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Role of zinc solubilizing bacteria on yield and yield attributes of aerobic rice in low and high zinc soil

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Abstract

A pot culture experiment was performed in a screen house at the Department of Soils and Environment, Agricultural College and Research Institute, Madurai. The study utilized a short-duration rice variety, Anna-4 (derived from Pantdhan 10 × IET 9911), as the experimental crop. The research followed a factorial completely randomized block design and was conducted across two distinct soil types: a zinc-deficient soil from the Madukkur series and a high-zinc soil from the Vyalogam series. The treatment consists of different combinations viz., Absolute control (T₁), 100% RDF alone (T₂) and 100% RDF + ZSB (T₃). The highest yield attributes (number of tillers per plant, number of panicles per plant and number of grains per panicle) and yield (straw and grain) was registered by soil application of 100% RDF + ZSB in both low and high zinc soil in comparison with inorganic fertilization. This study, the first of its kind, aimed to assess the efficiency of zinc-solubilizing bacteria (ZSB) on the growth of aerobic rice in soils with both low and high zinc levels. The results indicate that ZSB application, in combination with the recommended dose of fertilizer (RDF), has a significant positive effect on both crop growth and soil fertility.

Keywords: Aerobic rice, zinc solubilizing bacteria, Madukkur series, Vyalogam series

Introduction

Rice serves as a fundamental global cereal and the primary dietary staple for populations across Asia. As a historical hub for rice cultivation, India manages approximately 44 million hectares dedicated to this crop (Harbinson *et al.*, 2021) [2]. To address growing water scarcity, the aerobic rice system has been developed; this method enhances water productivity and conservation by minimizing requirements during land preparation and reducing losses from evaporation, seepage, and percolation. Aerobic rice also reduces labour requirement and greenhouse gas emission from rice field. In an aerobic rice system, the crop can be direct-seeded or transplanted and soils are kept aerobic throughout the growing season (Vijayakumar *et al.*, 2018) [8]. Supplemental irrigation is applied as and when necessary. Aerobic rice cultivars are adapted to aerobic soils and have higher yield potential than traditional upland cultivars. Grain yields of 5-6 t ha⁻¹ can be obtained in aerobic rice system. However, yield decline or even complete failure of aerobic rice under continuous monocropping threatens the widespread adoption of aerobic rice technology (Kumar *et al.*, 2021) [3].

Voluminous literature indicated that Zn concentration in the grain is inherently very low, particularly when grown on Zn-deficient soils. Customary application of inorganic zinc partially caters the plant need as 96-99% of applied Zn is converted into different insoluble forms depending upon the soil types and physicochemical reactions within 7 days of application (Rassaei *et al.*, 2020) [7]. Microbes are potential alternates that could cater to plant zinc requirement by

solubilising the complex zinc in soil. Several genera of rhizobacteria belonging to *Pseudomonas* spp. and *Bacillus* spp. are reported to solubilise Zinc. Microbes solubilise the metal forms by protons, chelated ligands, and oxido-reductive systems present on the cell surface and membranes (Bhakat *et al.*, 2021) [1]. These bacteria also exhibit other traits beneficial to plants, such as production of phytohormones, antibiotics, siderophores, vitamins, antifungal substances, and hydrogen cyanide.

Materials and Methods

This chapter details the methodology and analytical techniques employed in the pot culture experiment, which investigated the growth of aerobic rice in soils with varying zinc levels (low and high). Pots with an 8 kg capacity and dimensions of 25 cm by 15 cm were filled with zinc-deficient or high-zinc soil and sown with the paddy seed (Anna-4). According to the specific treatment combinations, the soil was mixed with 200 g of vermicompost and 200 g of diammonium phosphate (DAP). Paddy seeds were surface sterilized and then imbibed in 5 ml of zinc-solubilizing bacterial suspension (1×10⁹ CFU ml⁻¹) for four hours. For the control group, seeds were imbibed in 5 ml of sterile distilled water for the same duration. Six seeds were subsequently planted in each pot and watered, with each treatment replicated in four pots. The physical and chemical characteristics of experimental soil with low zinc were neutral in pH (6.7) and non-saline with an EC of 0.21 dS m⁻¹. The available nitrogen, phosphorus and potassium content of soil was 182, 11.16, 240 kg ha⁻¹ respectively with low,

high and high status of soil fertility respectively. The DTPA extractable Zinc, Copper, Iron and Manganese content recorded were 0.86, 0.24, 3.9, 4.6 mg kg⁻¹ respectively. The experimental soil with a high Zn belonged to a pH of 6.5 and EC of 0.31 dSm⁻¹. The available nitrogen, phosphorus and potassium of experimental soil was 230, 13.48 and 252 kg ha⁻¹ respectively which was categorized as low, high, high status of soil fertility. The DTPA extractable Zn, Cu, Fe, Mn was 1.71, 0.24, 2.7 and 3.7 mg kg⁻¹ respectively. The research followed a factorial completely randomized block design and was conducted across two distinct soil types: a zinc-deficient soil from the Madukkur series and a high-zinc soil from the Vyalogam series. The treatment consists of different combinations viz., Absolute control (T₁), 100% RDF alone (T₂) and 100% RDF + ZSB (T₃).

Results and Discussion

The application of Zinc solubilizing bacteria with 100% RDF was significantly higher than all the treatments and recorded the maximum number of tillers per plant, number of panicles per plant and number of grains per panicle (Table 1). This best treatment recorded the maximum number of tillers of 9.81 and 7.12 in low Zinc and high Zinc soil respectively. The number of panicles per plant ranged from 7.5 to 8.5 and 5.23 to 6.12 in low Zinc soil and high Zinc soil respectively where the maximum was recorded

with the soil application of 100% RDF+ZSB (T₃) was applied. The maximum number of grains per panicle of 146 in low Zinc soil and 132 in high Zinc soil was registered by 100% RDF+ZSB (T₃). The increase recorded in growth and yield attributes could be attributed to higher mobilization of Zn by Zn solubilising bacteria. Similar results were obtained by Minaxi *et al.* (2013)^[6].

The highest grain and straw yield were recorded by the combined application of 100% RDF + ZSB in both the experimental soils and was distinctly superior over absolute control. On close examination of grain yield of rice as furnished in Table 2, a significant increase was recorded by soil application of 100% RDF+ZSB (T₃) over the other treatments, recording a maximum grain yield of 23.45 g pot⁻¹ and 20.11 g pot⁻¹ in low Zinc soil and high Zinc soils, respectively. Among the different treatments imposed, the soil application of 100% RDF+ZSB (T₃) recorded the maximum straw yield of 46.30 g pot⁻¹ and 42.89 g pot⁻¹ in low Zinc and high Zinc soils, respectively. The higher grain and straw yield obtained was due to the favourable influence of steady, consistent and adequate availability of nutrients during the required stages of crop growth, favouring the production of photosynthates coupled with better partitioning to the sink, under higher level of nutrition. These results are in conformity with those of Maheswari *et al.* (2008)^[4] and Malla Reddy *et al.* (2012)^[5].

Table 1: Yield attributes of Aerobic Rice in low and high Zinc soils

Treatments	Yield Attributes					
	Low Zinc Soil			High Zinc Soil		
	Productive tillers plant ⁻¹	Total no. of Panicles plant ⁻¹	No. of grains panicle ⁻¹	Productive tillers plant ⁻¹	Total no. of Panicles plant ⁻¹	No. of grains panicle ⁻¹
T ₁ Absolute control	7.86	7.50	98	5.48	5.23	89
T ₂ 100% RDF alone	8.17	7.17	132	6.55	5.98	125
T ₃ 100% RDF + ZSB	9.81	8.50	146	7.12	6.12	132
Mean	8.61	7.72	125.33	6.38	5.77	115.33
SEd	0.12	0.15	1.48	0.07	0.10	0.66
CD (p=0.05)	0.28	0.35	3.36	0.17	0.22	1.50

Recommended dose of fertilizer = 150:50:50 kg of N: P₂O₅: K₂O ha⁻¹ ZSB = Zinc Solubilizing Bacterium

Table 2: Grain and Straw yield of Aerobic Rice in low and high Zinc soils

Treatments	Yield			
	Low Zinc Soil		High Zinc Soil	
	Grain yield (g pot ⁻¹)	Straw yield (g pot ⁻¹)	Grain yield (g pot ⁻¹)	Straw yield (g pot ⁻¹)
T ₁ Absolute control	18.8	41.20	16.5	39.56
T ₂ 100% RDF alone	20.56	44.22	19.23	42.13
T ₃ 100% RDF + ZSB	23.45	46.30	20.11	42.89
Mean	20.93	43.90	18.61	41.52
SEd	0.54	0.59	0.49	0.70
CD (p=0.05)	1.08	1.34	0.98	1.58

Recommended dose of fertilizer = 150:50:50 kg of N: P₂O₅: K₂O ha⁻¹ ZSB = Zinc Solubilizing Bacterium

Conclusion

The present investigation revealed that the yield attributes namely viz., productive tillers per plant, total number of panicles per plant and number of grains per panicle were also significantly influenced by the combined application of 100% RDF + ZSB. Application of 100% RDF (150:50:50) + ZSB (T₃) recorded the highest grain yield of 23.45 g⁻¹ pot in low zinc soil and 20.11 g⁻¹ pot in high zinc soil. Application of 100% RDF (150:50:50) + ZSB (T₃) recorded the highest straw yield of 46.30g⁻¹ pot in low zinc soil and 42.89 g⁻¹ pot

in high zinc soil. This research is a preliminary attempt to increase the growth and yield of aerobic rice using microbial cultures in low zinc soils. It could be concluded from the present study, that the application of zinc solubilizing bacteria can be a viable microbial culture to enhance the yield and growth of aerobic rice crop. However, research on use of Zinc solubilizing bacteria with different treatment combinations and the effectiveness of Zinc solubilizing bacteria at field levels is yet to be ascertained.

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