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Effect of zinc solubilizing bacteria on zinc use efficiency and yield of summer groundnut grown in Entisol

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Abstract
A field experiment was conducted during the year 2017-18 at Post Graduate Institute Farm, Mahatma Phule Krishi Vidyapeeth, Rahuri. The experiment was laid out in Randomised block design with three replication and eleven treatments. The treatments comprised of T_1 : Absolute control, T_2 : only ZnSB, T_3 : GRDF (25:50 kg ha^{-1} N:P_2O_5 + FYM @ 5 t ha^{-1}), T_4 to T_7 were GRDF + 100%, 75%, 50% and 25% RD of Zn through $ZnSO_4$+ ZnSB and T_8 to T_{11} were GRDF + 100%, 75%, 50% and 25% RD of Zn through ZnO + ZnSB. The biofertilizer zinc solubilizing bacteria was given as a seed treatment as well as soil drenching @ 5% at 30 days of sowing. The highest zinc use efficiency 5.04 g g^{-1} was found in treatment of T_7 (25% RD of Zn through $ZnSO_4$ + ZnSB) which was followed by T_{11} (4.60 g g^{-1}). The highest agronomic efficiency 11.13 kg kg^{-1} was observed in treatment of 100% GRDF + 100% RD of Zn through zinc sulphate + ZnSB followed by 100% GRDF + 75% RD of Zn through zinc sulphate + ZnSB (9.77 kg kg^{-1}). The oil percent was significantly increased in treatment of T_4 (40.96%) over all the treatment. The pod yield of groundnut was significantly increased in treatment of T_4 (30.63 q ha^{-1}) over all the treatments except treatment T_5 (29.44 q ha^{-1}) which was at par with T_4. Haulm yield of groundnut was significantly increased (62.70 q ha^{-1}) in treatment of 100% GRDF (25:50 kg ha^{-1} N:P_2O_5 + FYM @ 5 t ha^{-1} over all the treatments. Thus, It can be concluded that, the application of 100% recommended dose of Zn through Zinc sulphate @ 20 kg ha^{-1} + 5% ZnSB to seed treatment at sowing and through drenching at 30 DAS along with 100% recommended dose of nutrients to summer groundnut was found beneficial for increased in zinc use efficiency, agronomic efficiency of groundnut in *Entisol*.

Keywords: ZnSB, $ZnSO_4$, ZnO, zinc use efficiency, agronomic efficiency, pod yield

Introduction

India is blessed with the agro-ecological condition favourable for growing nine major oilseeds including seven edible oilseed namely groundnut, rapeseed, mustard, soybean, sunflower, safflower, sesame and niger and two non-edible sources, namely castor and linseed, apart from wide range of other minor oilseeds and oil bearing species. Among all the oilseed crops, groundnut occupies the first place in India accounting for more than 28% of acerage and 32% of production in the country. However, except for castor, the productivity of oilseed crops in India is one of the lowest in the world.

In India, the major cause for increased zinc deficiency is the adoption of intensive cultivation, imbalanced nutrient application generally devoid of zinc and dispensing with organic manures and the very nature of soils predominated with high pH, calcareous and low in organic matter content (Behera *et al*., 2011) [2]. In this context, there should be a paradigm shift toward developing strategies to overcome zinc deficiency, increasing crop yields and improve human health. Zinc deficiency is currently listed as a major risk factor for human health and cause of death globally.

Zinc is known to occur in a number of discreet chemical forms varying in their solubility and availability to crop plants. These includes presence in soil solutions as ionic or organically complexed species, exchange sites of soil organic and inorganic colloids, complexed with organic matter, occluded in oxides and hydrous oxides of Fe, Al and Mn, and entrapped in primary and secondary silicate minerals (Han *et al*., 2011; Behera *et al*., 2011) [8, 2]. To increase zinc availability, fertilization of food crops with Zn represents a short-term and complementary strategy, which is necessary to build the Zn pool for uptake or translocation (Cakmak, 2008) [3], whereas, plant breeding strategy (genetic biofortification) appears to be a most sustainable, affordable and cost-effective approach useful in improving Zn concentrations in grain. In this context, the use of beneficial rhizosphere microorganisms as bio-inoculants to increase availability of native zinc to crop assimilation and achieve the objective of low-input and sustainable agriculture (He *et al*., 2010) [9] and to overcome zinc malnutrition in human populations (Mäder *et al*., 2010) [12] could be a viable option.

Among the bacterial species, strains belonging to the genera *Acinetobacter, Bacillus, Gluconacetobacter and Pseudomonas have* been reported (Fasim *et al*., 2002) [5] as zinc solubilizers, fertilizers and manures, to enhance soil fertility and crop productivity has often negatively affected the complex biogeochemical cycles (Steinshamn *et al*., 2004) [13]. Exogenous application of zinc sources, similar to fertilizer application has been advocated to various crops. This causes transformation of about 96 to 99 percent of applied available zinc to various unavailable forms. The zinc thus, made unavailable can be reverted back to available form by inoculating bacterial strain capable of solubilizing it. Since zinc is a limiting factor in crop production, this study on zinc solubilization by bacteria has an immense importance in zinc nutrition to plant.

Thus, keeping this in the view, the present study has planned on Effect of Zinc Solublizing Bacteria Zinc use efficiency and yield of Summer Groundnut grown in Entisol.

Materials and Methods

The field experiment were conducted on groundnut (TG - 26) during Summer in 2016-17 in randomized block design with three replication on the soil belonging to order *Entisol* (Typic Ustorthent) at Post Graduate Institute, Mahatma Phule Agricultural University, Rahuri, Maharashtra, located between $19^0 34'$ N latitude and $74^0 64'$ E longitude. The treatment comprised of T_1 : Absolute control, T_2 : only ZnSB, T_3 : GRDF (25:50 kg ha^{-1} $N:P_2O_5$ + FYM @ 5 t ha^{-1}), T_4 to T_7 were GRDF 100%, 75%, 50% and 25% RD of Zn through $ZnSO_4$ + ZnSB and T_8 to T_{11} were GRDF + 100%, 75%, 50% and 25% Zn through ZnO + ZnSB. ZnSB was given through seed treatment at the time of sowing @ 5% and second 5% ZnSB was given by drenching in soil at 30 DAS. The experimental soil for groundnut crop had pH (8.16), EC (0.28 dSm^{-1}), Org. C (0.44%), $CaCO_3$ (5.41%), Available N (205 kg ha^{-1}), Available P (13.8 kg ha^{-1}), Available K (410 kg ha^{-1}), DTPA-Fe (4.02 mg kg^{-1}), Mn (10.70 mg kg^{-1}), Zn (0.49 mg kg^{-1}) and Cu (1.92 mg kg^{-1}). The seed of groundnut was coated with zinc solubilizing bacteria culture of consortia of viz., *Bacillus polymyxa, Bacillus megaterium, Pseudomonas striata, Pseudomonas fluroscence, Gluconoacetobacter diazotrophicus* and *Aspergillus awamori*. The general recommended dose of $N:P_2O_5$ @ 25:50 kg ha^{-1} + 5 t ha^{-1} FYM was applied to groundnut. The soil samples were collected before sowing and harvest of groundnut and analysed as per standard methods. The plant and pod samples were analysed for Total N by micro- Kjedahl method (Jackson 1958), Total P by vanodomolybdate yellow colour method (Chapman and Pratt 1961) in diacid mixture of $HNO_3:HCLO_4$ (9:4) and Total K by Flame photometer (Chapman and Pratt 1961) in $HNO_3:HCLO_4$ (9:4). The nutrient use efficiency calculated as a Agonomic efficiency and Zinc use efficiency by using following formula:

$$\text{Agronomic efficiency (kg kg}^{-1}) = \frac{\text{Pod yield, kg ha}^{-1}\text{ (fertilized)} - \text{Pod yield, kg ha}^{-1}\text{ (ZnSB)}}{\text{Nutrient added, kg ha}^{-1}}$$

$$\text{Zinc use efficiency (g g}^{-1}) = \frac{\text{Zn uptake, g ha}^{-1}\text{ (fertilized)} - \text{Zn uptake, g ha}^{-1}\text{ (ZnSB)}}{\text{Amount of Zn applied g ha}^{-1}}$$

Result and Discussion

Soil Chemical properties

The data regarding chemical properties of soil pH, EC, Org. C and $CaCO_3$ did not show any significant differences due to different treatment (Table 1)

Table 1: Effect of zinc fertilizer and zinc solubilizing bacteria on soil properties

Tr. No	Treatment	pH (1:2.5)	EC (dSm^{-1})	Organic carbon (%)	$CaCO_3$ (%)
T_1 :	Absolute control	8.17	0.26	0.40	5.40
T_2 :	ZnSB alone	8.14	0.24	0.41	5.41
T_3 :	100% GRDF (25:50 kg ha^{-1} $N:P_2O_5$ FYM+ @ 5 t ha^{-1})	8.06	0.27	0.49	5.54
T_4 :	T_3 + 100% RD of Zn through Zinc sulphate ZnSB	8.02	0.30	0.50	5.33
T_5 :	T_3 + 75% RD of Zn through Zinc sulphate + ZnSB	8.04	0.28	0.48	5.17
T_6 :	T_3 + 50% RD of Zn through Zinc sulphate + ZnSB	8.04	0.27	0.46	5.21
T_7 :	T_3 + 25% RD of Zn through Zinc sulphate + ZnSB	8.08	0.25	0.44	5.08
T_8 :	T_3 + 100% RD of Zn through Zinc oxide + ZnSB	8.16	0.26	0.46	5.71
T_9 :	T_3 + 75% RD of Zn through Zinc oxide + ZnSB	8.16	0.27	0.44	5.75
T_{10}:	T_3 + 50% RD of Zn through Zinc oxide + ZnSB	8.14	0.28	0.48	5.87
T_{11}:	T_3 + 25% RD of Zn through Zinc oxide + ZnSB	8.16	0.27	0.49	5.08
S.Em$\pm$		0.016	0.011	0.013	0.023
CD at 5%		NS	NS	NS	NS

Total micronutrients

The total uptake of Fe, Zn, Mn and Cu by groundnut as influenced by different treatment are presented in Table 2.

The total uptake of Fe was found to be significantly higher in T_4 treatment (1352 g ha^{-1}) over all the treatment except T_3 (1344 g ha^{-1}) which was at par with T_4. Total uptake of Zn significantly higher in treatment of T_4 (377 g ha^{-1}) over all the treatment. Amalraj *et al.* (2012) [1] also reported increased zinc uptake due to seed inoculation of PSB and solubilizers on soybean**.**

The total uptake of Mn was significantly increased in T_4 treatment (619 g ha^{-1}) over all the treatment except treatment T_3 (598 g ha^{-1}) which was at par with T_4 in respect of Mn uptake. This might be due to exudation of phytase which is important for Mn uptake from high pH soils. Similar results were also observed by George *et al.* (2014) [6]. The total uptake of Cu was observed significantly higher in T_4 (67 g ha^{-}

[1]) over all the treatment. The total uptake of Cu in application 100% of Zn through zinc sulphate + ZnSB treatment was higher than the other treatment Gururmurthy *et al.* (2009) reported increase in Cu uptake in grain and straw with N, P and K application of PSB to soybean.

Table 2: Effect of zinc fertilizer and zinc solubilizing bacteria on Total micronutrient uptake

Tr. No	Treatment	Total uptake of micronutrient (g ha^{-1})			
		Fe	Zn	Mn	Cu
T_1	Absolute control	897	207	401	36
T_2	ZnSB alone	972	235	431	43
T_3	100% GRDF (25:50 kg ha^{-1} N:P_2O_5 + FYM @ 5 t ha^{-1})	1344	307	598	53
T_4	T_3 + 100% RD of Zn through Zinc sulphate + ZnSB	1352	377	619	67
T_5	T_3 + 75% RD of Zn through Zinc sulphate + ZnSB	1213	336	504	61
T_6	T_3 + 50% RD of Zn through Zinc sulphate + ZnSB	1107	292	485	48
T_7	T_3 + 25% RD of Zn through Zinc sulphate + ZnSB	1051	265	457	47
T_8	T_3 + 100% RD of Zn through Zinc oxide + ZnSB	1130	311	498	54
T_9	T_3 + 75% RD of Zn through Zinc oxide + ZnSB	1069	286	455	45
T_{10}	T_3 + 50% RD of Zn through Zinc oxide + ZnSB	1060	276	451	49
T_{11}	T_3 + 25% RD of Zn through Zinc oxide + ZnSB	1007	260	441	43
S.Em±		19.90	4.13	8.58	0.74
CD at 5%		59.11	12.26	25.47	2.19

Zinc use efficiency

Zinc use efficiency and Agronomic efficiency of groundnut influenced by different treatments are presented in table 3 which revealed that highest zinc use efficiency was recorded in treatment T_7 (5.04 g g^{-1}) and T_{11} (4.60 g g^{-1}). In case of agronomic efficiency was recorded in treatment T_4 (11.81 kg ha^{-1}) followed by T_5 (10.55 kg ha^{-1}). The increased in nutrient use efficiency may be due to solubilizing of Zn from Zinc sulphate by Zn solubilizing bacteria which reflected on increased in uptake of total N, P, K, Fe, Zn, Mn and Cu by groundnut.

Table 3: Zinc use efficiency and agronomic efficiency of groundnut influenced by application of zinc fertilizer and zinc solubilizing bacteria

Tr. No	Treatment	Zinc use efficiency (g g^{-1})	Agronomic efficiency (kg kg^{-1})
T_1	Absolute control	-	-
T_2	ZnSB alone	-	-
T_3	100% GRDF (25:50 kg ha^{-1} N:P_2O_5 + FYM @ 5 t ha^{-1})	2.17	6.01
T_4	T_3 + 100% RD of Zn through Zinc sulphate + ZnSB	3.69	11.13
T_5	T_3 + 75% RD of Zn through Zinc sulphate + ZnSB	3.73	9.77
T_6	T_3 + 50% RD of Zn through Zinc sulphate + ZnSB	3.69	7.29
T_7	T_3 + 25% RD of Zn through Zinc sulphate + ZnSB	5.04	6.40
T_8	T_3 + 100% RD of Zn through Zinc oxide + ZnSB	2.26	6.84
T_9	T_3 + 75% RD of Zn through Zinc oxide + ZnSB	2.28	6.74
T_{10}	T_3 + 50% RD of Zn through Zinc oxide + ZnSB	3.00	6.63
T_{11}	T_3 + 25% RD of Zn through Zinc oxide + ZnSB	4.60	6.09

Pod and haulm yield

Pod and haulm yield of groundnut as influenced by different treatments are presented in table 4 The pod yield of groundnut was found to be significantly increased (30.63 q ha^{-1}) in treatment of T_4 over all the treatment except treatment T_5 (29.44 q ha^{-1}) which was at par. Overall, the percent increased of pod yield of groundnut was in the range of 15.32 to 0.33 in treatments of soil application of $ZnSO_4$ and 2.48 to 1.43 percent in soil application of ZnO treatment over GRDF (T_3).

The stover yield of groundnut was found to be significantly increased (62.70 q ha^{-1}) in treatment of GRDF T_3 over all the treatments under study. However, treatments of application of $ZnSO_4$ + ZnSB were found increased in pod and haulm yield of groundnut as compare to treatments of application of ZnO + ZnSB. Application of zinc in soil resulted in increased in yield of groundnut was in the range of 15.32 to 0.33 in treatments of soil application of $ZnSO_4$ and 2.48 to 1.43 percent in soil application of ZnO treatment over GRDF (T_3). The haulm yield of increased (62.70 q ha^{-1}) in treatment of GRDF T_3 over all the treatments under study. Application of zinc in soil resulted in increased in yield of groundnut the groundnut was reported by Talukdar and Islam (1982) [16].

Table 4: Effect of application of zinc fertilizer and zinc solubilzing bacteria on pod and haulm yield of groundnut

Tr. No	Treatment	Pod yield (q ha^{-1})	Haulm yield (q ha^{-1})	Percent increased pod yield over T_3
T_1	Absolute control	20.82	42.50	-
T_2	ZnSB alone	21.77	44.20	-
T_3	100% GRDF (25:50 kg ha^{-1} N:P_2O_5 + FYM @ 5 t ha^{-1})	26.56	62.70	-
T_4	T_3 + 100% RD of Zn through Zinc sulphate + ZnSB	30.63	58.90	15.32
T_5	T_3 + 75% RD of Zn through Zinc sulphate + ZnSB	29.44	53.72	10.84
T_6	T_3 + 50% RD of Zn through Zinc sulphate + ZnSB	27.41	48.60	3.20
T_7	T_3 + 25% RD of Zn through Zinc sulphate + ZnSB	26.65	45.90	0.33
T_8	T_3 + 100% RD of Zn through Zinc oxide + ZnSB	27.22	50.42	2.48
T_9	T_3 + 75% RD of Zn through Zinc oxide + ZnSB	27.06	47.34	1.88

T_{10}	T_3 + 50% RD of Zn through Zinc oxide + ZnSB	26.90	46.91	1.28
T_{11}	T_3 + 25% RD of Zn through Zinc oxide + ZnSB	26.41	44.98	1.43
S.Em±		0.478	1.027	
CD at 5%		1.42	3.05	

Conclusion

Application of 100% recommended dose of Zn through Zinc sulphate @ 20 kg ha^{-1} + 5% ZnSB to seed treatment at sowing and through drenching at 30 DAS along with 100% (25:50 kg ha^{-1} N:P_2O_5 + FYM @ 5 t ha^{-1}) to summer groundnut was found to be beneficial for increased in zinc use efficiency, agronomic efficiency, total uptake of micronutrient and pod yield of groundnut in Entisol.

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