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Effect of Zn solubilizer on Zn solubilizing potential in Inceptisol of Indo-Gangetic alluvial plain

KIRAN KUMAR MOHAPATRA, SATISH KUMAR SINGH* AND ABHIK PATRA

Department of Soil Science and Agricultural Chemistry, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi-21105, India

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ABSTRACT

An incubation study was conducted in laboratory at Banaras Hindu University, Varanasi (U.P.) to study the effect of zinc solubilizer (Zn SB) and inorganic zinc fertilizer on Zn release pattern in Inceptisol of middle Gangetic plain of Uttar Pradesh. In the present study, five different doses of $ZnSO_4$ (0, 1.25, 2.50, 5.00 and 10.0 mg kg^{-1}) along with 3 different doses of Zn SB (0, 2 and 4 ml kg^{-1}) were evaluated in completely randomized design with three replications. The amount of available Zn in soil at 10, 20, 30 and 45 days after incubation (DAI) was assayed and it was found that DTPA extractable Zn increased with incubation period and it was maximum (1.4 to 9.8mg Zn kg^{-1}) at 30 DAI. After 45 DAI, there was more than 1.2 to 3.6 folds' increase in cumulative available Zn content with Zn SB inoculated samples as compared to non-inoculated one. The highest mineralization of Zn (28.3 mg kg^{-1}) was recorded with 10 kg Zn ha^{-1} along with 4ml ZnSBkg^{-1}. Thus, use of Zn SB could be beneficial for increasing solubilisation of Zn in soil and its consequent availability to plants.

Keywords: Inceptisol, incubation study, zinc, Zn release pattern, Zn solubilizer

INTRODUCTION

Zinc is considered as the fifth most important yield limiting nutrient (following N, P, K, and S) in upland and second for low land crop production only after N. Zinc deficiency was reported widespread in soils and crops throughout the world. Almost 40% of Indian soils were found deficient in plant available Zn (Shukla and Tiwari 2016). Zinc plays an essential role for the growth and development of plant. It plays a very important role in photosynthesis, integrity of the membrane, synthesis of proteins, pollen formation and maintenance of immunity system (Alloway 2008). Its deficiency limits the degree of the phytohormones in plant tissues, leading to cell growth impairment. Even though the plant demands Zn in micro concentration, depending on different soil factors, its bio available fraction in soil was very low (Alloway 2009). Some soils cannot allow plant growth despite having a sufficient amount of Zn due to poor bioavailability of Zn. DTPA extractable Zn content of the soils increased with application of zinc sulphate in intensive cultivated areas of Haryana and Punjab states. Singh *et al.* (2016) reported that33.1% soils of Eastern Uttar Pradesh were deficient in Zn and DTPA extractable Zn content in soils of Varanasi district ranged from 0.03 to 5.36 mg kg^{-1}.The bio available Zn content in soils increased by integrating and managing inorganic, organic and biological sources of plant nutrients to maintain soil health for sustainable agricultural production. Mineral fertilizers are considered as a good source of Zn but they quickly fixed to the soil matrix resulting in poor plant availability (Singh, 2018). Increasing the bioavailability of Zn to plants through solubilizing fixed Zn and/or reducing the fixation of applied Zn fertilizers was crucial to enhance the bioavailable fraction of Zn. This could be achieved either by using Zn solubilizing biofertilizers and/or by combined application of zinc solubilizing bacteria (ZnSB) and Zn fertilizers. An important mechanism for solubilizing Zn was the production of organic acid by microbial strains. Zinc solubilizing *Bacillus* strains solubilize unavailable Zn by producing chelating ligands, organic acids, amino acids, vitamins and phytohormones (Saravanan *et al.* 2007). To understand the impact of Zn solubilizing bacteria (ZnSB) on bio-available Zn release pattern in soil, the present incubation study was conducted in Inceptisol of middle Gangetic plain of Uttar Pradesh, India.

*Corresponding author e-mail: sksingh_1965@rediffmail.com

MATERIALS AND METHODS

The Inceptisol of Indo-Gangetic plain alluvial was collected from the Agricultural Research Farm, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi for the incubation study. Soils were collected from the 0–15 cm soil layer, air dried and sieved through 2 mm sieve. The initial soil was sandy clay loam in texture. The soil had an alkaline pH of 7.71, EC 0.13 dS m^{-1} and organic carbon 8.01 g kg^{-1}. The initial soil was low in available N (275 kg ha^{-1}), medium in available K (179 kg ha^{-1}) while, high in available P (22 kg ha^{-1}), and available S (29 kg ha^{-1}). The available Fe, Mn, Zn, Cu and B concentrations were 45.2, 13.2, 1.20, 5.20 and 0.29 mg kg^{-1}, respectively. The initial soil had Zn content above critical limit *i.e.,* 1.20 mg kg^{-1}, which mean soil was sufficient in available Zn.

In each plastic glass 200g processed soil sample was taken and total 45 glasseswere used. The incubated soil sample was treated with compost, $ZnSO_4$ and Zn solubilizing bacteria (genus of *Bacillus*).The compost was amended @ 0.5% w/w into the soil, and mixed thoroughly. The experiment was laid down in completely randomised design with fifteen treatments *viz.,*T_1: Zn (0 kg ha^{-1}) + ZnSB (0 ml kg^{-1}), T_2: Zn (0 kg ha^{-1}) + ZnSB (2 ml kg^{-1}), T_3: Zn (0 kg ha^{-1}) + ZnSB (4 ml kg^{-1}), T_4: Zn (1.25 kg ha^{-1}) + ZnSB (0 ml kg^{-1}), T_5: Zn (1.25 kg ha^{-1}) + ZnSB (2 ml kg^{-1}), T_6: Zn (1.25 kg ha^{-1}) + ZnSB (4 ml kg^{-1}), T_7: Zn (2.50 kg ha^{-1}) + ZnSB (0 ml kg^{-1}), T_8: Zn (2.50 kg ha^{-1}) + ZnSB (2 ml kg^{-1}), T_9: Zn (2.50 kg ha^{-1}) + ZnSB (4 ml kg^{-1}),T_{10}: Zn (5 kg ha^{-1}) + ZnSB (0 ml kg^{-1}), T_{11}: Zn (5 kg ha^{-1}) + ZnSB (2 ml kg^{-1}), T_{12}: Zn (5 kg ha^{-1}) + ZnSB (4 ml kg^{-1}), T_{13}: Zn (10 kg ha^{-1}) + ZnSB (0 ml kg^{-1}), T_{14}: Zn (10 kg ha^{-1}) + ZnSB (2 ml kg^{-1}), and T_{15}: Zn (10 kg ha^{-1}) + ZnSB (4 ml kg^{-1}). Each treatments combination had replicated thrice. The water-filled porosity of the incubation chamber was brought up to 85%, WFP (maintained by weight monitoring) for a period of 6 weeks. Soil sample from each treatment was taken at 10, 20, 30, and 45 days after incubation (DAI) periods and analysed for plant available Zn *i.e.,* DTP Aextractable Zn (Lindsay and Norvell 1978) and estimation of Zn was done by atomic absorption spectrophotometer (Agilent FS 240) using Zn cathode lamps. The observations on the various traits were summarised by completely randomised design using statistical software SPSS 16.0. Using the Duncan Multiple Range Test (DMRT) significant differences within treatments means were detected.

RESULTS AND DISCUSSION

Significant variation in DTPA extractable Zn was observed among all the treatments at all intervals of the incubation study (Table 1 and Fig. 1). The release of DTPA extractable Zn increased at 30 DAI and thereafter it decreased till 45 DAI in all the treatments. After ten days of $ZnSO_4$addition the highest DTPA extractable Zn (7.62 mg kg^{-1}) was recorded at 10 kg Zn ha^{-1} + 0 ml Zn SB kg^{-1} and the lowest (0.19 mg Zn kg^{-1}) at 0 kg Zn ha^{-1}. There was more than 40.6 folds' increase in plant available Zn under 10 kg Zn ha^{-1} + 0 ml Zn SB kg^{-1} treatment as compared to 0 kg ha^{-1}. After 20 DAI, the highest mineralized Zn (9.00 mg kg^{-1}) was recorded at 10 kg Zn ha^{-1} + 4 ml Zn SB kg^{-1} and it was significantly higher over other treatments and the lowest DTPA extractable Zn (0.86 mg kg^{-1}) was recorded at 0 kg Zn ha^{-1}. The treatment 2.50 kg Zn ha^{-1} + 4 ml Zn SB kg^{-1} showed maximum Zn mineralization ability at 30 DAI, which was at par with 10 kg Zn ha^{-1} + 4 ml Zn SB kg^{-1} but statistically higher over others. Except 0 kg Zn ha^{-1} + 4 ml ZnSB kg^{-1}, the Zn mineralization ability was fell down in other treatments at 45 DAI and the highest mineralized Zn (6.85 mg kg^{-1}) was observed at 0 kg Zn ha^{-1} + 4 ml ZnSB kg^{-1}. It was observed that most of the Zn became unavailable when solely $ZnSO_4$ was applied and immobilization of Zn was increased with increasing doses of Zn fertilizer. However, co-application of Zn fertilizer and Zn SB resulted higher mobilization of plant available Zn in soil and Zn release was enhanced significantly with higher doses of Zn SB addition. Several bacterial species have been reported to solubilize insoluble Zn compounds in liquid medium (Saravanan *et al.* 2007) and soil (Tariq *et al.* 2007).

Table 1: Incubation study related to release of DTPA extractable Zn in soil

Treatments		DTPA extractable Zn (mg kg^{-1})			
		10 DAI*	20 DAI	30 DAI	45 DAI
T_1	Zn (0 kg ha^{-1}) + ZnSB$^{\#}$ (0 ml kg^{-1})	0.19^{h}	0.86^{k}	1.40^{d}	1.16^{g}
T_2	Zn (0 kg ha^{-1}) + ZnSB (2 ml kg^{-1})	0.61^{g}	1.24^{k}	1.61^{cd}	1.22^{fg}
T_3	Zn (0 kg ha^{-1}) + ZnSB (4 ml kg^{-1})	0.70^{g}	1.64^{jk}	3.18^{bcd}	6.85^{a}
T_4	Zn (1.25 kg ha^{-1}) + ZnSB (0 ml kg^{-1})	1.58^{f}	2.31^{ij}	4.7^{abcd}	3.20^{cde}
T_5	Zn (1.25 kg ha^{-1}) + ZnSB (2 ml kg^{-1})	1.40^{f}	2.65^{hi}	5.43^{abcd}	3.91^{bcd}
T_6	Zn (1.25 kg ha^{-1}) + ZnSB (4 ml kg^{-1})	1.61^{f}	3.28^{gh}	5.43^{abcd}	4.72^{b}
T_7	Zn (2.50 kg ha^{-1}) + ZnSB (0 ml kg^{-1})	3.10^{e}	3.90^{fg}	3.54^{bcd}	3.42^{bcde}
T_8	Zn (2.50 kg ha^{-1}) + ZnSB (2 ml kg^{-1})	2.90^{e}	4.20^{ef}	6.14^{abc}	4.35^{bc}
T_9	Zn (2.50 kg ha^{-1}) + ZnSB (4 ml kg^{-1})	3.00^{e}	5.11^{d}	9.80^{a}	2.60^{def}
T_{10}	Zn (5 kg ha^{-1}) + ZnSB (0 ml kg^{-1})	3.80^{d}	4.82^{de}	3.09^{bcd}	1.33^{fg}
T_{11}	Zn (5 kg ha^{-1}) + ZnSB (2 ml kg^{-1})	3.52^{d}	5.60^{d}	3.33^{bcd}	1.51^{fg}
T_{12}	Zn (5 kg ha^{-1}) + ZnSB (4 ml kg^{-1})	3.72^{d}	6.52^{c}	4.93^{abcd}	1.60^{fg}
T_{13}	Zn (10 kg ha^{-1}) + ZnSB (0 ml kg^{-1})	7.62^{a}	7.37^{b}	5.34^{abcd}	2.41^{efg}
T_{14}	Zn (10 kg ha^{-1}) + ZnSB (2 ml kg^{-1})	6.30^{c}	8.10^{b}	7.35^{ab}	3.10^{cde}
T_{15}	Zn (10 kg ha^{-1}) + ZnSB (4 ml kg^{-1})	6.80^{b}	9.00^{a}	8.9^{a}	3.51^{bcde}
	SEm ±	0.09	0.25	1.35	1.35
	CD(p=0.05)	0.29	0.78	4.09	4.09

*DAI: Days after incubation; $^{\#}$ZnSB: Zn solubilizing bacteria

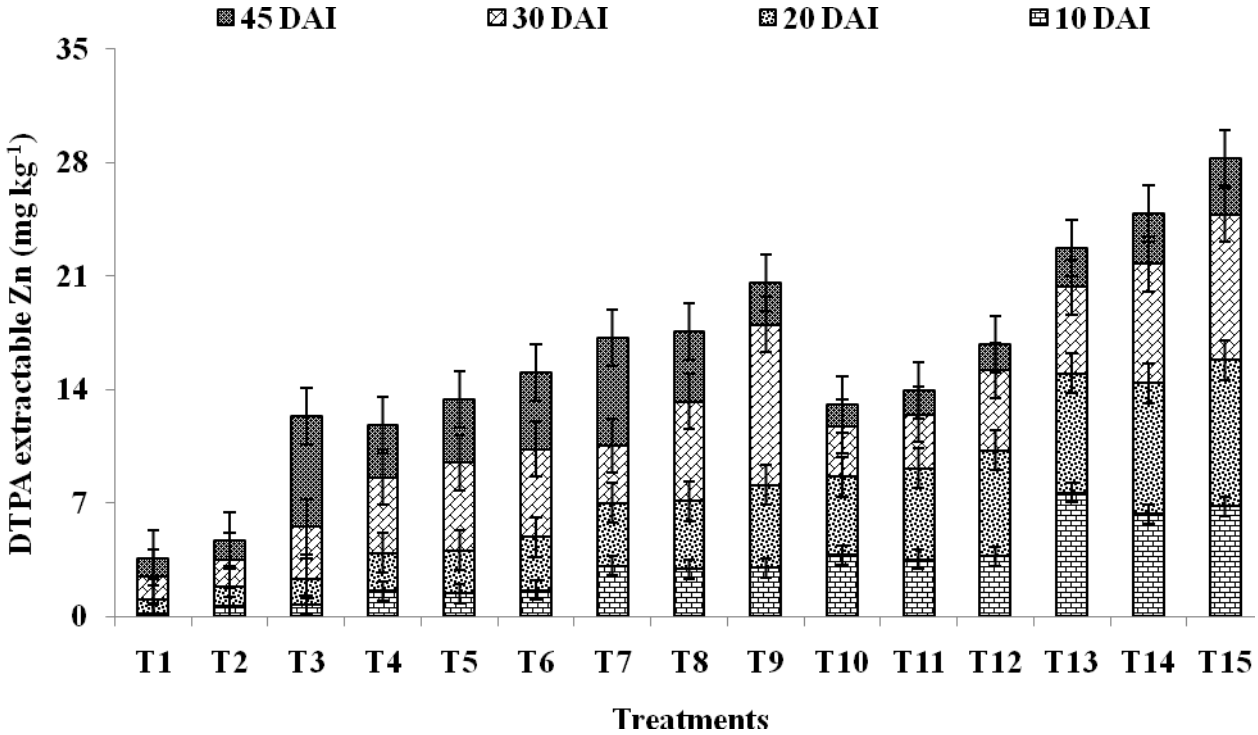

Figure 1: Release pattern of DTPA extractable Zn in soil at 10, 20, 30 and 45 days after incubation

The cumulative release pattern of DTPA extractable Zn was shown in Figure 2. It was observed that up to 10 DAI the performance of Zn SB was less effective but as the incubation period increases it's Zn release potential was increased significantly over solely Zn fertilized treatments. This may be due to the fact that Zn SB enhances the Zn mineralization. The maximum DTPA extractable Zn mineralization was in 10 kg Zn ha^{-1} + 4 ml Zn SB kg^{-1}at 45 DAI. After 45 days of incubation study, there was more than 1.2 to 3.6 folds' increase in cumulative available Zn content in Zn SB inoculated treatments as compared to non-

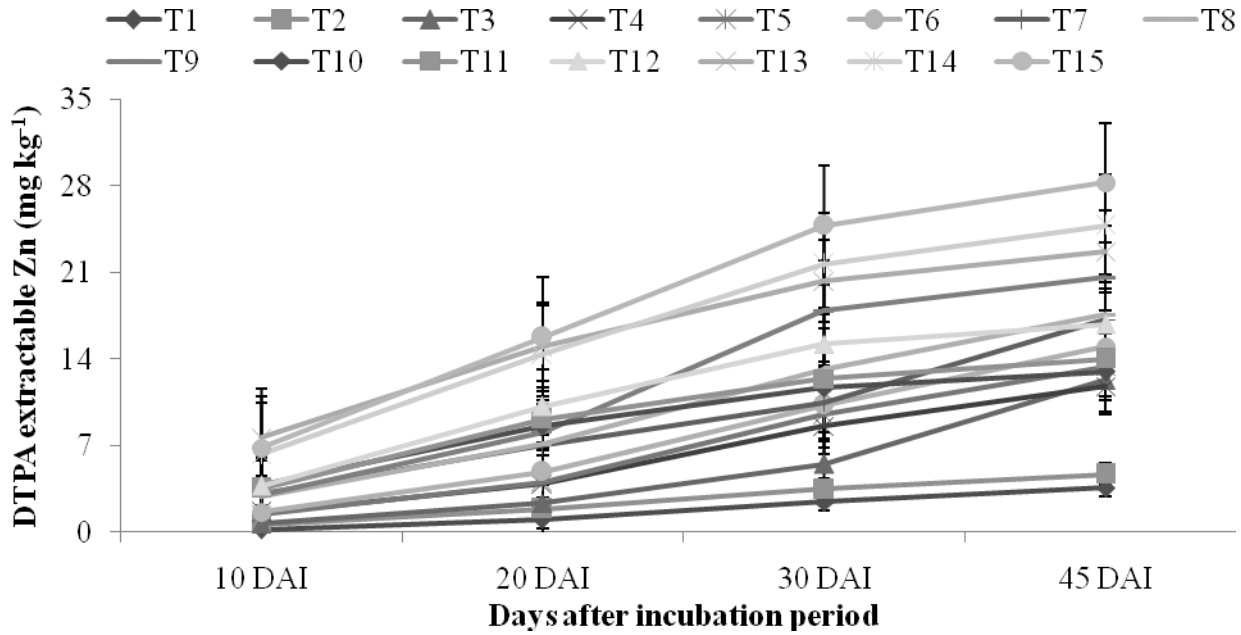

Figure 2: Cumulative release of DTPA extractable Zn at 10, 20, 30, and 45 days after incubation

inoculated treatments. Thus, use of Zn SB could be useful to increase solubilisation of Zn in soil and consequent availability of Zn to plants. The result of this experiment corroborated with the findings of Tariq *et al.* (2007). They observed that there was a significant increase in DTPA extractable Zn when soil was treated with Zn solubilizer.

From the results, it may be concluded that application of Zn fertilizer along with Zn SB was effective way to minimize the Zn fixation in soil and enhanced the Zn mineralization. It was observed that application of 10 kg Zn ha^{-1} along with 4ml ZnSBkg^{-1} was most effective for release of Zn up to 45 DAI.

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