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Effect of zinc mobilizing cultures and zinc levels on chemical properties and nutrient availability in soybean grown Vertisols

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Abstract
Field experiment was conducted during *Kharif* season of 2017 at Research Farm, Department of Soil Science and Agricultural Chemistry at Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani on zinc deficient Vertisol to study the zinc solubilization potential of different microorganisms in soybean crop. The experiment consist of sixteen treatment in which four laboratory pre-evaluated zinc solubilizing microbial cultures (Control, *Pseudomona strita* , *Bacillus megaterium*, and *Trichoderma viride*) and four graded doses of ZnSO4 (0,10,20,30, kg ha^{-1}) were used in the factorial randomized block design. The results emerged out indicated that, the availablility of N (185 kg ha^{-1}), P (18.53 kg ha^{-1}), K (661 kg ha^{-1}) and S (10.90 mg kg^{-1}). An increased with the interaction effect of pseudomonas strita along with ZnSO4 @30 kg ha^{-1}. The status of soc (5.84 g kg^{-1}) are improved with the combined apply of pseudomonas strata and ZnSO4 @ 30 kg ha^{-1}. The DTPA extractable Zn (0.66), Fe (3.71), Mn (7.92) and Cu (3.98) was significantly increased with incremental effect of zinc solublizers and zinc levels.

Keywords: Zinc Soublizer, ZnSO4, *Pseudomonas strita, Bacillus megathrum*

Introduction
In world the main producers of soybean are the United States contributing (32%), Brazil (31%), Argentina (18%), China (7%) and India (4%). In India, oilseed crops constitute the second largest agricultural produce, next to food grains and these are the important source of our national economy. Major soybean growing states in India are Madhya Pradesh, Maharashtra, Gujarat, Rajasthan, Karnataka and Andhra Pradesh. Maharashtra ranks 2nd in terms of production of soybean after Madhya Pradesh. In India area, production and productivity of soybean during 2017 is 101.5 lakh ha, 91.4 lakh million tonnes and 900 kg ha^{-1}, respectively, in Maharashtra area, production and productivity of soybean during 2017 is 34.4 lakh ha, 31.8 lakh million tonnes and 925kg ha^{-1}, respectively. (Anonymous, 2017) [2]. The area under soybean cultivation is increasing due to some reason such as soybean is short duration crop (90-110 days), good market price with its higher productivity compared to other pulses. It can be processed easily for different products *viz.*, soy cheese, soy milk, soy protein, soy yogurt, soybean oil, soy nut etc. Soybean is also used for making the soy ink, soy paint and soy molasses. It can give a boost to the food-processing industry in rural areas of India. Soybean is miracle golden bean of 21st century which possesses potential to revolutionized Indian economy by correcting the health of human being and soil.

Material and Methods
The present investigation was carried at Research Farm, Department of Soil Science and Agricultural Chemistry at Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani on Vertisol during 2017-18. The initial soil pH was 8.20, EC-0.22 dSm^{-1}, Organic Carbon- 4.43 g kg^{-1}, Calcium carbonate -4.05%, available nitrogen-145 kg ha^{-1}, Phosphorus -15.23, Potassium- 556 kg ha^{-1} and Sulphur-9.38 mg kg^{-1}. The initial micronutrient status was DTPA Copper-2.38, Mangnease-7.34, Zinc-0.58 and Ferrous – 3.15 mg kg^{-1}. The soil was clayey in texture, moderately alkaline in reaction, medium in available nitrogen, phosphorus and sufficient in available potassium and low in sulphur and iron. The field experiment was carried out on soybean crop (Variety MAU-162) in kharif season during year 2017-18. After completion of preparatory tillage operations, the experiment was laid out in factorial randomized block design comprising (16) treatments and replicated (3) times. Soil pH and EC were measured in a 1:2 soil: water suspension using pH and conductivity meters. Soil organic carbon determined by wet oxidation method (Walkley and Black 1934) [16] and were analysing available N by alkaline permanganate method (Subbiah and Asija 1965) [14], avialble P (Olsen *et al.*1954) [11] and available K (ammonium acetate extract).

The experiment consist of two factors

Factor-1- Zinc levels	Factor-2- Zinc mobilizing cultures
1. Zno- 0 kg ZnSo4 ha^{-1}	1. SO- Control
2. Zn1- 10 kg ZnSo4 ha^{-1}	2. S1- *Pseudomona strita*
3. Zn2- 20 kg ZnSo4 ha^{-1}	3. S2- *Bacillus megaterium*
4. Zn3- 30 kg ZnSo4 ha^{-1}	4. S3- *Trichoderma Viride*

Seed treatment was done immediate before sowing with liquid zinc mobilizing cultures @ 100 ml 10 kg^{-1} seed. The crop was raised following recommended agronomic practices. The recommended dose of chemical fertilizer applied @ 30:60:30 NPK kg ha^{-1}.The soil sample were collected after harvest of soybean for analysis of chemical properties and available nutrients status as per standard procedures.

Results and Discussion

Soil chemical properties

Zinc solubilizers decrease the soil pH. The uninoculated control pH is 8.34 and after addition of bioinoculants slightly decrease in soil pH *Pseudomona striata* 8.30, 0.27 *Bacillus megaterium* 8.32,0.23 and *Trichoderma viride* 8.31, 0.25 But addition of graded levels of zinc in the form of zinc sulphate also increase the soil pH and EC with each incremental dose up to 30 kg $ZnSO_4$ kg ha^{-1}. The soil pH and EC as influenced by Zn application ranged from 8.25 and 0.19 to 8.38, and 0.28. The non-significant results in the present investigation may be due to one season results i.e. treatments generally not affecting the physico-chemical properties in a single season particularly in the Vertisol.

Zinc solubilizers influenced the soil organic carbon which ranged from 5.67 to 5.76 g kg^{-1} showing significantly higher soil organic carbon in *Pseudomona striata* treated plots follows by *Bacillus megaterium* and *Trichoderma viride*. Whereas, significantly lower soil organic carbon per plot were noted in uninoculated control. Similarly, graded levels of zinc in the form of zinc sulphate also increase the soil organic carbon with each incremental dose up to 30 kg $ZnSO_4$ kg ha^{-1}. The soil organic carbon as influenced by Zn application ranged from 5.52 to 5.84 g kg^{-1}. Interaction effect of zinc solubilizers and zinc levels are statistically non- significant. Increased soil organic carbon due to application of bioagents and FYM sustains soil health for a longer period than the chemical fertilization (Jeyabal and Kuppuswamy, 2003) [7].

Soil calcium carbonate in soybean indicates significant effect of zinc solubilizers and non-significant effect of graded levels of zinc. The slightly increased calcium carbonate there afterat harvest due to various zinc solubilizing microbial treatments over control. Zinc solubilizers influenced the calcium carbonate which ranged from 23.50 to 28.08 g kg^{-1} showing significantly higher calcium carbonate in *Pseudomona striata* treated plots followed by *Bacillus megaterium* and *Trichoderma viride*.

Soil nutrient status

Zinc solubilizers influenced the available nitrogen which ranged between 175 to 183 kg ha^{-1} showing significantly higher available nitrogen in *Pseudomona striata* treated plots follows by *Bacillus megaterium* and *Trichoderma viride*. Whereas, significantly lower available nitrogen per plot were noted in uninoculated control. Similarly, graded levels of zinc in the form of zinc sulphate also increase the available nitrogen with each incremental dose up to 30 kg $ZnSO_4$ kg ha^{-1}. The available nitrogen as influenced by Zn application ranged from 169 to 185.

Interaction effect of zinc mobilizing cultures and zinc levls on available N in Table 2a. Snergistic effect of each factor was recorded showing significantly highest available nitrogen in *Pseudomona striata* X $ZnSO_4$ 30 kg ha^{-1} (189 kg ha^{-1}) it was found at par with *Trichoderma viride* X $ZnSO_4$ 30 kg ha^{-1}. However the lower values of available nitrogen (162 kg ha^{-1}) were recorded in without Zn. Our experimental results are in corroborate with the findings of Sarkar *et al*., (2008), they observed that the mineral N was highest at 60 DAS and thereafter decreased significantly. The buildup of soil available N could be attributed to greater multiplication of microbes due to addition of *Trichoderma viride* which helped in mineralization of soil N leading to higher available nitrogen and quickly released nutrients as previously reported by Thakur *et al*., (2010) [15].

Results shows that different zinc solubilizing microbial inoculants had significant effect on the available P_2O_5 content in soil. Zinc solubilizers influenced the available phosphorus which ranged from 16.50 to 18.46 kg ha^{-1} showing significantly higher available phosphorus in *Pseudomona striata* treated plots follows by *Bacillus megaterium* and *Trichoderma viride*. Whereas, significantly lower available phosphorus per plot were noted in uninoculated control.Similarly graded levels of zinc in the form of zinc sulphate also increase the available phosphorus with each incremental dose up to 30 kg $ZnSO_4$ kg ha^{-1}. The available phosphorus as influenced by Zn application ranged from 15.64 to 18.53 kg ha^{-1}.

Interaction effect of zinc solubilizers and zinc levels on phosphorus content in soil in Table 2a. Significantly highest available phosphorus in *Pseudomona striata* X $ZnSO_4$ 30 kg ha^{-1} (19.33 kg ha^{-1}) it was found at par with *Bacillus megaterium* X $ZnSO_4$ 30 kg ha^{-1}. However the lower values of available nitrogen (15.53 kg ha^{-1}) was recorded in uninoculated control. The increased availability of P with microbes could be ascribed to their solubilizing effect on the native insoluble P fractions through release of various organic acids, thus resulting into a significant improvement in available P status of the soil.The buildup of available P was higher in the integration of 75% RDF as inorganic manure and *PSB* treated plots. It might be due to release of organic acid during microbial decomposition of organic matter which might help in increasing solubility of phosphates thus increased available phosphorus (Khan *et al*. 1984) [8]. Similar results were noted by Reddy *et al*. (1990) [13].

Available K_2O in soil was influenced significantly due to various treatments of zinc solubilizing microbial inoculants in soybean are presented in Table 2. Zinc solubilizers influenced the available potassium which ranged from 580 to 652 kg ha^{-1} showing significantly higher available potassium in *Pseudomona striata* treated plots followed by *Bacillus megaterium* and *Trichoderma viride*. Whereas, significantly lower available nitrogen per plot were noted in uninoculated control. Similarly, graded levels of zinc in the form of zinc sulphate also increase the available potassium with each incremental dose up to 30 kg $ZnSO_4$ kg ha^{-1}. The available potassium as influenced by Zn application ranged from 563 to 661.

Interaction effect of zinc mobilizing cultures and zinc levels on available postassium from soil in Table 2a. Showing significantly highest available potassium in *Pseudomona striata* X $ZnSO_4$ 30 kg ha^{-1} (694 kg ha^{-1}) it was found at par with *Trichoderma viride* in to X $ZnSO_4$ 30 kg ha^{-1}. However the lower values of available potassium (540 kg ha^{-1}) was recorded in uninoculated control. The enhanced availability of

K with bioagent *Trichoderma viride* and FYM in sugarcane rhizosphere was reported by Yadav *et al*., (2009) [17].

The zinc mobilizing cultures influenced the available sulphur which ranged between 10.31 to 10.71 mg kg^{-1} showing significantly higher available sulphur in *Pseudomona striata* treated plots follows by *Bacillus megaterium* and *Trichoderma viride*. Whereas, significantly lower values per plot were noted in control plots. Similarly, graded levels of zinc in the form of zinc sulphate also increase the available sulphur with each incremental dose up to 30 kg $ZnSO_4$ kg ha^{-1}. The available sulphur as influenced by Zn application ranged from 9.77 to 10.90 mg kg^{-1}.

Interaction effect of zinc solubilizers and zinc levels on available sulphur in Table 2a. Significantly synergistic effect of each factor was recorded on each other showing significantly highest available sulphur in *Pseudomona striata* X $ZnSO_4$ 30 kg ha^{-1} (11.5 mg kg^{-1}) it was found at par with *Trichoderma viride* followed by *Bacillus megaterium* X $ZnSO_4$ 30 kg ha^{-1}. However the lower value of available sulphur (9.92 mg kg $^{-1}$) was recorded in without Zn application. An increased availability of sulphur through chemical and microbial inoculants may ascribed due to the accelerated microbial activates due to addition of biofertilizers as described by Pasricha and Sarkar (2002) [12].

DTPA micronutrients

The content of DTPA Zn in soil showed significant increase under all microbial inoculated treatments compared to control treatment. Zinc mobilizing cultures influenced the DTPA zinc which ranged from 0.55 to 0.66 mg kg^{-1} showing significantly higher DTPA zinc in *Pseudomona striata* treated plots follows by *Bacillus megaterium* and *Trichoderma viride*. Whereas, significantly lower DTPA zinc per plot were noted in uninoculated control. Similarly, increase in zinc content in soil with application of graded levels of zinc in the form of zinc sulphate also increase the DTPA zinc with each incremental dose up to 30 kg $ZnSO_4$ kg ha^{-1}. The DTPA zinc as influenced by Zn application ranged from 0.55 mg kg^{-1} to 0.66 mg kg^{-1}.

Interaction effect of zinc solubilizers and zinc levels on DTPA Zn in Table 3a. Showing significantly the highest build-up of soil DTPA Zn was noticed under in *Pseudomona striata* X $ZnSO_4$ 30 kg ha^{-1} (0.71 mg kg^{-1}) it was found at par with *Trichoderma viride* X $ZnSO_4$ 30 kg ha^{-1}. However the lower values of DTPA zinc (0.50 mg kg^{-1}) was recorded in uninoculated control plots.

The zinc mobilizing cultures influenced the DTPA iron which ranged from 3.24 to 3.61 mg kg^{-1} showing significantly higher DTPA iron in treatment *Pseudomona striata* treated plots followed by *Bacillus megaterium* and *Trichoderma viride*. Whereas, significantly lower DTPA iron per plot were noted in uninoculated control.Similarly, graded levels of zinc in the form of zinc sulphate also increased the DTPA iron with each incremental dose up to 30 kg $ZnSO_4$ kg ha^{-1}. The DTPA iron as influenced by Zn application ranged between 3.10 mg kg^{-1} to 3.71 mg kg^{-1}.

Interaction effect of zinc solubilizers in to zinc levels in Table 3a. Showing significantly the highest DTPA iron was noticed under in *Pseudomona striata* X $ZnSO_4$ 30 kg ha^{-1} (3.82 mg kg^{-1}) it was found at par with *Bacillus megaterium* X $ZnSO_4$ 30 kg ha^{-1}. However the lower values of DTPA iron (2.76 mg kg^{-1}) was recorded in without zinc application. Our results are in line with the findings of Adriana *et al.*, (2010), they concluded that the microorganisms are able to mobilize metals by formation of organic or inorganic acids (e.g. citric acid, sulphuric acid) by oxidation and reduction reactions and by the excretion of complexion agents.

Zinc solubilizers influenced the DTPA copper which ranged from 3.41 to 3.82 mg kg^{-1} have showing significantly higher DTPA copper in treatment *Pseudomona striata* treated plots follows by *Bacillus megaterium* and *Trichoderma viride*. Whereas, significantly lower DTPA copper per plot were noted in uninoculated control. Similarly, applied zinc levels in the form of zinc sulphate also increase the DTPA copper with each incremental dose up to 30 kg $ZnSO_4$ kg ha^{-1}. The DTPA copper as influenced by Zn application ranged from 3.24 mg kg^{-1} (Zn0) to 3.98 mg kg^{-1} ($ZnSO_4$).

Interaction effect of zinc solubilizers and zinc levels on DTPA Cu in Table 3a. Showing significantly the highest DTPA copper was noticed under in *Pseudomona striata* X $ZnSO_4$ 30 kg ha^{-1} (4.31 mg kg^{-1}) it was found at par with both *Trichoderma viride* and *Bacillus megaterium* X $ZnSO_4$ 30 kg ha^{-1}. However the lower values of DTPA copper (2.71 mg kg^{-1}) was recorded in without Zn. These results are in consonance with the findings of Jayant Raman (2012) [6] who found the highest availability of Cu in soil with the inoculation of treatment combination of *Pseudomona striata* + *Trichoderma viride* and *Azotobacter chroococcum.*

Inoculation of zinc solubilizing microbial inoculants enhanced the DTPA manganese content in soil as compared to initial vlues. ranged between 7.32 to 7.80 mg kg^{-1} showing significantly higher DTPA manganese in *Pseudomona striata* treated plots follows by *Bacillus megaterium* and *Trichoderma viride*. Similarly, application of zinc leves in the form of zinc sulphate also increased the DTPA manganese with each incremental dose up to 30 kg $ZnSO_4$ kg ha^{-1}. The DTPA manganese as influenced by Zn application ranged from 7.32 mg kg^{-1} to 7.92 mg kg^{-1}.

Interaction effect of zinc solubilizers and zinc levels on DTPA manganese in Table 3a. Increase the DTPA manganese significantly synergistic effect of each factor was recorded on each other showing significantly the highest DTPA manganese was noticed under in *Pseudomona striata* X $ZnSO_4$ 30 kg ha^{-1} (7.56 mg kg^{-1}) it was found at par with *Bacillus megaterium* X $ZnSO_4$ 30 kg ha^{-1}. However, the lower values of DTPA manganese (6.90 mg kg^{-1}) was recorded in without Zn application. The DTPA Mn increase might be due to transformation of oxidized form of Mn to reduced form similar results are also in agreement with the findings of Jadhao and Konde, (2007) [5].

Table 1: Effect of zinc mobilizing cultures and zinc levels on chemical properties in soil after harvest of soybean

Treatments	pH (1:2.5)	EC (dSm^{-1})	$CaCO_3$ (g kg^{-1})	Organic carbon (g kg^{-1})
Zinc solubilizers (S)				
S0: Control	8.35	0.21	23.50	5.67
S1: *Pseudomonas striata*	8.30	0.27	28.08	5.76
S2: *Bacillus megaterium*	8.32	0.23	25.42	5.71
S3: *Trichoderma viride*	8.31	0.25	26.08	5.70
S.Em.±	0.008	0.01	0.516	0.01
C.D. at 5%	0.023	0.028	1.49	0.029

Levels of $ZnSO_4$ (Zn)				
Zn0: $ZnSO_4$ 0 kg ha^{-1}	8.25	0.19	25.00	5.52
Zn1: $ZnSO_4$ 10 kg ha^{-1}	8.30	0.25	25.33	5.72
Zn2: $ZnSO_4$ 20 kg ha^{-1}	8.35	0.26	26.33	5.76
Zn3: $ZnSO_4$ 30 kg ha^{-1}	8.38	0.28	26.42	5.84
S.Em.±	0.008	0.01	0.516	0.01
C.D. at 5%	0.023	0.028	NS	0.029
Interaction (SxZn)				
S.Em.±	0.016	0.019	1.032	0.02
C.D. at 5%	NS	NS	NS	NS
CV %	0.32	14.55	6.94	0.61

Table 2: Effect of zinc mobilizing cultures and zinc levels on nutrient availability in soybean

Treatments	Available N (Kg ha^{-1})	Available P_2O_5 (Kg ha^{-1})	Available K_2O (Kg ha^{-1})	Available S (mg kg^{-1})
Zinc solubilizers (S)				
S0: Control	175	16.50	580	10.31
S1: *Pseudomona striata*	183	18.46	652	10.71
S2: *Bacillus megaterium*	179	17.32	624	10.38
S3: *Trichoderma viride*	178	17.13	630	10.57
S.Em.±	0.81	0.12	3.21	0.04
C.D. at 5%	2.35	0.37	9.27	0.12
Levels of $ZnSO_4$ (Zn)				
Zn0: $ZnSO_4$ 0 kg ha^{-1}	169	15.64	563	9.77
Zn1: $ZnSO_4$ 10 kg ha^{-1}	178	17.34	615	10.57
Zn2: $ZnSO_4$ 20 kg ha^{-1}	182	18.26	647	10.74
Zn3: $ZnSO_4$ 30 kg ha^{-1}	185	18.53	661	10.90
S.Em.±	0.81	0.12	3.21	0.04
C.D. at 5%	2.35	0.37	9.27	0.12
Interaction (SxZn)				
S.Em.±	1.63	0.25	6.42	0.08
C.D. at 5%	4.70	0.74	18.55	0.24
CV %	1.57	2.6	1.79	1.39

Table 2a: Interaction effect of zinc solubilizers and graded level of zinc on nutrient availability in soil

Treatments	Zn0: $ZnSO_4$ 0 kg ha^{-1}	Zn1: $ZnSO_4$ 10 kg ha^{-1}	Zn2: $ZnSO_4$ 20 kg ha^{-1}	Zn3: $ZnSO_4$ 30 kg ha^{-1}
Available N (kg ha^{-1})				
S0: Control	162	176	180	183
S1: *Pseudomonas striata*	175	182	186	189
S2: *Bacillus megaterium*	175	178	180	184
S3: *Trichoderma viride*	166	177	183	186
Interaction	S	Zn	SXZn	
SEm±	0.81	0.81	1.63	
CD at 5%	2.35	2.35	4.70	
Available P_2O_5 (kg ha^{-1})				
S0: Control	15.53	16.33	17.79	17.80
S1: *Pseudomona striata*	16.54	18.78	19.17	19.33
S2: *Bacillus megaterium*	15.24	17.03	18.29	18.71
S3: *Trichoderma viride*	15.25	17.22	17.77	18.28
Interaction	S	Zn	SXZn	
SEm±	0.12	0.12	0.25	
CD at 5%	0.37	0.37	0.74	
Available K_2O (kg ha^{-1})				
S0: Control	540	559	604	615
S1: *Pseudomona striata*	570	660	685	694
S2: *Bacillus megaterium*	566	619	643	667
S3: *Trichoderma viride*	573	623	656	668
Interaction	S	Zn	SXZn	
SEm±	3.21	3.21	6.42	
CD at 5%	9.27	9.27	18.55	
Available S (mg kg^{-1})				
S0: Control	9.92	10.32	10.39	10.61
S1: *Pseudomona striata*	9.63	10.96	11.12	11.15
S2: *Bacillus megaterium*	9.89	10.43	10.69	10.52
S3: *Trichoderma viride*	9.63	10.58	10.77	11.30
Interaction	S	Zn	SXZn	
SEm±	0.04	0.04	0.08	
CD at 5%	0.12	0.12	0.24	

Table 3: Effect of zinc mobilizing cultures and zinc levels on DTPA micronutrient in soil after harvest of soybean

Table 3: Effect **Treatments**	**DTPA Zn (mg kg^{-1})**	**DTPA Fe (mg kg^{-1})**	**DTPA Cu (mg kg^{-1})**	**DTPA Mn (mg kg^{-1})**
Zinc solubilizers (S)				
S0: Control	0.55	3.24	3.41	7.32
S1: *Pseudomonas striata*	0.66	3.61	3.82	7.80
S2: *Bacillus megaterium*	0.61	3.56	3.66	7.79
S3: *Trichoderma viride*	0.62	3.55	3.66	7.76
S.Em.±	0.003	0.04	0.049	0.045
C.D. at 5%	0.008	0.13	0.142	0.13
Levels of $ZnSO_4$ (Zn)				
Zn0: $ZnSO_4$ 0 kg ha^{-1}	0.55	3.10	3.24	7.32
Zn1: $ZnSO_4$ 10 kg ha^{-1}	0.59	3.53	3.54	7.65
Zn2: $ZnSO_4$ 20 kg ha^{-1}	0.63	3.62	3.66	7.78
Zn3: $ZnSO_4$ 30 kg ha^{-1}	0.66	3.71	3.98	7.92
S.Em.±	0.003	0.04	0.049	0.045
C.D. at 5%	0.008	0.13	0.142	0.13
Interaction (SxZn)				
S.Em.±	0.005	0.092	0.099	0.09
C.D. at 5%	0.015	0.265	0.285	0.26
CV %	1.5	4.56	4.7	2.03

Table 3b: Interaction effect of zinc solubilizers and graded level of zinc on DTPA micronutrient in soil

Treatments	**Zn0: $ZnSO_4$ 0 kg ha^{-1}**	**Zn1: $ZnSO_4$ 10 kg ha^{-1}**	**Zn2: $ZnSO_4$ 20 kg ha^{-1}**	**Zn3: $ZnSO_4$ 30 kg ha^{-1}**
DTPA Zn (mg kg^{-1})				
S0: Control	0.50	0.53	0.56	0.59
S1: *Pseudomonas striata*	0.61	0.65	0.68	0.71
S2: *Bacillus megaterium*	0.54	0.58	0.62	0.67
S3: *Trichoderma viride*	0.54	0.59	0.63	0.68
Interaction	S	Zn	SXZn	
SEm±	0.003	0.003	0.005	
CD at 5%	0.008	0.008	0.015	
DTPA Fe (mg kg^{-1})				
S0: Control	2.76	3.33	3.36	3.50
S1: *Pseudomona striata*	3.35	3.50	3.75	3.82
S2: *Bacillus megaterium*	3.33	3.48	3.65	3.76
S3: *Trichoderma viride*	2.95	3.80	3.70	3.73
Interaction	S	Zn	SXZn	
SEm±	0.04	0.04	0.092	
CD at 5%	0.13	0.13	0.265	
DTPA Cu (mg kg^{-1})				
S0: Control	2.71	3.45	3.71	3.77
S1: *Pseudomona striata*	3.43	3.58	3.95	4.31
S2: *Bacillus megaterium*	3.41	3.55	3.72	3.94
S3: *Trichoderma viride*	3.41	3.58	3.77	3.90
Interaction	S	Zn	SXZn	
SEm±	0.049	0.049	0.099	
CD at 5%	0.142	0.142	0.285	
DTPA Mn (mg kg^{-1})				
S0: Control	6.56	7.51	7.55	7.64
S1: *Pseudomona striata*	7.65	7.78	7.86	7.90
S2: *Bacillus megaterium*	7.53	7.63	7.85	8.11
S3: *Trichoderma viride*	7.54	7.64	7.84	8.00
Interaction	S	Zn	SXZn	
SEm±	0.045	0.045	0.09	
CD at 5%	0.13	0.13	0.26	

Conclusion

From the study, it can be concluded that, the incremental levels of zinc solublizers and ZnSO4 caused significant improvement in soil chemical properties, soil nutrient status and DTPA micro nutrient status of soil. The combined use of Zn solublizer and ZnSO4 significantly increased the soil nutrients and micronutrient status of soil.

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