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Influence of Graded Levels of $ZnSO_4.7H_2O$ with Rice Straw Compost and Microbial Consortium on Yield and Zn Uptake in Maize

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ABSTRACT

A field experiment was conducted in sandy loam soil of Agricultural College farm, Bapatla, India to study the effect of graded levels of zinc sulphate with and without rice straw compost and microbial consortium on yield and Zn uptake of maize (var. 30v92) during *rabi* season of 2014-15 by taking the treatment combinations based on graded levels of zinc sulphate, microbial consortium (MC) and rice straw compost (RSC) at fixed fertilizer schedule. The experimental soil (0-15 cm) had pH 7.32; organic C 0.39 %; available Zn 0.46 mg kg^{-1}; available N 174.2 kg ha^{-1}; available P 12.1 kg ha^{-1} and available K 284.0 kg ha^{-1}. The results of graded levels of zinc sulphate show that all the growth and yield attributes were significantly influenced by Zn uptake. The mean Zn uptake at tasseling, stover and kernel at harvest varied from 57.7-111.6, 151.9-298.6 and 109.8-225.2 g ha^{-1} respectively, in maize. Kernel yield displayed conspicuous relationships with uptake of Zn by kernel. The highest mean kernel yield of 6695 kg ha^{-1} was recorded by the addition of rice straw compost with microbial consortium followed by MC (6350 kg ha^{-1}), RSC (6112 kg ha^{-1}) and control (5408 kg ha^{-1}). Application of $ZnSO_4.7H_2O$ @ 37.5 kg $ha^{-1}$with conjunction with RSC +MC was recorded the highest and significant kernel yield of 7154 kg ha^{-1} which was 19.2 per cent more over control. The results further show that $ZnSO_4.7H_2O$ @ 37.5 kg ha^{-1} in combination with rice straw compost and microbial consortium have been proved to be superior treatments for best management of zinc in sandy loam soils under maize cultivation.

Keywords: *Microbial consortium, Rice straw compost, zinc and maize, zinc sulphate.*

Understanding the complex chemical behaviour of Zn in soils is an important aspect of ensuring the efficient use of Zn-containing fertilizers. There is increasing interest in the simultaneous and effective delivery of Zn to crops via fertilizer application. There is also an increasing range of macronutrient fertilizers that can act as carriers for Zn. However, the water solubility of a Zn fertilizer is an important factor in its agronomic effectiveness (Milani *et al*., 2012). Plant availability of Zn in soil is strongly correlated with water solubility of the compound, in that more water-soluble compounds confer higher amounts of plant Zn availability and uptake (Shaver *et al.*, 2007).

For better Zn nutrition of human beings, cereal grains should contain around 40 to 60 mg Zn kg^{-1}; however, the current situation is 10 to 30 mg Zn kg^{-1} (Cakmak, 2008). Although soil application of $ZnSO_4.7H_2O$ with microbial consortium is not a standard practice in India, the beneficial role for the application of microbial consortium in increasing the yield of maize was evident through several studies. In India, about 106 million tonnes of rice straw is produced annually and it adds about 0.61, 0.27 and 1.76 million tonnes of N, P and K, respectively (Manna and Ganguly, 2001). This cumbersome volume of rice straw occupies large area of land and possesses threat to environment up on burning. Hence, there is an urgent and imperative need to adapt technologies for gainful utilization and safe management of rice straw on sustainable basis. As the rice straw compost have promising role, it was programmed to investigate the effect of zinc sulphate with microbial consortium, rice straw compost on yield and Zn uptake of maize.

MATERIAL AND METHODS

A field experiment was conducted in Agricultural College farm ,Bapatla for maize (in *rabi*), replicated thrice in a split plot design. The 30V92 for maize was taken as a test crop. The field was divided into four main plots and each main plot into six sub plots carrying the following treatments. The main plot treatments were M_1: Control; M_2: RSC @ 5 t ha^{-1}; M_3: Microbial consortium @ 2kg ha^{-1} and M_4: RSC + MC and sub plots were graded levels of fly zinc sulphate at 0, 12.5, 25.0, 37.5, 50.0 and 62.5 kg ha^{-1}. The initial physicochemical properties of soil were analysed and characterization of rice straw compost was carried out for experimentation are mentioned in table.1. The available Zn (DTPA (pH 7.3) extractable Zn) of experimental soil was low (0.46 mg kg^{-1}). The fixed NPK recommendation made uniformly to all the plots. The major yield limiting attributes *viz*., number of kernels per cob and cob weight were recorded. The samples from tasseling, kernel and stover at harvest

were collected and oven dried at 65°c for 72 hours and powdered in Wiley mill. These samples were analysed for content of Zn after digestion with tri acid (Lindsay and Norvell, 1978). All the data were subjected to statistical analysis and relevant data for correlation following the standard procedures. Zn uptake was calculated as following

$$\text{Zn uptake (g ha}^{-1}) = \frac{\text{Zn content (mg kg}^{-1}) \times \text{Dry matter yield (kg ha}^{-1})}{1000}$$

RESULTS AND DISCUSSION

Kernel and Stover yield

A n increase in kernel yield from applied $ZnSO_4.7H_2O$ ranged from 4866-6993 kg ha^{-1} (Table 2) depending on the treatment as compared to control, no Zn application (4866 kg ha^{-1}). The maximum mean kernel yield of 6695 kg ha^{-1} was recorded by the addition of RSC+MC followed by MC (6350 kg ha^{-1}), RSC (6112 kg ha^{-1}) and control (5408 kg ha^{-1}) (Table 2). The treatment received 37.5 kg $ZnSO_4.7H_2O$ ha^{-1} with RSC+MC recorded significantly the highest kernel yield (7154 kg ha^{-1}). However, the treatments received rice straw compost alone and microbial consortium exclusively was on par with each other. The manure was believed to increase yields of maize as a result of improved water holding capacity, soil aeration, soil structure, nutrient retention and microbial activities, all of which were known to play a significant role in enhancing crop performance (Lekasi *et al*., 2000; FAO, 2006). The percentage increase in kernel yield of maize with RSC+ MC (M_4) was in the order of 5.44, 9.54 and 23.80 per cent over MC, RSC alone and control during 2014-15. Kanimozhi *et al.* (2015) found that the mycorrhizal inoculation increased the maize kernel yield by 17 percent on comparison with uninoculated treatments.

The stover yield was varied from 6124 to 7582 kg ha^{-1} irrespective of treatments and progress of crop growth. Significant and positive correlation was observed in between applied doses of $ZnSO_4.7H_2O$ and dry matter produced at different growth stages of maize. Among main plot treatments, RSC+MC registered higher stover yield (7582 kg ha^{-1}) followed by MC (7191 kg ha^{-1}). Among the graded levels, application of zinc sulphate at 37.5 kg ha^{-1} recorded 7465 kg ha^{-1} of stover yield which was higher among the different levels of zinc sulphate applied. Similar to kernel, application of $ZnSO_4.7H_2O$ at 37.5 kg ha^{-1} along with RSC+MC showed its superiority over rest of the treatments (8102 kg ha^{-1}) (Table 2). The percentage increase in stover yield with RSC+ MC was 24.2 per cent over untreated plots during 2014-15. Studies of Sharma, *et al.* (2001) revealed that organic manures had considerable positive effect on the physical properties of the soil, which might had translated into an increase in stover yield.

Zn uptake by kernel and stover of maize

Data presented in the Table 3 indicated that the Zn uptake by maize kernel increased with increase in level of $ZnSO_4.7H_2O$ application correspondingly. However, the increase was not significant beyond 50.0 kg ha^{-1} irrespective of treatments imposed. Whereas, Zn uptake attained the peak at $ZnSO_4.7H_2O$ level of 37.5 kg ha^{-1} in the second year of study. The mean highest and significant Zn uptake by maize kernel was recorded in the treatment S_5 with 216.8 g ha^{-1} followed by S_4 with 201.5 g ha^{-1} during first year of the study. The mean percent increase of Zn uptake by S_5 and S_4 treatments were 29.5 and 16.7 % over untreated check during first and second year, respectively. These results were in line with the findings of Suganya and Saravanan (2015) who have observed increase in uptake of Zn by maize kernel at $ZnSO_4.7H_2O$ level of 37.5 and 50 kg ha^{-1} (Table 3).

Among the interactions, significant Zn uptake by maize kernel was recorded in the treatment M_4S_4 with 235.3 g ha^{-1}. Treatments received $ZnSO_4.7H_2O$ level of 50 and 62.5 kg ha^{-1} showed similar results with respect to Zn uptake by maize kernel. Application of 62.5 kg $ZnSO_4.7H_2O$ with MC also resulted on par with M_4S_4 followed by M_3S_5 with 226.7 g ha^{-1} during the study period. These results corroborate with the findings of Kaur *et al*. (2014) and Kanimozhi *et al.* (2015) who reported the increased nutrients uptake due to the application of microbial inoculation to the crop. Regarding Zn fertilizer levels, graded levels of Zn application enhanced the nutrient uptake correspondingly. However, the increase was not significant beyond 37.5 and 50 kg of $ZnSO_4$ ha^{-1}. The probable reason might be due to the increase in soil nutrient status which favored the enhanced uptake. Similar findings were also reported by Muthumanikam *et al.* (2015).

Uptake of Zinc by maize stover also followed the similar trend as kernel Zn uptake. Data on stover Zn uptake presented in the table 3 indicated that irrespective of the treatments imposed, Zn uptake by stover was increased with graded levels of $ZnSO_4.7H_2O$ linearly. However, the increase was not significant beyond 50.0 and 37.5 kg of $ZnSO_4.7H_2O$ ha^{-1} during first year and second year of study, respectively. Among the main plot treatments, the treatments received RSC and MC alone recorded the similar stover Zn uptake (i.e. 205.9 and 215.3; 267.4 and 267.2, respectively) during both the years of experimentation. Similar trend as kernel Zn uptake was observed among the interactions with respect to stover Zn uptake during

Table 1. Initial characterization of experimental soil and schedule of activities of field experiments

Particulars	Rice straw compost	Field I
Mechanical Composition		
Sand (%)	-	78.4
Silt (%)	-	12.54
Clay (%)	-	9.06
Soil Texture	-	sandy loam (sl)
Physicochemical properties		
$pH_{1:2.5}$	-	7.32
$EC_{1:2.5}$ (dSm^{-1})	-	0.16
Cation Exchange Capacity (c mole(p^{+})kg^{-1})	-	12.60
Organic Carbon (g kg^{-1})	30.6	3.92
Available Nitrogen (Alkaline permanganate N) (kg ha^{-1})	0.81	174.20
Available Phosphorus (Olsen's P)(kg ha^{-1})	0.36	12.1
Available Potassium (NH_4OAc K)(kg ha^{-1})	0.54	284.00
Available Zn (DTPA 7.3 Zn) (mg kg^{-1})	23.00	0.46

Table 2. Graded levels of zinc sulphate with and without rice straw compost and microbial consortium on number of yield of maize during 2014-15

Sources/ Levels	Kernel yield							Stover yield						
	Levels of $ZnSO_4.7H_2O$ (kg ha^{-1})							Levels of $ZnSO_4.7H_2O$ (kg ha^{-1})						
	0	12.5	25	37.5	50	62.5	Mean	0	12.5	25	37.5	50	62.5	Mean
M_1	4372	4619	5094	5566	6249	6547	5408	4951	5231	5769	6304	7077	7414	6124
M_2	4575	5433	5976	6776	6908	7003	6112	5181	6153	6767	7673	7823	7931	6921
M_3	5024	5843	6223	6870	7022	7116	6350	5690	6618	7047	7781	7952	8059	7191
M_4	5495	6235	6732	7154	7249	7306	6695	6223	7061	7624	8102	8209	8274	7582
Mean	4866	5533	6006	6592	6857	6993		5511	6266	6802	7465	7765	7920	
	SEm±		CD (p=0.05)			CV (%)		SEm ±		CD (p=0.05)			CV (%)	
M	82		285			5.6		102		353			6.2	
S	64		184			5.1		64		184			5.3	
M at S	143		438					156		485				
S at M	128		367					129		368				

M_1- RDF (Control),
M_2- Rice straw compost (RSC) @ 5 t ha^{-1} + RDF,
M_3- Microbial consortium (MC) @ 2 kg ha^{-1}+ RDF,
M_4- M_2 +M_3
M- Sources of zinc solubilizers applied
S- Graded levels of $ZnSO_4.7H_2O$ applied (kg ha^{-1})

Table 3. Graded levels of Zn with/without RSC, MC on Zn uptake (g ha^{-1}) by maize at tasseling, kernel and stover at harvest during 2014-15

Sources/ Levels	Tasseling					Kernel at harvest					Stover at harvest				
	M_1	M_2	M_3	M_4	Mean	M_1	M_2	M_3	M_4	Mean	M_1	M_2	M_3	M_4	Mean
S_1	48.0	52.0	60.9	70.1	57.7	87.9	96.2	116.1	138.8	109.8	126.3	136.9	160.3	184.3	151.9
S_2	53.1	72.7	82.5	90.3	74.6	98.1	135.7	156.9	178.8	142.4	139.7	191.3	217.0	237.5	196.4
S_3	63.4	86.4	91.8	103.3	86.2	119	164.2	178.0	208.4	167.5	166.8	227.2	241.6	271.9	226.9
S_4	74.8	109.7	110.6	115.3	102.6	142	211.1	217.0	235.3	201.5	196.7	288.6	290.9	303.3	269.9
S_5	98.7	115.6	115.0	117.2	111.6	180	219.4	226.7	241.6	216.8	248.0	300.0	298.5	305.9	288.1
S_6	97.5	114.2	115.6	117.8	111.3	197	225.4	232.8	245.4	225.2	268.8	304.6	308.3	312.5	298.6
Mean	72.6	91.8	96.1	102.3		137	175.3	187.9	208.1		184.0	205.9	215.3	245.0	212.6
	SEm ±		CD (p=0.05)		CV (%)	SEm ±		CD (p=0.05)		CV	SEm ±		CD (p=0.05)		CV (%)
M	1.43		4.9		8.6	3.34		11.5		9	3.76		13		8.7
S	1.24		3.5		6.7	2.58		7.4		6.1	3.28		9.4		6.8
M at S	2.68		8.1			5.78		17.7			7.07		21.4		
S at M	2.49		7.1			5.16		14.7			6.56		18.7		

M_1- RDF (Control),
M_2- Rice straw compost (RSC) @ 5 t ha^{-1} + RDF,
M_3- Microbial consortium (MC) @ 2 kg ha^{-1}+ RDF,
M_4- M_2 +M_3
M- Sources of zinc solubilizers applied
S- Graded levels of $ZnSO_4.7H_2O$ applied (kg ha^{-1})

Table 4. Simple Correlation Matrix Showing the Relationship of Zn Uptake at Different Growth Stages of maize with kernel Yield

Parameter	Zn uptake at tasseling	Zn uptake by stover	Zn uptake by kernel	Kernel yield
Zn uptake at tasseling	1			
Zn uptake by stover	0.94**	1		
Zn uptake by kernel	0.81**	0.89**	1	
Kernel yield	0.69*	0.90**	0.87**	1

* Significant at the 0.05 probability level and
** significant at the 0.01 probability level.

both the years of experimentation. The results were in conformity with the findings of Suganya and Saravanan (2015).

CONCLUSION

The treatment consists of $ZnSO_4.7H_2O$ @ 37.5 kg ha^{-1} + RSC+MC proved optimum and superior in terms of yield and Zn uptake of maize in low Zn soils.

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