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Effect of Biofertilizer and Micronutrient on Growth and Yield of Summer Maize (*Zea mays* L.)

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ABSTRACT

A field experiment was conducted at the Crop Research Farm, Department of Agronomy, Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj during *Zaid* season 2022 on maize crop. The treatment consist of seed inoculation with biofertilizer (*Azotobacter* and *Azospirillum* 20 g/kg each), boron (5 kg/ha and 0.30%) and zinc (25 kg/ha and 0.25%) soil as well as foliar spray and a control (120-60-40 kg NPK/ha). The experiment was laid out in Randomized Block Design which consisted of nine treatments and replicated thrice. The results of the experiment showed that, plant height (193.00 cm), dry weight (86.33 g), number of rows/cob (16.22), number of grains/row (34.66), weight of cob (196.55 g), seed index (30.33 g), grain yield (4.97 t/ha) and stover yield (9.82 t/ha) were recorded significantly highest with application *Azotobacter* 20 g/ha + Boron 0.30% + Zinc 0.25%. Maximum gross returns (156769 INR/ha), net returns (105439.38 INR/ha), and B-C ratio (2.5) were also obtained with the same treatment.

Keywords *Azospirillum, Azotobacter,* Boron, Economics, Zinc.

INTRODUCTION

Maize is one of the most adaptable crops, cultivated in both tropical and temperate regions of the world. It is a day-neutral plant that is referred to as "Queen of cereals" due to its highest genetic yield potential and belongs to the family of the Poaceae. Maize can use extensively as a silage crop, both in temperate and tropical climate. It is the most important coarse grain; it serves as a staple food in many countries. Besides being intensively used as human food and animal feed, corn is also a major source of a wide range of diverse industrial products. In India, maize is emerging as the third most important cereal crop after rice and wheat which occupies an area of 9.86 Mha with a production of 31.51 MT, having average productivity of about 3.19 t/ha (Agricultural Statistics at a Glance 2021). About 28% of produced maize is used as food, 11% for livestock feed, 48% as poultry

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feed, 12% in wet milling industry and 1% as seed (Layek *et al.* 2016).

Biofertilizers offer a tremendous potential for supplying nutrients and are inexpensive, environmentally acceptable input that can reduce the dose of chemical fertilizer (Khadka *et al.* 2022) for sustainable agriculture and the economy. It can purify the environment, magnify the productivity of soil (Hossein and Farshad 2013) and enhance crop growth. *Azospirillum* is an important non-symbiotic micro-organism bacterium that can fix atmospheric nitrogen from 20 to 40 kg ha^{-1} in the soil and help in synthesis of phytohormones (Abd El-Latteif 2016). Many studies have been done on the *Azospirillum* species, which also proved to have a high potential for commercial production. The *Azotobacter* species not only contributes to nitrogen fixation but also has the ability to produce large quantities of bioactive compounds like vitamins, auxin and gibberellins (Suhag 2016). The first and most familiar biofertilizer for cereals was *Azotobacter,* fixed 20-40 kg of nitrogen per hectare in soil annually and also produced auxin, cytokinin and gibberelin (Abd El-Latteif 2016), which promote root proliferation, ultimately increasing root density and branching, which in turn increases nutrients and water availability and enhances the plant growth and yield.

Maize is a highly nutrient-demanding crop that also needs micronutrients in addition to major elements for better growth and yield (Singh *et al.* 2017). It can suffer from several micronutrient deficiencies, like boron and zinc. Boron is one of the crucial nutrients for the optimum growth and development of cereal crops (Gupta and Solanki 2013) and increases stress tolerance in a plants (Singh *et al*. 2017). The increased need for boron in developing tissues demonstrates that it is essential for cell division and elongation (Kumar *et al.* 2019). It is also essential for pollen tube growth, plasma membrane integrity and encouraging fertilization for seed development (PARC 2015). The requisite amount of boron aids in seed formation, flower formation and retention, and the transport of photosynthetic carbohydrates (Kaur and Nelson 2015). Zinc is an important structural component or regulatory co- factor for variety of enzymes (Zhang *et al.* 2016) in several crucial metabolic pathways, which mostly deal with carbohydrate metabolism, maintaining the integrity of cellular membranes, protein synthesis and regulation of auxin metabolism (Begum *et al.* 2016), as well as in photosynthesis, the conversion of carbohydrates to starch and pollen formation (Keram and Singh 2014). Foliar application is effective for micronutrients, as 90% of the fertilizer is utilized by the plant when applied in foliar form (Manasa and Devaranavadagi 2015).

MATERIALS AND METHODS

During the *Zaid* season of 2022, a field experiment was conducted in alluvial soil at the Crop Research Farm of the Department of Agronomy, SHUATS, Prayagraj, UP. The soil of experimental plot was sandy loam, having a nearly neutral soil reaction (pH 6.9), electrical conductivity 0.48 ds/m, medium in available nitrogen (270.81 kg/ha) and potassium (215.9 kg/ha), and low in available phosphorus (11.5 kg/ha). Maize seeds (Kanchan K-25) were sown on April 4, 2022 with a spacing of 50 x 20 cm. The experiment was conducted in a Randomized Block Design consisting of 9 treatment combinations and 3 replications. Fertilizers were applied as band placement, for which 4-5 cm deep furrows were made along the seed rows with a hand hoe. The nutrient sources were urea, single super phosphate (SSP) and murate of potash (MOP), applied as per the recommended dose of 120:60:40 kg NPK/ha. As per the treatment, seed inoculation with biofertilizer (*Azotobacter* and *Azospirillum*) was carried out by using a 10% sugar solution. Seeds were coated uniformly with biofertilizer and sugar solution mixture and dried for 30 minutes under shade and sown immediately. After germination, the gaps were filled by dibbling after 10 days of sowing. Seedlings were thinned out wherever required to maintain spacing of 50 x 20 cm. Manual weeding was done with the help of khurssspi at 20 and 40 days after sowing to minimize the crop weed competition. Foliar application of boron and zinc was done at 30 days after sowing as per the treatments. The crop was harvested on June 4^{th} 2022. Plant growth parameters viz., plant height (cm), dry weight (g/plant) were measured at a regular intervals from germination till harvest and yield metrics viz., cobs/plant, rows/cob, grains/row, weight of cob (g), seed index (g), seed yield (t/ha), stover yield (t/ha) and harvest index (%) were measured at harvest. The ob-

Table 1. Effect of biofertilizer and micronutrient on growth attributes of summer maize.

Sl. No. .	Treatments	Plant height 80 DAS	Dry weight 80 DAS
1	*Azotobacter* 20 g/kg + Boron 5 kg/ha+Zinc 25 kg/ha	187.27	84.11
2	*Azotobacter* 20 g/kg + Boron 5 kg/ha + Zinc 0.25%	184.80	78.11
3	*Azotobacter* 20 g/kg + Boron 0.30% + Zinc 25 kg/ha	169.53	75.22
4	*Azotobacter* 20 g/kg + Boron 0.30% + Zinc 0.25%	193.00	86.33
5	*Azospirillum* 20 g/kg + Boron 5 kg/ha + Zinc 25 kg/ha	185.40	82.22
6	*Azospirillum* 20 g/kg + Boron 5 kg/ha + Zinc 0.25%	169.13	73.83
7	*Azospirillum* 20 g/kg + Boron 0.30% + Zinc 25 kg/ha	182.87	76.56
8	*Azospirillum* 20 g/kg + Boron 0.30% + Zinc 0.25%	185.20	80.89
9	Control	174.77	76.00
	SEm (±)	3.49	1.70
	CD (p= 0.05)	10.46	5.11

served data was statistically analyzed using analysis of variance (ANOVA) as applicable to Randomized Block Design (Gomez and Gomez 1984).

RESULTS AND DISCUSSION

Growth parameter

The data of growth parameter are presented in Table 1. Significantly highest plant height (193.00 cm) was recorded with the application of *Azotobacter* 20 g/kg of seeds and foliar applications of boron 0.30% and zinc 0.25%. However, treatments 1, 2, 5, 7 and 8 (187.27 cm, 184.80 cm, 185.40 cm, 182.87 cm and 185.20 cm, respectively) were statistically at par with the highest. This might be due to seed inoculation with *Azotobacter,* which increases the germination capacity and results in the early growth of seedlings. The creation of cell walls, cell division, elongation and nucleic acid metabolism all depend on the mineral borax. Tryptophan, a precursor to IAA, is synthesized with the assistance of zinc. Auxin, a vital growth hormone, is also actively produced with the help of zinc. Hence, in this treatment, the plant height is at its highest. (Kumar et al. 2019) reported results that were comparable. Seed inoculation with *Azotobacter* 20 g/kg followed by foliar spray of Boron 0.30% and zinc 0.25% recorded significantly highest dry weight (86.33 g) which was statistically at par with treatments 1 and 5 (84.11 and 82.22 g, respectively). The probable reason for this result was attributed to higher plant height and foliage recorded in this treatment. *Azotobacter* and zinc encourage the growth and development of roots, which improve nutrient uptake and shoot development. The effect of boron on cell division and elongation leads to higher plant growth, which is expressed in terms of plant dry weight. Similar finding were reported by Tariq *et al.* (2014) and Wasaya *et al.* (2017).

Yield attributes

The data pertaining to yield attributing characters are presented in Table 2. The maximum number of cob/plant (1.67) was recorded with the application of *Azotobacter* 20 g/kg + Boron 0.3% + Zinc 0.25%, which was found to be statistically at par to all treatment. Significantly higher number of rows/cob (16.22), number of grains/row (34.66), weight of cob (196.55 g), and seed index (30.33 g) were recorded with application of *Azotobacter* 20 g/kg + Boron 0.3% + Zinc 0.25%, whereas number of rows/cob (15.78) and seed index (26.33 g) with application of *Azotobacter* 20 g/kg + Boron 5 kg/ha + Zinc 25 kg/ha were statistically at par with the highest. The probable reason for these results attributed to seeds inoculated with biofertilizer are well-nourished and able to transport enough nutrients and metabolites to the growing seedling. Boron application improved grain setting, protein and carbohydrate synthesis and pollen tube germination, which increase the effectiveness of fertilization. Zinc has role in synthesis of chlorophyll and auxin, which affects photosynthesis. Additionally, it stimulates a number of developmental

Table 2. Effect of biofertilizer and micronutrient on yield attributes and yield of summer maize.

Sl. No.	Treatments	No. of cobs/plant	No. of rows/cob	No. of grains/row	Weight of cob (g)	Seed index (g)	Grain yield (t/ha)	Stover yield (t/ha)	Harvest index (%)
1	*Azotobacter* 20 g/kg + Boron 5 kg/ha + Zinc 25 kg/ha	1.53	15.78	31.89	186.44	26.33	4.70	9.39	32.60
2	*Azotobacter* 20 g/kg + Boron 5 kg/ha + Zinc 0.25%	1.40	13.67	26.22	176.67	24.00	4.10	8.20	32.27
3	*Azotobacter* 20 g/kg + Boron 0.30% + Zinc 25 kg/ha	1.13	12.44	23.33	144.22	22.00	3.57	7.57	30.45
4	*Azotobacter* 20 g/kg + Boron 0.30% + Zinc 0.25%	1.67	16.22	34.66	196.55	30.33	4.97	9.82	32.58
5	*Azospirillum* 20 g/kg + Boron 5Kg/ha + Zinc 25 kg/ha	1.47	14.78	29.11	190.44	25.00	4.45	8.95	32.51
6	*Azospirillum* 20 g/kg + Boron 5 kg/ha + Zinc 0.25%	1.27	12.00	20.66	138.66	21.00	3.63	7.92	32.08
7	*Azospirillum* 20 g/kg + Boron 0.30% + Zinc 25 kg/ha	1.40	13.56	25.55	169.11	23.67	3.87	8.03	31.83
8	*Azospirillum* 20 g/kg + Boron 0.30% + Zinc 0.25%	1.47	14.67	25.89	180.22	24.33	4.37	8.63	32.41
9	Control	1.33	12.89	23.77	150.22	23.67	3.29	7.00	29.79
	SEm (±)	0.11	0.40	0.72	1.70	1.61	0.18	0.40	1.49
	CD (p= 0.05)	-	1.1	2.17	5.11	4.85	0.55	1.21	-

process, like protein synthesis and hormone production. The results are in accordance with Wasaya *et al.* (2017) and Kumar *et al.* (2019).

Grain yield

The statistical data in Table 2 showed that significantly highest grain yield (4.97 t/ha) was recorded in treatment 4, which was statistically at par with treatments 1 and 5 (4.70 and 4.45 t/ha, respectively). These results might be due to better seed germination and a larger root system for nutrient uptake, which are the results of the early nourishment offered to the seeds by *Azotobacter* in the form of growth-promoting chemicals. Zinc plays a crucial role in the production of auxin and other enzymes. Boron facilitates the transport of photosynthates from the leaves to the kernel and also causes the production of tassels and silk, which improve fertilization. The current findings are consistent with Baral and Adhikari (2013), Salimi *et al.* (2013) and Wasaya *et al.* (2017).

Stover yield

The data in Table 2 showed that a significantly maximum stover yield (9.82 t/ha) was recorded with the application of *Azotobacter* 20 g/kg + Boron 0.30% + Zinc 0.25%, whereas treatments 1, 5 and 8 (9.39, 8.95 and 8.63 t/ha, respectively) found to be statistically at par with the highest. The application of *Azotobacter,* boron, and zinc resulted in significantly higher stover yield; this might be due to improved growth in terms of seedling emergence, plant height, and dry matter accumulation, which raises photosynthetic efficiency. Greater photosynthetic accumulation in vegetative components leads to superior vegetative development and hence the stover yield increases. Similar results reported by Barel and Adhikari (2013) and Wasaya *et al.* (2017).

Harvest index

Data presented in Table 2 showed that the highest harvest index (32.60 %) was recorded with the application of *Azotobacter* 20 g/kg + Boron 5 kg/ha + Zinc 25 kg/ha which was statistically at par to all treatment.

Economics

The data on the economics of different treatments presented in Table 3 showed that the maximum gross return (₹156769/ha), net return (₹105439.38/ha) and

Table 3. Effect of biofertilizer and micronutrient on economics of summer maize.

Sl. No.	Treatments	Cost of cultivation (₹/ha)	Gross returns (₹/ha)	Net returns (₹/ha)	Benefit-cost ratio (B:C)
1	*Azotobacter* 20 g/kg + Boron 5 kg/ha + Zinc 25 kg/ha	58194.62	148925	90730.38	1.55
2	*Azotobacter* 20 g/kg + Boron 5 kg/ha + Zinc 0.25%	54979.62	129970	74990.38	1.36
3	*Azotobacter* 20 g/kg + Boron 0.30% + Zinc 25 kg/ha	54894.62	115964	61069.38	1.11
4	*Azotobacter* 20 g/kg + Boron 0.30% + Zinc 0.25%	51329.62	156769	105439.38	2.05
5	*Azospirillum* 20 g/kg + Boron 5 kg/ha + Zinc 25 kg/ha	58179.62	141390	83210.38	1.43
6	*Azospirillum* 20 g/kg + Boron 5 kg/ha + Zinc 0.25%	54964.62	119361	64396.38	1.17
7	*Azospirillum* 20 g/kg + Boron 0.30% + Zinc 25 kg/ha	54879.62	124564	69684.38	1.26
8	*Azospirillum* 20 g/kg + Boron 0.30% + Zinc 0.25%	51314.62	137814	86499.38	1.68
9	Control	43784.62	107023	63238.38	1.44

Note : Price of grain yield - ₹18700/t (MSP) and price of stover yield - ₹6500/t.

benefit-cost ratio (2.05) was recorded with application of *Azotobacter* 20 g/kg + Boron 0.30% + Zinc 0.25% and the minimum gross return (₹107023/ha) and net return (₹63238.38/ha) was observed in the control (₹107023/ha) and lowest benefit-cost ratio (1.11) was recorded in treatment 3. These results might be due to an increase in grain and stover yields in the same treatment as a result of enhanced availability of nutrients by the biofertilizer and better utilization of micronutrients (boron and zinc). The current findings are consistent with Tomar *et al.* (2017) and Wasaya *et al.* (2017).

CONCLUSION

On the basis of one season experimentation, it can be concluded that with the application of *Azotobacter* 20 g/kg + Boron 0.30% + Zinc 0.25% (T_4) was found to be more desirable in terms of increasing growth, yield and economics of summer maize.

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