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Effect of Zinc application on soil properties and uptake of nutrients by wheat grown on calcareous soil

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Abstract
The present field experiment was conducted at PGI, Research Farm. Department of Soil Science and Agril. Chemistry, M.P.K.V., Rahuri, during the *Rabi* 2016-17.
The experiment was laid out in a randomized block design with three replication and nine treatments. The treatment comprised of T_1: Absolute control, T_2: General recommended dose of fertilizer 120:60:40 kg ha^{-1} N: P_2O_5:K_2O + 10 t FYM ha^{-1}, T_3: GRDF with soil application of $ZnSO_4$ @ 20kgha^{-1}, T_4: GRDF with 120 kg N through zinc coated urea + 60:40 P_2O_5:K_2O kg ha^{-1} + 10 t ha^{-1} FYM, T_5: GRDF with soil application of cow dung slurry with $ZnSO_4$, T_6: GRDF with soil application of 100 kg FYM + $ZnSO_4$ @20kgha^{-1}, T_7: GRDF with seed coating treatment of $ZnSO_4$ @ 20kgha^{-1}, T_8: GRDF with seed coating treatment of chelated Zn EDTA and T_9: GRDF with seed treatment of zinc solubilizing bacteria + soil application of zinc sulphate @ 20kgha^{-1}.
The results of investigation revealed that the application of different methods of zinc in soil was influenced the soil properties. The available nutrients N,P and K at harvest were found to be significantly increased due to treatment of GRDF +soil application of $ZnSO_4$ @ 20kgha^{-1} with 100 kg FYM incubated for one week and treatment of GRDF+soil application of cow dung slurry with $ZnSO_4$ @ 20 kgha^{-1}.
Total uptake of nitrogen, phosphorus and potassium by wheat crop were found to be significantly higher (138, 36 and 88 kgha^{-1} respectively) in treatment of application of $ZnSO_4$ @ 20kgha^{-1} incubated with FYM for one week along with GRDF however, it was at par with treatment of application of $ZnSO_4$ @ 20kgha^{-1} with cow dung slurry @500 Lha^{-1} at 30 DAS through irrigation along with GRDF.
Total uptake of iron, zinc, manganese and copper were found to be significantly higher (5177, 570, 1889 and 192 gha^{-1} respectively) in treatment of GRDF+application of ZnSO4@ 20kgha^{-1} incubated with FYM for one week.
Therefore, based on above findings, soil application of 100 kg FYM + $ZnSO_4$ @20 kgha^{-1} incubated for one week or soil application of cow dung slurry with $ZnSO_4$@20 kgha^{-1} (1:4) @500Lha^{-1} at 30 DAS through irrigation along with the general recommended dose of fertilizer (120:60:40 N:P_2O_5:K_2O kg ha^{-1} + 10 t ha^{-1} FYM) to wheat was found beneficial for increase in total uptake of nitrogen, phosphorus, potassium, iron, zinc, manganese and copper in wheat grown on medium deep black calcareous soil.

Keywords: Calcareous soil

Introduction

The importance of nutrients (micro and macro) for the normal growth of crop plants are universally recognized. In under-developed and developing countries however, plant nutrition is not being used in optimal and balanced levels and as consequence the production potential of soils are frequently not being fully exploited and the application of only major plant nutrients (N, P and K) are not adequate to achieve full potential yield of crops in many agricultural systems. Zinc is an important essential element present in plant enzymatic systems. Genc *et al.* (2006) [8] reported that zinc has vast numbers of functions in plant metabolism and consequently zinc deficiency has a multitude of effects on plant growth. Zinc deficiency is a worldwide nutritional constraint for crop production in many types of soil in the world (Sillanpaa 1982; Rengel and Graham, 1995) [27, 24, 25] and particularly in cereals growing on calcareous soil (Graham *et al.*, 1992; Cakmak *et al.*, 1996a; Singh *et al.*, 2005) [11, 3, 28].
Zinc deficiency is common on neutral and calcareous soils, intensively cropped soils, paddy soils and poorly drained soils, sodic and saline soils, peat soils, soils with high available phosphorus and silicon, sandy soils, highly weathered acid and coarse-textured soils. Factors such as topsoil drying, subsoil, disease interactions and high cost of fertilizer also contribute to zinc deficiency. The critical soil levels for occurrence of zinc deficiency are between 0.6 and

2.0 mg zinc kg^{-1} depending on the method of extraction used. Calcareous soils (pH>7) with moderate to high organic matter content (>1.5% organic carbon) are likely to be Zn deficient due to high HCO_3 in the soil solution. A ratio of more than 1 for exchangeable Mg:Ca in soil may also indicate Zn deficiency.

In the Indian context, more than 50% of the agricultural soils is zinc-deficient. The causes for occurrence of Zn deficiencies of this magnitude are related to the introduction of high yielding varieties, neglect of application of bulky organic manures, imbalanced use of fertilizer and low Zn uptake and accumulation of Zn which depends upon the pH, soil organic matter, temperature, crop species, etc. Zn deficiency is quite widespread in the Indo-Gangetic plain and other important cereal-growing states like Punjab, Uttar Pradesh, etc. which account for almost three-fourths of the country food grain production. The total area under Zn deficiency is about 10 Mha in India and approximately 85% of rice–wheat system cropping takes place in the Indo-Gangetic plain which has calcareous soils with high pH and thus low Zn availability. Improving production from this cereal belt is therefore, vital for sustaining grain production in the country. Correction of Zn deficiency through addition of Zn fertilizers is a common practice. With regard to human Zn-nutrition, fortification of Zn in food is practised, but is expensive and difficult to implement in developing countries like India, Bangladesh, Nepal, etc. Development of crop plants that are efficient Zn accumulators, especially under Zn deficiency is, therefore, a potentially important endeavour for improving zinc deficiency tolerance of cereal species *vis-à-vis*, grain productivity and micronutrient quality. There is a need for selection and/or breeding of plant genotypes with higher resistance to Zn deficiency both in terms of a higher grain yield and a higher grain Zn content. (Graham *et.al*., 1992) [11] Realization of this approach is possible in view of the large genotypic differences in Zn sensitivity among crop plants, particularly when its availability to the roots is limited (Cakmak I. *et al*., 1998; Rengel *et al*. I and II, 1995) [4, 24, 25].

In Maharashtra soils, Chavan (1978) [5] reported that konkan soils have potential to supply total zinc in the range of 30 to 125 mg kg^{-1}. The orchard soil of Maharashtra were analysed by Jadhav *et al*. (1978) [14] and showed that the total zinc ranged from 84 to 192 mg kg^{-1}. However, Chavan and Banerjee (1980) [6] reported 20 to 125 mg kg^{-1} total zinc in soil profile from different agroclimatic zones of Maharashtra. Patil and Shingte (1982) [22] and More *et al*. (1984) [18] surveyed the drought prone area of Shirur and rice growing soils of Mulsi and Marval tehsils of Pune district and reported that the soils were varied in available zinc between 0.15-2 and 0.8-1.80 mg kg^{-1}.

Material and Methods

The present investigation was carried out during the year 2016-17 in the Department of Soil Science and Agricultural Chemistry, Post Graduate Institute, Mahatma Phule Krishi Vidyapeeth, Rahuri. The experimental plot situated at $19^0$34' N latitude and $74^0$64' E longitude, medium deep black soil belonging to Inceptisol order. The soils were deficient in Zn and Fe, The field experimental site climatically belongs to semi arid zone with an average rainfall of 519 mm.

Experiment was conducted on medium deep black soil belonging to order Inceptisol (*Vertic Haplustepts*) having clay in texture, slightly alkaline (pH 8.18), normal in soluble salt (EC 0.34 dSm^{-1}), high in organic carbon (0.68%) and calcareous in nature (12.75% $CaCO_3$). Fertility status was low in available N (169.15 kg ha^{-1}), medium in P (17.90 $kgha^{-1}$) and high in available K (337.63 kg ha^{-1}) however, DTPA micronutrients Mn and Cu were sufficient and deficient in Fe and Zn in soil.

Samadhan variety of wheat were used in the field Experiments which are used predominantly by fanners in that locality Seeding rate was 100 kg per hactare and plot sizes were 3.6x 3.2 m. The basal fertilizer applications were 120 kg N ha^{-1} 60 kg P_2O_5 and 40 kg K_2O ha^{-1} as urea, single superphosphate and muriate of potash, respectively. Of the total N dose, 60 kg N ha^{-1} was applied during planting and the rest was applied 30 DAS. Zn in the form of $ZnSO_4.7H_2O$, Zinc coated urea, Zn-EDTA and Zinc solubilizing bacteria were used as per treatment under study

The experiment was laid out in a randomized block design with three replication and nine treatments. The treatment comprised of T_1: Absolute control, T_2: General recommended dose of fertilizer 120:60:40 kg ha^{-1} N: P_2O_5:K_2O + 10 t FYM ha^{-1}, T_3: GRDF with soil application of $ZnSO_4$ @ 20$kgha^{-1}$, T_4: GRDF with 120 kg N through zinc coated urea + 60:40 P_2O_5:K_2O kg ha^{-1} + 10 t ha^{-1} FYM, T_5: GRDF with soil application of cow dung slurry with $ZnSO_4$, T_6: GRDF with soil application of 100 kg FYM + $ZnSO_4$ @20$kgha^{-1}$, T_7: GRDF with seed coating treatment of $ZnSO_4$ @ 20$kgha^{-1}$, T_8: GRDF with seed coating treatment of chelated Zn EDTA and T_9: GRDF with seed treatment of zinc solubilizing bacteria + soil application of zinc sulphate @ 20$kgha^{-1}$ Differences among means and treatments were compared by the significant differences (SD) at $P<0.05$.

Before planting, surface (0–30 cm) soil samples from plots were collected, air-dried, and crushed to pass a 2-mm sieve, and stored for further analysis. Soil pH was measured by Potentiometric method (Jackson 1973) [12] in a digital pH-meter. Electrical conductivity (EC) was measured by conductivity electrode (Jackson 1973) [12]. The Organic carbon were analysed by Walkely and Black method (Nelson and Sommer, 1982) [20]. The $CaCO_3$ was measured by Acid neutralization (Alison and Moodier, 1965) [1] available-P content was extracted by $NaHCO_3$ (Olsen and Watanabe, 1954) [21] and available-K was extracted with NH_4-OAc (Jackson, 1973) [12] and determined by flamephotometer Soil Zn was extracted with DTPA (Lindsay and Norvell, 1978) [16] and then determined using AAS technique. The selected soil chemical properties are shown in Table 1.

Table 1: Initial fertility status of soil

Sr. No.	Parameters	Value
A.	**Chemical properties**	
1.	pH (1:2.5)	8.18
2.	EC (dSm^{-1})	0.34
3.	Organic carbon (%)	0.68
4.	Calcium carbonate (%)	12.75
5.	Available N (kg ha^{-1})	169.15
6.	Available P (kg ha^{-1})	17.90
7.	Available K (kg ha^{-1})	337.63
8.	Available Fe (ppm)	3.63
9.	Available Zn (ppm)	0.52
10.	Available Mn (ppm)	14.68
11.	Available Cu (ppm)	0.84

Results and Discussion

The results showed low status (169.15 $kgha^{-1}$) in available nitrogen in soil at initial stage and significant variation at harvest. The available N status in soil at harvest was significantly higher (170.33 kg ha^{-1}) in application of cow dung slurry with $ZnSO_4$ treatment of T_5 over all other treatments except treatment T_6 (168.33 kg ha^{-1}) (Table 2).

The soil available P showed medium status (17.90 kg ha^{-1}) at initial. At harvest it was higher in treatment T_6 (14.63 kg ha^{-1}) over all other treatments. Overall available P showed low status in soil at harvest in all treatments except medium status in treatment of T_6 and T_5. The low status of available P in soil in rest of the treatment may be due to higher fixation of P in calcareous soil. Low phosphorus availability in calcareous soil might be due to their transformation to more complicated forms with $CaCO_3$ and these changed forms are rendered less available to growing plants. Similar results were also recorded by Bashour *et al.* (1983). The effect of low P solubility in alkaline and calcareous soil was due to poor fertilizer P efficiency. The similar results were also supported by Stark and Westermann (2003) [29], and Javid and Rowell (2003) [13] (Table 2).

Soil available K status was high (337.63 kg ha^{-1}) in soil at initial stage but the available K status at harvest showed significantly higher status in T_6 treatment over all other treatment except T_7. The available K status at harvest stage showed very high fertility status which did not change the category of fertility status of available K in soil as influenced by various treatments (Table 2).

Table 2: Effect of different methods of zinc application on available nitrogen, phosphorus and potassium in calcareous soil

Tr. No.	Treatment	Av.N(kgha^{-1})		Av.P(kgha^{-1})		Av.K (kgha^{-1})	
		Initial	At harvest	Initial	At harvest	Initial	At harvest
T_1	Absolute control	171.00	143.33	18.00	10.43	337.67	289.33
T_2	GRDF(120:60:40 N:P_2O_5:K_2O kg ha^{-1} + 10 t ha^{-1} FYM)	168.00	154.67	16.93	13.37	338.33	309.00
T_3	T_2 + Soil application of $ZnSO_4$ @ 20 kg ha^{-1}	167.33	149.67	17.07	13.27	336.33	307.67
T_4	120 Kg N through zinc coated urea+60:40 P_2O_5:K_2O kg ha^{-1}+10t ha^{-1} FYM	174.33	162.33	17.23	12.70	336.33	301.00
T_5	T_2 + Soil application of cow dung slurry with $ZnSO_4$ @ 20 kg ha^{-1} (1:4) @ 500 L ha^{-1} at 30 DAS through irrigation.	176.33	170.33	17.37	14.20	335.00	312.00
T_6	T_2 + Soil application of 100 kg FYM +$ZnSO_4$ @ 20 kg ha^{-1} incubated for one week	175.33	168.33	17.33	14.63	337.00	323.00
T_7	T_2 + Seed coating treatment of $ZnSO_4$ @ 2%	168.00	159.67	17.43	14.20	339.67	317.00
T_8	T_2 + Seed coating treatment of chelated Zn EDTA @ 0.5%	167.00	157.67	17.53	12.53	335.33	308.00
T_9	T_2 + Seed treatment of Zinc solubilizing bacteria @5%+soil application of zinc sulphate @ 20 kg ha^{-1}	170.33	162.00	17.93	13.80	334.67	313.67
	SE±		1.58		0.12		2.02
	CD at 5%		4.76		0.37		6.07

The soils were deficient in iron and zinc as the critical limit of iron and zinc are 4.5 and 0.6 µgg^{-1}respectively. The results showed low status (3.63 µgg^{-1}) at initial stage as well as at harvest (3.31 µgg^{-1}) in respect of soil available iron but in case of available zinc, the result showed low status (0.52 µgg^{-1}) at initial but at harvest available Zn was found to be significantly increased in T_6 treatment (0.59 µgg^{-1}) over all other treatment except T_3 (0.56 µgg^{-1}) and T_5(0.58 µgg^{-1}). This might be due to natural chelates of humic and fulvic acid formed during incubation and slurry treatment, may be chelates with the zinc and its efficiency increased in soil, reflected in increased of available zinc in soil at harvest (Table 3).

Table 3: Available zinc and iron content in soil as influenced by methods of zinc application in calcareous soil

Tr. No.	Treatment	DTPA-Zn (µgg^{-1})		DTPA-Fe (µgg^{-1})	
		Initial	At harvest	Initial	At harvest
T_1	Absolute control	0.54	0.44	3.59	2.81
T_2	GRDF(120:60:40 N:P_2O_5:K_2O kg ha^{-1} + 10 t ha^{-1} FYM)	0.51	0.47	3.57	2.89
T_3	T_2 + Soil application of $ZnSO_4$ @ 20 kg ha^{-1}	0.52	0.56	3.63	3.03
T_4	120 Kg N through zinc coated urea+60:40 P_2O_5:K_2O kg ha^{-1}+10t ha^{-1} FYM	0.52	0.54	3.61	2.95
T_5	T_2 + Soil application of cow dung slurry with $ZnSO_4$ @ 20 kg ha^{-1} (1:4) @ 500 L ha^{-1} at 30 DAS through irrigation.	0.54	0.58	3.60	3.13
T_6	T_2 + Soil application of 100 kg FYM +$ZnSO_4$ @ 20 kg ha^{-1} incubated for one week	0.51	0.59	3.77	3.57
T_7	T_2 + Seed coating treatment of $ZnSO_4$ @ 2%	0.52	0.48	3.69	3.52
T_8	T_2 + Seed coating treatment of chelated Zn EDTA @ 0.5%	0.50	0.47	3.59	3.46
T_9	T_2 + Seed treatment of Zinc solubilizing bacteria @5%+soil application of zinc sulphate @ 20 kg ha^{-1}	0.51	0.49	3.63	3.48
	SE±		0.01		0.25
	CD at 5%		0.03		NS

The result showed sufficient (14.68 µgg^{-1}) in available manganese at initial stage and at harvest, available Mn was found to be significantly higher in T_6 treatment (14.03 µgg^{-1}) over all other treatment except T_4 (13.82 µgg^{-1}) and T_5 (13.80 µgg^{-1}). This is because of production of root exudates that are toxic to Mn-oxidizing microorganisms in the rhizosphere which increased Mn availability. Similar results were also reported by Timonin (1946) [30] (Table 4).

Similarly in case of copper at initial result was sufficient (0.84 µgg^{-1}) but at harvest it was found to be significantly higher in treatment T_6 (0.89 µgg^{-1}) over all other treatments. So this may be due to application of zinc fertilizer which enable Zn^{2+} activity much higher than Cu^{2+} activity at the absorbing sites making it an effective competitor in Cu absorption and making its absorption less sensitive to competition from Cu. Similar result also showed by Loneragan *et al.* (1993) (Table 4).

Table 4: Available copper and manganese content in soil as influenced by methods of zinc application in calcareous soil

Tr. No.	Treatment	DTPA-Mn (μgg^{-1})		DTPA-Cu (μgg^{-1})	
		Initial	At harvest	Initial	At harvest
T_1	Absolute control	14.50	12.18	0.82	0.62
T_2	GRDF(120:60:40 N:P_2O_5:K_2O kg ha^{-1} + 10 t ha^{-1} FYM)	14.89	13.56	0.86	0.73
T_3	T_2 + Soil application of $ZnSO_4$ @ 20 kg ha^{-1}	14.98	13.58	0.84	0.80
T_4	120 Kg N through zinc coated urea+60:40 P_2O_5:K_2O kg ha^{-1}+10t ha^{-1} FYM	14.51	13.82	0.86	0.76
T_5	T_2 + Soil application of cow dung slurry with $ZnSO_4$ @ 20 kg ha^{-1} (1:4) @ 500 L ha^{-1} at 30 DAS through irrigation.	14.45	13.80	0.85	0.72
T_6	T_2 + Soil application of 100 kg FYM +$ZnSO_4$ @ 20 kg ha^{-1} incubated for one week	14.95	14.03	0.82	0.89
T_7	T_2 + Seed coating treatment of $ZnSO_4$ @ 2%	14.91	13.53	0.84	0.76
T_8	T_2 + Seed coating treatment of chelated Zn EDTA @ 0.5%	14.69	13.26	0.86	0.80
T_9	T_2 + Seed treatment of Zinc solubilizing bacteria @5%+soil application of zinc sulphate @ 20 kg ha^{-1}	14.29	13.36	0.82	0.74
	SE±		0.09		0.01
	CD at 5%		0.28		0.03

The data in respect of total nitrogen uptake by wheat was found significant results as influenced by methods of zinc application in calcareous soil.The treatments of T_5 and T_6 showed significantly higher uptake of total N (138 kg ha^{-1}) as compare to all other treatments except T_4(135 kg ha^{-1}) and T_9(134 kg ha^{-1}) which were at par with treatment T_5(138 kg ha^{-1}) and T_6(138 kg ha^{-1}). Higher total uptake of nitrogen was may be due to application of zinc sulphate@20kgha^{-1} incubated one week with FYM and use of cow dung slurry given through irrigation might have increased the zinc use efficiency in soil as compare to other treatments. Potarzycki and Grzebisz (2009) [23] also reported similar result that zinc exerts a great influence on basic plant life processes such as nitrogen metabolism and uptake of nitrogen (Table 5).

The highest total P uptake by wheat plant was found to be significantly observed higher in treatment of T_6(36 kg ha^{-1}) over treatments of T_1, T_7 and T_9, however, treatment T_2, T_3, T_4, T_5 and T_8 were at par with treatment T_6. This can be because of application of zinc sulphate @ 20 kg ha^{-1} along with incubated FYM for one week might have increased the availability of P in soil (Table 5).

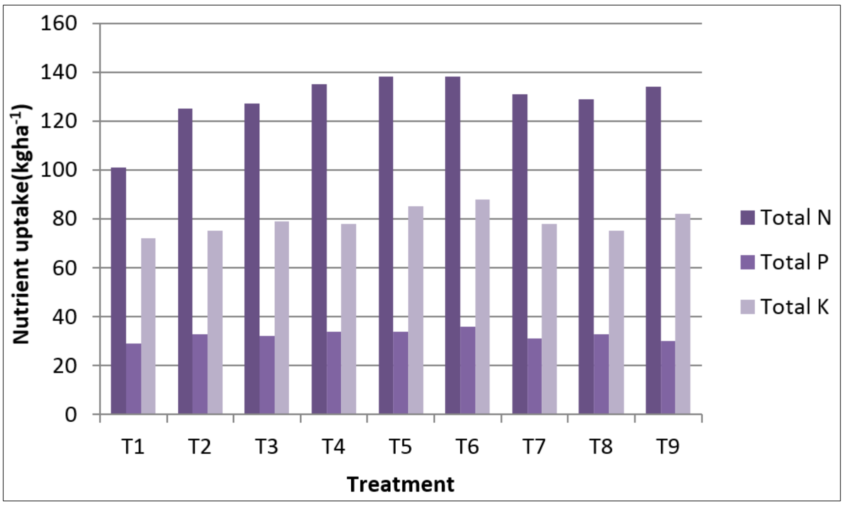

Fig 1: Effect of methods of zinc application on total uptake of N, P and K by wheat crop at harvest stage

Data on total potassium uptake by wheat revealed that, the significant increased in total K uptake (88 kg ha^{-1}) was observed in treatment T_6 (T_2 + Soil application of 100 kg FYM +$ZnSO_4$ @ 20 kg ha^{-1} incubated for one week) over all other treatments except treatment T_5(85kgha^{-1}) which was at par with T_6(Table 5).

Table 5: Effect of methods of zinc application on total uptake of N, P and K by wheat crop at harvest stage

Tr. No.	Treatment	Total uptake of macronutrient (kg ha^{-1})		
		N	P	K
T_1	Absolute control	101	29	72
T_2	GRDF(120:60:40 N:P_2O_5:K_2O kg ha^{-1} + 10 t ha^{-1} FYM)	125	33	75
T_3	T_2 + Soil application of $ZnSO_4$ @ 20 kg ha^{-1}	127	32	79
T_4	120 Kg N through zinc coated urea+60:40 P_2O_5:K_2O kg ha^{-1} +10t ha^{-1} FYM	135	34	78
T_5	T_2 + Soil application of cow dung slurry with $ZnSO_4$ @ 20 kg ha^{-1} (1:4) @ 500 L ha^{-1} at 30 DAS through irrigation.	138	34	85
T_6	T_2 + Soil application of 100 kg FYM +$ZnSO_4$ @ 20 kg ha^{-1} incubated for one week	138	36	88
T_7	T_2 + Seed coating treatment of $ZnSO_4$ @ 2%	131	31	78
T_8	T_2 + Seed coating treatment of chelated Zn EDTA @ 0.5%	129	33	75
T_9	T_2 + Seed treatment of Zinc solubilizing bacteria @5%+soil application of zinc sulphate @ 20 kg ha^{-1}	134	30	82
	SE±	1.38	1.35	1.40
	CD at 5%	4.14	4.05	4.21

The higher total uptake of nutrients (N, P and K) might be due to increased in grain and stover yield of wheat and availability of zinc in soil due to incubation and slurry treatment. The increase in total N and K uptake could be attributed to synergistic effect between N and Zn and due to the positive interaction of K and Zn, respectively. The present findings also support the results of Ashoka *et al*. (2008), Morshedi and Farahbakhsh (2010) [19] (Fig. 1).

The results indicated that, there was significant variation in uptake of Fe and Zn. The maximum total micronutrient uptake Fe (5177 g ha^{-1}), and Zn (570 g ha^{-1}), were found to be significantly higher in treatment T_6 (T_2 + Soil application of 100 kg FYM +$ZnSO_4$ @ 20 kg ha^{-1} incubated for one week) over the rest treatments (Fig. 2).

The increase in the zinc content in grain and straw might be due to the presence of increased amount of Zn in soil solution by the application of zinc fertilizer that facilitated greater absorption. Similar result was also reported by Sakal *et al.*, 1987 [26]; Mollah *et al.*, 2009 [17]; Fageria *et al.*, 2011 [7]. (Table 6)

Higher uptake of iron probably due to differences in experimental details, especially in plant species and the concentration, ionic state and complexation of Fe. Similar results were also supported by Giordano *et al.* (1974) [10] (Table 6)

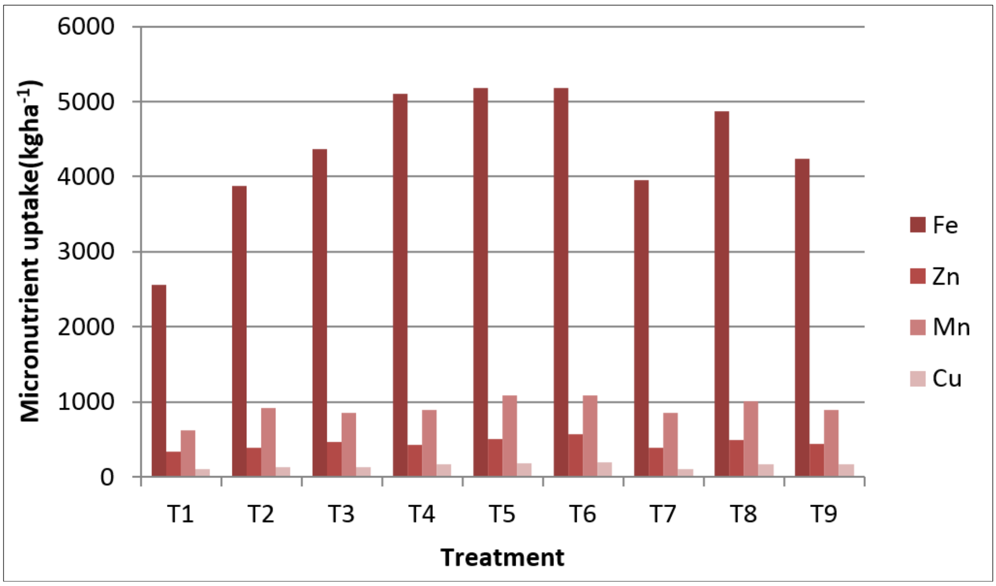

Fig 2: Effect of different methods of zinc application on total uptake of Iron, Zinc, Manganese, copper by wheat crop at harvest stage

Table 6: Effect of different methods of zinc application on total uptake of Iron, Zinc Manganese and Copper by wheat crop at harvest stage

Tr. No.	Treatment	Total uptake of micronutrients (gha^{-1})			
		Fe	Zn	Mn	Cu
T_1	Absolute control	2559	344	625	107
T_2	GRDF(120:60:40 N:P_2O_5:K_2O kg ha^{-1} + 10 t ha^{-1} FYM)	3877	397	924	132
T_3	T_2 + Soil application of $ZnSO_4$ @ 20 kg ha^{-1}	4373	474	850	138
T_4	120 Kg N through zinc coated urea+60:40 P_2O_5:K_2O kg ha^{-1}+10t ha^{-1} FYM	5106	429	891	170
T_5	T_2 + Soil application of cow dung slurry with $ZnSO_4$ @ 20 kg ha^{-1} (1:4) @ 500 L ha^{-1} at 30 DAS through irrigation.	5176	510	1085	188
T_6	T_2 + Soil application of 100 kg FYM +$ZnSO_4$ @ 20 kg ha^{-1} incubated for one week	5177	570	1089	192
T_7	T_2 + Seed coating treatment of $ZnSO_4$ @ 2%	3950	386	854	113
T_8	T_2 + Seed coating treatment of chelated Zn EDTA @ 0.5%	4876	491	1014	166
T_9	T_2 + Seed treatment of Zinc solubilizing bacteria @5%+soil application of zinc sulphate @ 20 kg ha^{-1}	4233	440	893	175
	SE±	0.98	1.32	1.38	1.41
	CD at 5%	2.92	3.97	4.15	4.25

The results indicated that, there was significant variation in uptake of Cu and Mn. The maximum total micronutrient uptake of Cu (192 g ha^{-1}) was found in T_6 (T_2 + Soil application of 100 kg FYM + $ZnSO_4$ @ 20 kg ha^{-1} incubated for one week) over all other treatments except T_5 treatment (188 g ha^{-1}) which was at par with treatment T_6, and total uptake of Mn (1089 g ha^{-1}), was found higher in treatment T_6 (T_2 + + Soil application of 100 kg FYM + $ZnSO_4$ @ 20 kg ha^{-1} incubated for one week) over all other treatments except T_5 which was at par with treatment T_6. This might be due to exudation of phytase which is important for Mn uptake from high-pH soils, similar results also observed by George *et al.* (2014) [9] (Fig. 2).

Conclusion

It is concluded that, soil application of one week incubated zinc sulphate @ 20kgha^{-1}+100 kg FYM or soil application of cow dung slurry with ZnSO4 @ 20kgha^{-1}(1:4) @ 500 Lha^{-1} at 30 DAS through irrigation along with the general recommended dose of fertilizer (120:60:40 N:P_2O_5:K_2O kg ha^{-1} + 10 t ha^{-1} FYM) to wheat was found beneficial for increase in, total uptake of macronutrient and micronutrient.

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