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Effect of zinc solubilizing bacteria in enhancing growth attributes of aerobic rice in low and high zinc soil

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Abstract

Zinc deficiency in soil poses a significant threat to agricultural productivity due to its importance in plant and human metabolism. This study explores the impact of zinc-solubilizing bacteria (ZSB) on growth of aerobic rice in low and high zinc soil. A pot experiment was conducted at the Agricultural College and Research Institute in Madurai within the Department of Soils and Environment. The study used the short-duration rice variety Anna-4 (a cross between Pantdhan 10 and IET 9911) as the test subject. Using a factorial completely randomized block design, the experiment utilized two distinct soil series: the zinc-deficient (Madukkur series) and the zinc-rich (Vyalogam series). The treatment consists of different combinations viz., Absolute control (T_1), 100% RDF alone (T_2) and 100% RDF + ZSB (T_3). The maximum growth attributes of aerobic rice (root length, shoot length and number of root hairs) were registered by soil application of 100% RDF + ZSB. As a pioneering study, this investigation evaluated aerobic rice growth in both low and high zinc soil to measure the effectiveness of zinc-solubilizing bacteria (ZSB). The results demonstrated that applying ZSB along with the recommended dose of fertilizer (RDF) significantly enhances both crop productivity and soil nutrient status.

Keywords: Low zinc soil, zinc solubilising bacterium, aerobic rice, high zinc soil

Introduction

Rice (*Oryza sativa* L.) accounts for more than 20% of the world's caloric consumption and serves as the primary source of income and food security for over three billion people throughout Asia. Rice production was reported as 34.6 million tonnes (mt) during 1960-1961, which is expected to rise to 122.3 mt, during 2020-2021 (PBAS 2020; PIB 2021) ^[10,11]. It is estimated that more than 30% of people globally suffer from Zinc deficiency (White *et al.*, 2009) ^[15]. Zinc deficiency disrupts multiple biological and physiological functions in plants, such as carbohydrate metabolism, regulation of cell turgor, and protein synthesis. At the same time, increasing water scarcity is driving a transition from flooded to aerobic rice cultivation systems, a change that can significantly alter zinc availability in soils (Hafeez *et al.*, 2013) ^[7]. Zinc deficiency in rice is a major cause of yield losses worldwide. Under adequate nutrition, zinc concentrations in rice tissues generally range from about 35 to 100 ppm, while deficiency symptoms begin to appear when tissue zinc levels fall below 20 ppm (Singh and Prasad, 2014) ^[12]. The increasing shortage of water resources has led to the development and adoption of aerobic rice system, which saves water input and increases water productivity by reducing water use during land preparation and limiting seepage, percolation, and evaporation. Aerobic rice also reduces labour requirement and greenhouse gas emission from rice field. Chaudhary *et al.*, 2007 ^[5] reported Zn deficiency as a key factor in determining the rice production in several parts of India. According to Singh (2009) ^[13], 48% soils in India are affected with Zn deficiency. In rice, Zn deficiency causes

multiple symptoms that usually appear 2 to 3 weeks after transplanting (WAT) rice seedlings; leaves develop brown blotches and streaks that may fuse to cover older leaves entirely, plants remain stunted and in severe cases may die also, while those which recover show substantial delay in maturity and reduction in yield. The aftermath of low Zn consumption is the impairment in growth and immune functions leading to infectious diseases such as diarrhoea and pneumonia in the developing world (Volkmar and Bremer, 1998) ^[14]. Brain function and development is also significantly affected by Zn deficiency, mainly in newborns (Benton, 2008) ^[2]. Zinc deficiency was found to be one of the major reasons for child death worldwide, and was responsible for nearly 4, 50,000 deaths in children less than 5 years of age (Black *et al.*, 2008; Cakmak, 2010) ^[3, 4]. According to a report published in 2002 by WHO, Zn deficiency is considered as the fifth most important risk factor responsible for illness and death in the developing world. In human body, Zn plays an important role in maintaining the structure and function of large number of macromolecules and is also found responsible for controlling over 300 enzymatic reactions. The use of chemical fertilizers and manures, to enhance soil fertility and crop productivity has often negatively affected the complex biogeochemical cycles. Continuous application of fertilizers as well as their low use efficiency has caused leaches and runoff of nutrients, especially N and P leading to environmental degradation. On the other hand, high cost associated with the application of Zn fertilizers in order to correct Zn deficiency pays considerable burden on resource poor farmers.

Materials and Methods

Pot culture experiment

A pot culture experiment was conducted in the Glass house of the Department of Soils and Environment, Agricultural College and Research Institute, Madurai to study the growth of aerobic rice in low and high zinc soil as affected by Zinc Solubilizing Bacteria in comparison with control. It was conducted during Rabi 2016 with short duration Anna 4 (Parentage Pantdhan10/ IET 9911) as test crop in low and high zinc soil with different treatmental combinations in a factorial completely randomized block design replicated four times. Paddy seed (variety Anna 4) was surface sterilized and imbibed in 5 ml of Zinc solubilizing bacterial suspension (1×10^9 CFU ml⁻¹) for 4 hours. Six seeds were placed in a pot; and irrigated immediately; four pots were used for each treatment. In case of control, seeds were imbibed in 5ml of sterile distilled water for 4 hours. 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 recorded DTPA extractable Zn, Cu, Fe, Mn of 1.71, 0.24, 2.7 and 3.7 mg kg⁻¹ respectively. The treatment consists of different combinations viz., Absolute control (T₁), 100% RDF alone (T₂) and 100% RDF + ZSB (T₃) with recommended dose of fertilizer = 150:50:50 kg of N: P₂O₅: K₂O ha⁻¹.

Observations recorded

Growth attributes viz., root length, root hairs and shoot length were recorded in low and high zinc soils of aerobic

rice and expressed in cm, numbers and cm respectively.

Results and Discussion

Root length

The effect of seed treatment with zinc solubilising bacteria along with combination of inorganic fertilizers on root length of aerobic rice at different stages revealed a significant increase over control. The values ranged from 5.20 to 14.20, 8.30 to 20.50 and 12.10 to 25.20 cm during tillering, panicle initiation and at post-harvest stages, respectively in low zinc soil. With respect to high zinc soil the root length ranged from 6.22 to 11.20 cm, during tillering stage, 8.10 to 22.15 cm during panicle initiation and 10.50 to 23.40 cm during post-harvest stage. Application of RDF with ZSB recorded the maximum root length of 25.20 cm in low zinc soil and 23.40 cm in high zinc soil at post-harvest stage, the maximum number of root length was marked by the application of zinc solubilizing bacteria in both the soils as depicted in Table 1. This might be due to the bacterial isolate responsible for production of phytohormone which is responsible for increasing the length of the root hairs which could promote better absorption of nutrients from the soil. According to Volkmar and Bremer, (1998) [14] rapid establishment of roots including elongation of primary roots or proliferation of lateral/ adventitious roots is advantageous for young seedlings as it increases their ability to explore the soil to easily obtain water and nutrients.

Table 1: Root Length of Aerobic Rice at different growth stages of in low and high Zinc soils

Treatments	Root Length (cm)					
	Low Zinc Soil			High Zinc Soil		
	35DAS	45DAS	Harvest	35DAS	45DAS	Harvest
T ₁ Absolute control	5.20	8.30	12.10	6.22	8.10	10.50
T ₂ 100% RDF alone	10.13	15.11	19.00	8.30	14.20	17.80
T ₃ 100% RDF + ZSB	14.20	20.50	25.20	11.20	22.15	23.40
Mean	9.84	14.63	18.76	8.57	14.81	17.23
SEd	0.22	0.20	0.53	0.02	0.20	0.44
CD (p=0.05)	0.51	0.44	1.06	0.05	0.47	0.87

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

Shoot length

In both the soils experimental soils, viz., low zinc and high zinc soils, the length of shoot was longer in the treatment of RDF with ZSB and has recorded least shoot length in absolute control. In low zinc soil, the shoot length varied from 37.20 to 52.10 cm, 48.30 to 65.10 cm and 58.24 to 72.45 cm during tillering, panicle initiation and at post-harvest stage. The longer shoot length of 52.10, 65.10 and 72.45cm was recorded by the application of 100% RDF (150:50:50) and ZSB at tillering, panicle initiation and post-harvest stages respectively as depicted in Table 2. There was a significant increase in shoot length over absolute control in high zinc soil at different growth stages. The treatmental mean values extended from 38.20 to 51.20 cm, 46 to 66.20 cm and 59.10 to 69.60 cm tillering, panicle initiation and post-harvest stages respectively. Nitrogen application thus results in growth of shoot system, which ultimately helps to increase the straw yield. Nayak *et al.* (1986) [9] reported that ZSB inoculation can increase height and number of tillers in rice plants. They mentioned that

PGPR treatment increases chlorophyll content in plants and thereby enhances the rate of photosynthesis leading to improved overall plant health. Similar observations were reported by Mohite, (2013) [8].

Table 2: Shoot Length of Aerobic Rice at different growth stages of in low and high Zinc soils

Treatments	Shoot Length (cm)					
	Low Zinc Soil			High Zinc Soil		
	35DAS	45DAS	Harvest	35DAS	45DAS	Harvest
T ₁ Absolute control	37.20	48.30	58.24	38.20	46.00	59.10
T ₂ 100% RDF alone	48.51	63.50	64.15	47.40	64.10	62.12
T ₃ 100% RDF + ZSB	52.10	65.10	72.45	51.20	66.20	69.60
Mean	45.93	58.96	64.94	44.94	58.76	63.60
SEd	0.62	0.58	1.16	0.40	1.06	0.32
CD CD (p=0.05)	1.41	1.32	2.63	0.91	2.40	0.73

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

Root hairs

Increasing trend of root hairs was observed during the growth stages in both the experimental soil. The mean values irrespective of growth stages ranged from 15 to 32, 24 to 52, 36 to 63 in low zinc soils and 18 to 29, 27 to 50, 40 to 58 in high zinc soils (Table 3). The maximum number of root hairs registered in low zinc and high zinc soils during the harvest stage is 63 and 58 numbers respectively, by treating the seeds with zinc solubilizing bacterial culture and 100% RDF. One of the most commonly reported plant

growth promotion mechanism by bacteria is the challenging of morphological and physiological changes in root system (Dalla *et al.*, 2004)^[6]. An increase in number of lateral roots and root hairs cause addition of root surface available for nutrients and water uptake. Higher water and nutrient uptake by inoculated roots caused an improved water status of plant, which in turn could be the main factor enhancing plant growth (Bai *et al.*, 2003 and Wu *et al.*, 2005)^[1,16]. The maximum number of root hairs was recorded by application of zinc solubilizing bacteria in both the soils.

Table 3: Number of Root hairs of Aerobic Rice at different growth stages of in low and high Zinc soils

Treatments	Root Hairs (numbers)					
	Low Zinc Soil			High Zinc Soil		
	35DAS	45DAS	Harvest	35DAS	45DAS	Harvest
T ₁ Absolute control	15	24	36	18	27	40
T ₂ 100% RDF alone	23	36	50	20	34	48
T ₃ 100% RDF + ZSB	32	52	63	29	50	58
Mean	23.33	37.33	49.66	22.33	37.00	48.61
SEd	0.46	0.61	0.68	0.29	0.78	0.51
CD (p= CD (p=0.05)	0.99	1.38	1.55	0.65	1.77	1.16

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 application of 100% RDF (150:50:50) + ZSB influenced the root of both the experimental soils at all growth stages. Other growth attributes namely viz., root length and number of root hairs were also significantly influenced by the combined application of 100% RDF + ZSB. This study represents a preliminary effort to improve the growth and yield of aerobic rice through the use of microbial cultures in zinc-deficient soils. The results suggest that the application of zinc-solubilizing bacteria has the potential to serve as an effective microbial inoculant for enhancing the growth and productivity of aerobic rice. Nevertheless, further research is required to evaluate different treatment combinations involving zinc-solubilizing bacteria and to verify their effectiveness under field-level conditions.

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