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Rakhi S Gandhar

M.Sc. Student, Department of
Agronomy, N. M. College of
Agriculture, Navsari Agricultural
University, Navsari, Gujarat, India

Rahul R Pisal

Assistant Professor, Department of
Agronomy, N. M. College of
Agriculture, Navsari Agricultural
University, Navsari, Gujarat, India

Anshul Choudhary

M.Sc. Student, Department of
Agronomy, R. A. K. College of
Agriculture, R. V. S. K. V. V.,
Sehore, Madhya Pradesh, India

Shikha Ojha

M.Sc. Student, Department of
Agronomy, N. M. College of
Agriculture, Navsari Agricultural
University, Navsari, Gujarat, India

Shruti M Patel

M.Sc. Student, Department of
Agronomy, N. M. College of
Agriculture, Navsari Agricultural
University, Navsari, Gujarat, India

Corresponding Author:

Rakhi S Gandhar

M.Sc. Student, Department of
Agronomy, N. M. College of
Agriculture, Navsari Agricultural
University, Navsari, Gujarat, India

Effect of native zinc solubilizing bacteria and zinc levels on growth, yield and economics of maize

Rakhi S Gandhar, Rahul R Pisal, Anshul Choudhary, Shikha Ojha and
Shruti M Patel

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Abstract

A field experiment entitled “Effect of native Zinc Solubilizing Bacteria and Zinc Levels on Growth and Yield Attributes of Maize” was conducted during the summer season of 2024-25 at the College Farm, N. M. College of Agriculture, Navsari Agricultural University, Navsari, Gujarat. The experiment was laid out in Randomized Block Design (RBD) with six treatments replicated four times using maize variety GM-6. Treatments comprised T₁ (Control), T₂ (Zinc solubilizing bacteria), T₃ (Zn at 5 kg/ha), T₄ (Zn at 10 kg/ha), T₅ (Zn solubilizing bacteria + Zn at 5 kg/ha) and T₆ (Zn solubilizing bacteria + Zn at 10 kg/ha). Treatment T₆ (Zn solubilizing bacteria + Zn at 10 kg/ha) significantly enhanced the growth and yield attributes of maize, recording higher dry matter accumulation (137.88 g/plant), number of grains per cob (263.0), grain weight per cob (50.16 g), cob weight (83.68 g), grain yield (3106 kg/ha) and stover yield (6314 kg/ha). The highest gross return (₹99,999/ha) and net return (₹57,208/ha) was achieved with T₆, closely followed by T₅ and T₄. The maximum B:C ratio (2.38) was observed under T₅, followed by T₆ (2.34).

Keywords: Maize, economics, growth attributes, yield attributes, zinc levels, zinc solubilizing bacteria

Introduction

Maize (*Zea mays* L.), commonly referred to as the “queen of cereals,” is the third most significant cereal crop globally following rice and wheat. It belongs to the poaceae family and is a versatile staple crop that thrives across various environmental conditions. Nutritionally, maize grain contains approximately 6.38% crude protein, 2.81% crude fat, 53.12% TDN, 22.5% hemicellulose and 32.9% cellulose (Noersidiq *et al.*, 2024) ^[10], though its primary protein zein lacks essential amino acids such as tryptophan and lysine. The crop is predominantly grown under rainfed conditions, typically requiring 300-500 mm of rainfall (Sah *et al.*, 2020) ^[12]. Globally, the United States continues to dominate maize production, with an estimated output of 432.34 million metric tonnes for 2025-26 (USDA). In the agricultural year 2025-26, India ranks as the sixth-largest maize producer globally, with approximately 144.08 lakh hectares under cultivation with a production of 550.93 lakh tonnes and an average productivity of 3824 kg/ha (Anon., 2025a). Madhya Pradesh leads in both area and production, followed by Karnataka, Maharashtra, Bihar and Andhra Pradesh. In Gujarat during 2025-26, maize occupied 414.72 thousand hectares with production of 949.85 thousand tonnes and an average productivity of 2290.75 kg/ha.

Widespread zinc deficiency in soils not only limits crop yields but also adversely affects the nutritional quality of food. Zinc plays a key role in various enzymatic, metabolic and redox reactions within plants. A deficiency in Zn disrupts the synthesis of carbohydrates, chlorophyll, auxins, cytochromes and nucleotides and compromises membrane stability (Das *et al.*, 2018) ^[5]. Studies suggest that 96-99% of applied Zn becomes unavailable in soil due to its transformation into insoluble forms, posing a significant challenge especially in calcareous soils. Zinc solubilizing bacteria (ZSB) residing in the rhizosphere convert insoluble Zn fractions into bioavailable forms through secretion of organic acids that lower soil pH (Dinesh *et al.*, 2018) ^[6]. Important ZSB genera include *Pseudomonas*, *Bacillus*, *Gluconacetobacter*, *Enterobacter* and *Azotobacter*. Besides Zn solubilization, ZSB possess multiple plant growth-promoting (PGP) traits including phosphorus and potassium solubilization, nitrogen fixation and production of IAA, gibberellic acid, siderophores and ACC deaminase (Senthil *et al.*, 2018) ^[14]. Maize is particularly

sensitive to Zn deficiency, especially in calcareous soils, where deficiency can severely impact grain yield and quality (Behera *et al.*, 2015) ^[4].

Materials and Methods

A field experiment was conducted during the summer season of 2024-25 at College Farm, N. M. College of Agriculture, Navsari Agricultural University, Navsari, Gujarat. Navsari falls under the South Gujarat Heavy Rainfall Zone-1 (Agro Ecological Situation III). The experimental soil was deep black clayey in texture and slightly alkaline in reaction. The experiment was laid out in a Randomized Block Design (RBD) with six treatments replicated four times (24 plots total). Maize variety GM-6 was sown at 20 kg/ha seed rate with 60 × 20 cm spacing on 24 February 2025. The recommended dose of fertilizer (RDF) was 120:60:00 N:P₂O₅:K₂O kg/ha. The six treatments evaluated were: T₁ - Control; T₂ - Zinc solubilizing bacteria; T₃ - Zn at 5 kg/ha; T₄ - Zn at 10 kg/ha; T₅ - Zn solubilizing bacteria + Zn at 5 kg/ha; and T₆ - Zn solubilizing bacteria + Zn at 10 kg/ha.

Maize seeds were treated by spraying 5 ml of ZSB culture (*Microbacterium paraoxydans*) per kg of seed, followed by shade-drying for 3 hours before sowing. Basal fertilizer comprised the full dose of phosphorus (*via* SSP) and 33% of recommended nitrogen (*via* Urea); remaining N was applied in two equal splits at knee-high and pre-tasseling stages. Zinc sulphate was applied as a basal dose at recommended rates as per treatments. Atrazine 50% WP was applied as a pre-emergence herbicide. Irrigation was given as per crop requirement. Harvesting was carried out at physiological maturity (98 DAS), followed by threshing and cleaning. In each net plot, five plants were randomly chosen and tagged for recording growth, yield attributes.

Statistical analysis

Data were statistically analysed using Randomized Block Design

methodology; significance of variance was tested by 'F' test and Critical Difference (CD) at 5% level of significance was computed (Panse and Sukhatme, 1985) ^[11].

Results and Discussion

Growth attributes

Dry matter accumulation at harvest was significantly influenced by different treatments. T₆ (ZSB + Zn at 10 kg/ha) recorded significantly higher dry matter accumulation of 137.88 g/plant, which was statistically at par with T₅ and T₄. Plant height and number of leaves per plant at harvest was not significantly influenced by the treatments, numerically higher plant height (177.84 cm) and number of leaves per plant (11.81) was recorded under T₆.

The progressive enhancement in dry matter accumulation under combined ZSB and zinc treatments can be attributed to the dual action of potassium nutrients directly inorganic zinc supplementation and microbial solubilization of native soil zinc fractions through production of organic acids by ZSB, which maintain a continuous supply of plant available zinc in the rhizosphere while simultaneously enhancing uptake of nitrogen and potassium nutrients directly governing photosynthesis, assimilate synthesis and overall biomass production. Similar findings were also reported by Goteti *et al.* (2013) ^[7], Verma *et al.* (2023) ^[17] and Khongchui *et al.* (2025) ^[8].

Yield attributes and yield

Application of T₆ (Zn solubilizing bacteria + Zn at 10 kg/ha) recorded the significantly highest number of grains per cob (263.0), grain weight per cob (50.16 g), cob weight (83.68 g), grain yield (3106 kg/ha) and stover yield (6314 kg/ha) over control, however these values are statistically at par with T₅ and T₄. In contrast, different treatments were failed to exert significant effect on number of cobs per plant, cob length, cob girth and seed index.

Table 1: Plant height, dry matter accumulation and number of leaves per plant of maize as influenced by different treatments

Treatments	Plant height (cm)	Dry matter accumulation (g/plant)	Number of leaves per plant
T ₁ Control	164.02	111.81	10.34
T ₂ Zinc solubilizing bacteria	168.48	117.70	10.63
T ₃ Zn at 5 kg/ha	169.32	122.65	10.88
T ₄ Zn at 10 kg/ha	171.15	130.04	11.17
T ₅ Zn solubilizing bacteria + Zn at 5 kg/ha	174.50	135.04	11.43
T ₆ Zn solubilizing bacteria + Zn at 10 kg/ha	177.84	137.88	11.81
S.Em±	8.82	5.04	0.44
CD at 5%	NS	15.34	NS
CV (%)	10.33	8.01	7.99

Table 2: Yield attributes and yield of maize as influenced by different treatments

Treatments	Number of cobs per plant	Number of grains per cob	Grain weight per cob (g)	Seed index (g)	Cob length (cm)	Cob girth (cm)	Cob weight (g)	Grain yield (kg/ha)	Stover yield (kg/ha)
T ₁	1.02	221.0	38.83	17.32	12.13	11.34	71.24	2353	4732
T ₂	1.04	230.3	41.27	18.02	12.91	11.57	72.83	2510	5198
T ₃	1.05	235.0	43.71	18.23	12.98	11.82	75.41	2649	5431
T ₄	1.07	256.3	47.71	18.89	13.04	12.11	78.62	2824	6023
T ₅	1.08	260.8	49.95	19.36	13.11	12.38	82.20	2945	6150
T ₆	1.10	263.0	50.16	19.67	13.87	12.65	83.68	3106	6314
S.Em±	0.04	9.2	2.12	0.69	0.64	0.53	2.73	125	217
CD at 5%	NS	28.0	6.45	NS	NS	NS	8.21	380	661
CV (%)	8.31	7.53	9.37	7.40	9.92	8.78	7.05	9.14	7.71

The improvement in grains per cob, grain weight, cob length, cob weight, grain yield and stover yield under combined ZSB and zinc treatments may be attributed to the important role of zinc in

enhancing photosynthesis (by activating carbonic anhydrase enzyme), promoting efficient translocation of photosynthates towards grains, auxin synthesis, chlorophyll formation, protein

synthesis and carbohydrate metabolism, which together improved plant growth and biomass production. These findings are consistent with research reported by Mumtaz *et al.* (2017)^[9], Bashir *et al.* (2021)^[3], Sasank and Dawson (2022)^[13] and Verma *et al.* (2023)^[17].

Economics

Among different treatments, the highest gross return (₹99,999/ha), net return (₹57,215/ha) was realized with T₆ (Zn solubilizing bacteria + Zn at 10 kg/ha) followed by T₅ and T₄ whereas in case of benefit cost ratio, the highest BCR value of 2.38 was obtained with T₅ (Zn solubilizing bacteria + Zn at 5 kg/ha) followed by T₆, T₄, T₂, T₃ and T₁. Similar findings were reported by Sasank and Dawson (2022)^[13] and Sukhwal *et al.* (2023)^[15].

Table 3: Economics of maize as influenced by different treatments

Treatments	Gross return (₹/ha)	Cost of cultivation (₹/ha)	Net return (₹/ha)	B:C Ratio
T ₁	75452	37371	38081	2.02
T ₂	81388	37430	43951	2.17
T ₃	85556	40259	45297	2.13
T ₄	92608	42725	49883	2.17
T ₅	95800	40318	55476	2.38
T ₆	99999	42784	57208	2.34
Selling price			Maize grain: 20 ₹/kg Maize stover: 6 ₹/kg	

Conclusion

The combined application of RDF with Zn at 10 kg/ha with ZSB treated seeds (T₆) was the most effective treatment, recording the highest growth attributes, yield attributes and yield of maize, followed closely by T₅ and T₄. However, T₅ (ZSB + Zn at 5 kg/ha) proved to be more profitable, giving the highest benefit:cost ratio, even though T₆ recorded the highest gross and net returns.

References

- Anonymous. All India crop-wise area, production and yield statistics. Unified Portal for Agricultural Statistics (UPAg), Department of Agriculture and Farmers Welfare, Government of India; 2025. <https://www.upag.gov.in>.
- Anonymous. Third advance estimates of area, production and yield of major kharif, rabi and summer crops of Gujarat State for the year 2025-26. Directorate of Agriculture, Government of Gujarat; 2025. <https://dag.gujarat.gov.in/Home/AreaProductionAndYield>.
- Bashir S, Basit A, Abbas RN, Naeem S, Bashir S, Ahmed N, Li Y. Combined application of zinc-lysine chelate and zinc-solubilizing bacteria improves yield and grain biofortification of maize (*Zea mays* L.). PLoS One. 2021;16(7):1-15.
- Behera SK, Shukla AK, Singh M, Wanjari RH, Singh P. Yield and zinc, copper, manganese and iron concentration in maize (*Zea mays* L.) grown on vertisol as influenced by zinc application from various zinc fertilizers. Journal of Plant Nutrition. 2015;38(10):1544-1557.
- Das SK, Avasthe RK, Singh M, Dutta SK, Roy A. Zinc in plant-soil system and management strategy. Agrica. 2018;7:1-6.
- Dinesh R, Srinivasan V, Hamza S, Sarathambala C, Anke Gowda SJ, Ganeshamurthy AN, *et al.* Isolation and characterization of potential Zn solubilizing bacteria from soil and its effects on soil Zn release rates, soil available Zn and plant Zn content. Geoderma. 2018;321:173-186.
- Goteti PK, Emmanuel LDA, Desai S, Shaik MHA. Prospective zinc solubilising bacteria for enhanced nutrient uptake and growth promotion in maize (*Zea mays* L.). International Journal of Microbiology. 2013;2013(1):1-7.
- Khongchiu P, Murase J, Wongkaew A, Sajjaphan K, Kumdee O, Rakpenthai A, *et al.* Effect of zinc application on maize dry matter, zinc uptake and soil microbial community grown under different paddy soil pH. Agronomy. 2025;16(1):1-18.
- Mumtaz MZ, Ahmad M, Jamil M, Hussain T. Zinc solubilizing *Bacillus* spp. potential candidates for biofortification in maize. Microbiological Research. 2017;202:51-60.
- Noersidiq A, Yanuarianto O, Fahrullah F, Maslami V, Hasma H. Nutrient content of corn straw (crude fibre, crude fat and TDN) caused by different doses of urea. Jurnal Pijar Mipa. 2024;19(4):673-677.
- Panse VG, Sukhatme PV. Statistical methods for agricultural workers. New Delhi: Indian Council of Agricultural Research; 1985.
- Sah RP, Chakraborty M, Prasad K, Pandit M, Tudu VK, Chakravarty MK, *et al.* Impact of water deficit stress in maize: phenology and yield components. Scientific Reports. 2020;10(1):1-15.
- Sasank SS, Dawson J. Response of different biofertilizers and zinc levels on growth and yield of maize (*Zea mays* L.). International Journal of Environment and Climate Change. 2022;12(11):237-243.
- Senthil Kumar CM, Jacob TK, Devasahayam S, Stephy T, Geethu C. Multifarious plant growth promotion by an entomopathogenic fungus *Lecanicillium psalliotae*. Microbiological Research. 2018;207:153-160.
- Sukhwal A, Jain D, Sharma V, Ojha SN, Jat G, Upadhyay SK, *et al.* Efficacy evaluation of newly isolated zinc solubilizing bacteria for their potential effect on maize (*Zea mays* L.) under zinc deficient soil conditions. Land Degradation and Development. 2023;34(16):4912-4923.
- U.S. Department of Agriculture, Foreign Agricultural Service. Grain and Feed Annual-India. Washington (DC): USDA Foreign Agricultural Service; 2025. <https://www.fas.usda.gov/data/production/0440000>.
- Verma D, Meena RH, Sukhwal A, Jat G, Meena SC, Upadhyay SK, Jain D. Effect of ZSB with graded levels of zinc fertilizer on yield and zinc uptake under maize cultivation. Proceedings of the National Academy of Sciences, India, Section B: Biological Sciences. 2023;93(2):379-385.