 kg/ha) was statistically comparable to Treatment 9 (PSB + Azotobacter + $ZnSO_4$– 30 kg/ha). According to Monib et al. [15], an increase in soil nitrogen by fixation by azotobacter inoculation has boosted crop growth. Fallik et al. [16] reported that under controlled circumstances, Zea mays showed improved root and shoot development. Even though only comparatively modest amounts of fertilisers are needed in the very early stages of plant growth, large concentrations of nutrients in the root zone at that time are advantageous in encouraging early growth [17].

3.2 Yield Attributes

3.2.1 Number of cobs/plant

Treatment 9 with (PSB + Azotobacter + $ZnSO_4$– 30 kg/ha), which was much better than the rest of the treatments, had a considerable and greater number of Cobs/plant (1.8). Treatment 8 (PSB + Azotobacter + $ZnSO_4$– 25 kg/ha) was discovered to be statistically equivalent to Treatment 9 (PSB + Azotobacter + $ZnSO_4$– 30 kg/ha). Because of the secretion of growth-promoting substances like gibberellin, cytokinin, and auxin as well as the availability of nitrogen fixed by the microorganisms, seed inoculation with Azotobacter and PSB resulted in a significant increase in the number of cobs per plant in the current Investigation [18]. This favourable environment also allowed for better root growth.

3.2.2 Number of seeds/cob

Treatment 9 with (PSB + Azotobacter + $ZnSO_4$– 30 kg/ha) had a greater and much more significant number of Seeds/cob (553.4) than the other treatments. However, it was discovered that treatment-8 (PSB + Azotobacter + $ZnSO_4$– 25 kg/ha) was statistically equivalent to treatment-9 (PSB + Azotobacter + $ZnSO_4$– 30 kg/ha). In this field experiment, the use of biofertilizers and zinc together barely boosted the quantity of grains per cob. Given that the number of grains per cob is a direct indicator of pollen viability and that magnesium has been shown to increase fruit set and pollen viability as well as have a significant impact on pollen formation, Mahgoub et al. [19] and Siam et al. (2008) speculate that the increase in grains per cob is the result of the presence of magnesium in multi-nutrient solutions.

3.2.3 Number of rows/cob

Treatment 9 with (PSB + Azotobacter + $ZnSO_4$– 30 kg/ha) had a considerable and greater number of Rows/cob (16.85), which was much better than the other treatments. However, it was discovered that treatment 8 (PSB + Azotobacter + $ZnSO_4$– 25 kg/ha) was statistically equivalent to treatment 9 (PSB + Azotobacter + $ZnSO_4$– 30 kg/ha). With the application of zinc, a considerable and larger number of Rows/cob

Table 1. Influence of bio-fertilizers and zinc sulphate on growth parameters of maize

S. No.	Treatment combinations	Plant height	Plant Dry Weight	Crop growth rate
1.	PSB + $ZnSO_4$- 20kg/ha	148.23	142.72	52.50
2.	PSB + $ZnSO_4$- 25kg/ha	149.87	148.33	54.75
3.	PSB + $ZnSO_4$- 30 kg/ha	152.45	151.32	57.75
4.	*Azotobacter* + $ZnSO_4$- 20kg/ha	151.99	152.70	60.37
5.	*Azotobacter* + $ZnSO_4$- 25kg/ha	154.04	156.71	60.16
6.	*Azotobacter* + $ZnSO_4$-30kg/ha	155.72	158.72	61.61
7.	PSB + *Azotobacter* + $ZnSO_4$- 20 kg/ha	154.97	159.00	63.75
8.	PSB + *Azotobacter* + $ZnSO_4$- 25 kg/ha	156.65	161.32	62.62
9.	PSB + *Azotobacter* + $ZnSO_4$- 30 kg/ha	159.03	162.70	64.12
10.	Control RDF (120-60-40) kg/ha	143.50	146.07	53.62
	F test	S	S	S
	SE m (±)	2.88	2.07	1.63
	CD (p=0.05)	8.54	6.15	4.85

Table 2. 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 + $ZnSO_4$-20kg/ha	1.3	12.1	332.6	26.0	3.6	7.4	32.1
2.	PSB + $ZnSO_4$- 25kg/ha	1.4	14.1	351.5	26.8	3.8	8.9	30.4
3.	PSB + $ZnSO_4$- 30kg/ha	1.5	14.5	383.4	27.6	3.9	9.8	28.6
4.	*Azotobacter* + $ZnSO_4$-20kg/ha	1.3	12.7	374.3	26.9	4.0	10.5	27.7
5.	*Azotobacter* + $ZnSO_4$- 25kg/ha	1.6	14.7	425.4	27.4	4.2	11.1	27.6
6.	*Azotobacter* + $ZnSO_4$- 30kg/ha	1.7	14.9	463.7	27.9	4.5	11.4	29.3
7.	PSB + *Azotobacter* + $ZnSO_4$- 20 kg/ha	1.6	14.4	495.3	27.2	5.4	11.9	32.1
8.	PSB + *Azotobacter* + $ZnSO_4$- 25 kg/ha	1.7	16.1	519.7	28.4	6.3	12.3	33.4
9.	PSB + *Azotobacter* + $ZnSO_4$- 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
	SEm(±)	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

(15.5) were seen. The increased availability of zinc and metabolites for the growth and development of the reproductive structure caused a favourable reaction in the yield components of maize, which finally led to the recognition of better productivity of individual plants. Gupta et al. [20] support the findings of the current research.

3.2.4 Seed Index (gm)

Treatment 9 with (PSB + Azotobacter + $ZnSO_4$– 30 kg/ha) had a considerably higher Test weight (29.35 gm), which was superior to the other treatments. Treatment 8 (PSB + Azotobacter + $ZnSO_4$– 25 kg/ha) was discovered to be statistically equivalent to Treatment 9 (PSB +Azotobacter + $ZnSO_4$– 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 results were consistent with those of Kader et al. [21], who found that Azotobacter, a bio-fertilizer, enhances nitrogen availability in the soil, which may increase the number of grains and 100-grain weight.

3.2.5 Seed yield (t/ha)

Treatment 9 with (PSB + Azotobacter + $ZnSO_4$– 30 kg/ha), which was much better than the other treatments, had a considerable and higher Seeds yield (6.5 t/ha). Treatment 8 (PSB + Azotobacter + $ZnSO_4$– 25 kg/ha) was discovered to be statistically equivalent to Treatment 9 (PSB + Azotobacter + $ZnSO_4$– 30 kg/ha). Due to the availability of nutrients in the right quantities during the crop's reproductive period, the use of biofertilizer contributed to the development of maize yield attributing characteristics. The application of zinc, which enhanced the concentration of chlorophyll, is responsible for the rise in yield. It appears that seed treatment with biofertilizers had a good impact on photosynthetic activity, the synthesis of metabolites and growth-regulating chemicals, oxidation and metabolic activities, and ultimately enhanced growth and development of crop, which led to increase in yield attributes of baby corn. These results are in agreement with the findings of Shaikh Wasim Chand et al. [22] and Chandra Naik et al. [23].

3.2.6 Stover yield (t/ha)

Treatment 9 with (PSB + Azotobacter + $ZnSO_4$– 30 kg/ha) had a considerable and higher Stover yield (12.9 t/ha), which was much better than the other treatments. However, it was discovered that treatment 8 (PSB + Azotobacter + $ZnSO_4$– 25 kg/ha) was statistically equivalent to treatment 9 (PSB + Azotobacter + $ZnSO_4$– 30 kg/ha). Zinc fertilisation has positive effects on plant growth and metabolism, increasing output. Zinc treatment and the use of biofertilizers such Azotobacter increased the production of green cob and green fodder, and the results were confirmed by Tariq et al. [24] and Palai et al. (2018).

3.2.7 Harvest index (%)

Treatment 9 with (PSB + Azotobacter + $ZnSO_4$– 30 kg/ha), which was much better than the other treatments, had a considerable and higher Harvest Index (33.8%). However, it was discovered that treatment 8 (PSB + Azotobacter + $ZnSO_4$– 25 kg/ha) was statistically equivalent to treatment 9 (PSB + Azotobacter + $ZnSO_4$– 30 kg/ha). According to data that concur with Afzal et al., a biofertilizer's beneficial effects may be attributable to its capacity to boost the availability of phosphorus and other nutrients, particularly when the soil is particularly calcareous, which reduces the availability of nutrients [25-27].

4. CONCLUSION

The application of (PSB + Azotobacter + $ZnSO_4$-30kg/ha) resulted in greater seed performance (6.5 t/ha) compared to other treatments. Results may need to be confirmed by additional testing as they are based on studies that were only completed during one season.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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