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Zinc fertilization: Practice to improve zinc use efficiency and yield of wheat grown on calcareous soil

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Abstract
The present investigation 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 grain and straw yield of wheat was significantly increased (48.39 qha^{-1} and 53.52 qha^{-1} respectively) in treatment of GRDF with soil application of 100 kg FYM + $ZnSO_4$ @ 20kgha^{-1} incubated for one week. Which 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 i.e. 47.89 qha^{-1} grain yield and 51.06 qha^{-1} straw yield respectively. In conclusion, it was observed that zinc fertilization in zinc deficient calcareous soils improved the zinc use efficienc and yield of wheat.

Keywords: Zinc Sulphate, Zinc Use Efficiency, ZnSB

Introduction
In India, zinc is now considered the fourth most important yield limiting nutrient after, nitrogen, phosphorus and potassium, respectively. Analysis of 256,000 soils and 25,000 plant samples from all over India showed that 48.5% of the soils and 44% of the plant samples were potentially zinc deficient and this was the most common micronutrient problem affecting crop yields in India. Deficiency of zinc has increased in southern states due to extensive use of NPK without micronutrients. Periodic assessment of soil test data also suggests that zinc deficiency in soils of India is likely to increase from 49 to 63% by the year 2025 as most of the marginal soils brought under cultivation are showing zinc deficiency. Farming families consuming their zinc deficient crop produce leads to low zinc in their blood plasma compared to those which were fed on produce received from farms fertilized with zinc regularly. Zinc supplementation is therefore essential for maintaining high zinc content in soil, seed and blood plasma of human and animals (Singh 2009) [20].
Zinc deficiency is a worldwide nutritional constraint for crop production in many types of soil in the world (Sillanpaa 1982; Rengel and Graham, 1995) [17, 15] and particularly in cereals growing on calcareous soil (Graham *et al.*, 1992; Cakmak *et al.*, 1996a; Singh *et al.*, 2005) [10, 3, 19].
Zinc has been found useful in improving yield and yield components of wheat (Cakmak *et al*., 1996; Modaihsh, 1997; Kaya *et al*., 2002 and Singh, 2004) [3, 13, 11, 18] and adequately applied zinc has been shown to improve the water use efficiency of wheat plants (Bagci *et al*., 2007) [1]. High temperature during maturation and ripening is a major stress in many wheat production areas (Gibson and Paulsen 1999) [6], and zinc can help provide thermo-tolerance to the photosynthetic apparatus of wheat (Graham and McDonald, 2001) [9]. In general zinc application appears to improve the overall field performance of wheat plants.

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 hectare 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 $P<0.05$.

For the determination of Zn concentrations in whole straw and grains, samples were taken at the harvest stages from each plot. Concentrations of Zn in straw and grain were determined by atomic absorption Spectrometry after digesting samples at 250 °C by diacid HNO_3: $HClO_4$ (9:4) (Zososki and Burau (1977)) [22].

Result and Discussion

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.

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 [16]; Mollah *et al*., 2009 [14]; Fageria *et al*., 2011 [4].

Table 1: 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

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) [7] (table 1).

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) [5] (table 1).

It was observed from grain yield data of wheat that, the grain yields were significantly increased (2.00 to 14.13 per cent) over general recommended dose of fertilizer treatment (T_2) with significantly highest (48.39 qha^{-1}) in treatment of 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 and T_8 (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 and T_2 + Seed coating treatment of chelated Zn EDTA @ 0.5%) having yield of 47.89 and 46.56 q ha^{-1} respectively, which were at par with treatment T_6. Soil application of 100 kg FYM incubated with $ZnSO_4$@ 20 kg ha^{-1}along with recommended dose of fertilizer (T_6) recorded

14.13 % more grain yield as compared to only recommended dose of treatment (T_2). This might be due to availability of zinc in soil and its uptake by wheat crop. (table 2)

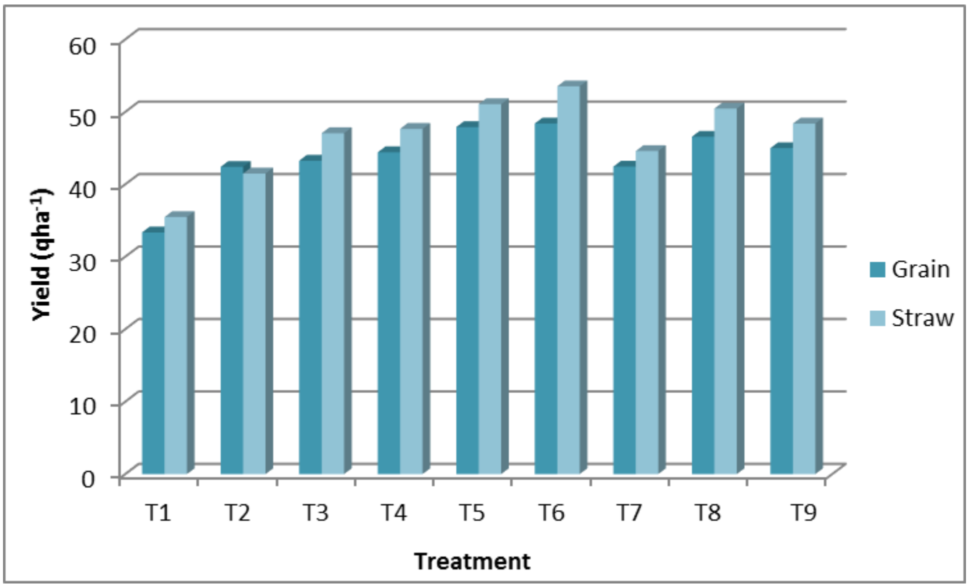

Fig 1: Effect of zinc application on grain and straw yield of wheat in calcareous soil

The straw yield of wheat data that, the per cent increased in straw yield was 7.50 to 29.03 over GRDF of treatment T_2. The treatment T_6 (T_2 + Soil application of 100 kg FYM + $ZnSO_4$ @ 20 kg ha^{-1} incubated for one week) showed significantly higher stover yield (53.52 q ha^{-1}) among all the treatments except treatment 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) with stover yield of 51.06 q ha^{-1} which was at par with treatment T_6. Soil application of 100 kg FYM incubated with $ZnSO_4$@ 20 kg ha^{-1}along with recommended dose of fertilizer (T_6) found 29.03 % more stover yield (T_6) as compared to only RDF treatment (T_2) under study. This might be due to slight increase in chlorophyll content in leaves of wheat plant and availability of zinc in soil during plant growth. (table 2)

The increase in grain and straw yield (fig.1) due to Zn fertilization might be the fact that Zn plays an important role in biosynthesis of the IAA and initiation of primodia for reproductive parts and a result of favourable effect of zinc on the metabolic reactions within the plants. Similar results were also reported by Goswami (2007) [8], Singh *et al*. (2012) [21] and Keram *et al*. (2012) [12].

Table 2: Grain and straw yield of wheat in calcareous soil

Tr. No.	Treatments	Yield (qha^{-1})		Percent increase yield over T_2 treatment	
		Grain	Straw	Grain	Straw
T_1	Absolute control	33.35	35.48	-	-
T_2	GRDF(120:60:40 N:P_2O_5:K_2O kg ha^{-1} + 10 t ha^{-1} FYM)	42.40	41.48	-	-
T_3	T_2 + Soil application of $ZnSO_4$ @ 20 kg ha^{-1}	43.25	47.05	2.00	13.15
T_4	120 Kg N through zinc coated urea+60:40 P_2O_5:K_2O kg ha^{-1}+10 t ha^{-1} FYM	44.42	47.65	4.76	14.87
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.	47.89	51.06	12.95	23.09
T_6	T_2 + Soil application of 100 kg FYM +$ZnSO_4$ @ 20 kg ha^{-1} incubated for one week	48.39	53.52	14.13	29.03
T_7	T_2 + Seed coating treatment of $ZnSO_4$ @ 2%	42.44	44.59	0.09	7.50
T_8	T_2 + Seed coating treatment of chelated Zn EDTA @ 0.5%	46.56	50.45	9.81	21.62
T_9	T_2 + Seed treatment of Zinc solubilizing bacteria @5%+soil application of zinc sulphate @ 20 kg ha^{-1}	44.98	48.38	6.08	16.63
	SE±	1.03	0.85		
	CD at 5%	3.10	2.57		

Zinc use efficiency was increased (table 3) in different methods of zinc application on wheat in treated plots over control (T_1). The zinc use efficiency was recorded highest (1.13 g g^{-1}) in treatment T_6 (T_2 + Soil application of 100 kg FYM +$ZnSO_4$ @ 20 kg ha^{-1} incubated for one week) followed by treatment T_5 (0.83 g g^{-1}). This indicated increase in zinc use efficiency due to different methods of zinc application. This might be due to increase in availability of Zn in soil and uptake of zinc by plant. (fig.2)

Table 3: Zinc use efficiency of wheat as influenced by different zinc fertilization to wheat on calcareous soil

Tr. No.	Treatment	Zinc use efficiency(gg^{-1})
T_1	Absolute control	-
T_2	GRDF(120:60:40 N:P_2O_5:K_2O kg ha^{-1} + 10 t ha^{-1} FYM)	1.26
T_3	T_2 + Soil application of $ZnSO_4$ @ 20 kg ha^{-1}	3.09
T_4	120 Kg N through zinc coated urea+60:40 P_2O_5:K_2O kg ha^{-1} +10 t ha^{-1} FYM	2.02
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.	3.90
T_6	T_2 + Soil application of 100 kg FYM +$ZnSO_4$ @ 20 kg ha^{-1} incubated for one week	5.30
T_7	T_2 + Seed coating treatment of $ZnSO_4$ @ 2%	1.00
T_8	T_2 + Seed coating treatment of chelated Zn EDTA @ 0.5%	3.50
T_9	T_2 + Seed treatment of Zinc solubilizing bacteria @5%+soil application of zinc sulphate @ 20 kg ha^{-1}	2.28
	SE±	0.09
	CD at 5%	0.27

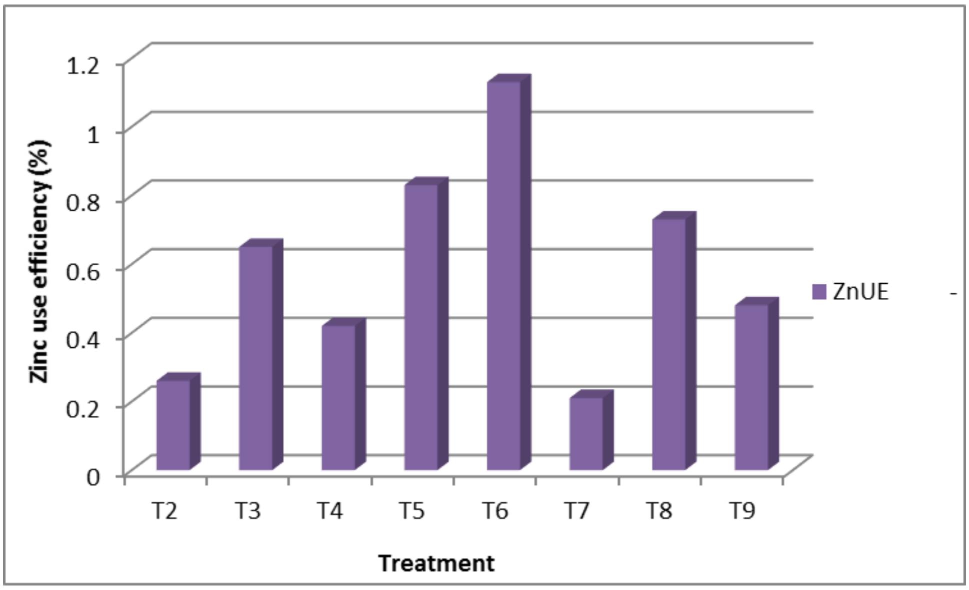

Fig 2: Zinc use efficiency of wheat as influenced by zinc fertilization to wheat on calcareous soil

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 grain and stover yield of wheat and zinc use efficiency,

Zinc deficiency is one major micronutrient deficiency in humans, particularly in developing countries, where cereals with very low levels of Zn are the primary stable foods for human consumption (Graham and Welch, 1995) [15]. In countries that have serious Zn deficiency problems in plants and humans, combined applications of Zn to soils and leaves may be necessary for short-term solutions to Zn deficiencies in plants and humans.

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