EFFECT OF ZINC FERTILIZATION ON RICE YIELD AND CHEMICAL FRACTION IN SOIL

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ABSTRACT: The experiment was conducted during kharif seasons of April-July in the year 2011 to study the response of zinc fertilization on rice yield and zinc fraction in to two soil (clay loam- Kondal series -Typic Haplusterts) and (sandy clay loam - Padugai series-Typic Ustifluvents). The treatment consist with two factors viz., Factor A – Zinc levels (mg kg^{-1}) Zn_0 – 0, Zn_1- 2.5,Zn_2- 5.0 and Zn_3- 7.5 and Factor B- Zinc sources S_1 – Zinc sulfate (Zn – 21%),S_2 – Zn-EDTA (Zn – 12%),S_3 – Zn humate (Zn – 9%). The result of experiment revealed that Addition of 5.0 mg Zn kg^{-1} registered the highest grain yield (5556 and 5771 kg ha^{-1}) and straw yield (7029 and 7120 kg ha^{-1}) with per cent increase in grain yield due to $Zn_{5.0}$ over Zn_0 was 25.9 in Vertisol and 21.8 in Entisol, respectively. With respect to zinc sources, application of Zn through Zn-EDTA recorded the highest grain yield (5307, 5546 kg ha) and straw yield (6691 and 6913 kg ha^{-1}) in Vertisol and Entisol respectively which was significantly superior to $ZnSO_4$ and Zn-humate. The interaction effect between zinc sources and Zn level was significant. At all levels of zinc, Zn-EDTA registered significantly higher grain and straw yield over other two sources. The highest grain and straw yield was obtained when 5.0 mg Zn kg^{-1} was applied through Zn-EDTA (5732, 5946 kg ha^{-1}) and (7234, 7302 kg ha^{-1}) with per cent increase due to this treatments over control was 30.0 and 24.4 and 26.7 and 20.4 in Vertisol and Entisol respectively. All forms of zinc fractions increased with Zn levels and the highest was observed with 7.5 mg Zn kg^{-1} and it was significantly superior to rest of the levels.

Key words: Rice, Zinc, Zn-EDTA, Zn-Humate, zinc fractions.

INTRODUCTION:

Rice is the staple food for about 50 per cent of the world's population (72.7 billion) that resides in Asia where 90 per cent of the world's rice is grown and consumed. It is an important staple food that provides 66 to 70 per cent body calorie intake of the consumers (Barah and Pandey, 2005). On a global basis, rice provides 21 per cent of energy and 15 per cent of protein requirement of human population (MacLean *et al.*, 2002; Depar *et al.*, 2011). Among micronutrients, Zn deficiency is a widespread nutritional constraint throughout the world. Zinc (Zn) is essential for human body and is involved in physiological and nutritional functions in human growth and development, including humoral and cellular immunity as well as the synthesis of proteins and nucleic acids (Bonaventuraa et al., 2015).Globally about two billion people are zinc deficient (Muller and Krawinkel, 2005). Zinc deficiency problem exists in both developed as well as developing countries (Gibbson, 2006).The productivity and quality of rice depends on environmental conditions and agronomic management practices of the area. In Tamil Nadu, rice cultivation spreads over an area of 21 lakh hectares with a total production of 93 lakh Mt (Anonymus, 2015). The Zn adsorption-desorption reactions between the solution and solid phases control Zn concentrations in soil solution and the availability of Zn to plants (Lindsay, 1991; Catlett *et al.*, 2002), which depend on the pH, organic matter, soil minerals, and co-existing ions as well as the distribution into various fractions(Alloway, 2008). The Zn fractions in soil are often distinguished with regard to chemical binding characteristics, including exchangeable, organic matter-bound, carbonate-bound, Fe-Mn oxides and residual Zn (Tessier et al 1979; Jiang et al., 1990). Exchangeable Zn is the most labile binding form and has the closest correlation with Zn uptake in plants (Chahal et al., 2005; Li et al., 2007).Organic matter-bound Zn is also available to plants due to the exchangeable sites for Zn in soil solid matrix provided and cation exchange capacity increased by organic matter (Khoshgoftarmanesh et al.,2018). When Zn is bound to carbonate or Fe-Me oxides in soil, this binding will reduce the bioavailability of Zn and will enhance the ability of rice to resist Zn stress (Shuman and Wang,1997).Plants have direct or indirect influences on the nutrients availability in diverse ways, such as the release of root exudates (Clemens et al., 2002;Udom et al., 2004). Root exudates in oat can dissolve the heavy metals bound to carbonate and oxides and can convert them to the exchangeable form, improving the availability of heavy metals (Mench and Fargue, 1994). Thus field experiments were conducted to study the response of zinc fertilization in clay loam and sandy clay loam soils deficient in zinc.

MATERIALS AND METHODS

Two field experiments were conducted in zinc deficient soil belonging to two soil series:Kondal series (Typic Haplusterts) and Padugai series(Typic Ustifluvents) at the farmer 's holding during the karife season of year 2011. Before imposition of treatments, the soil used in the experiment had the following properties viz., pH-8.50, EC-0.92 dSm^{-1}, organic carbon-5.41 g kg^{-1}, CEC-43.2 c mol(p^+) kg^{-1},$CaCO_3$- 4.31%, $KMnO_4$-N- 302 kg ha^{-1}, Olsen-P- 19.0 kg ha^{-1}, NH_4OAc-K- 603 kg ha^{-1} and DTPA-Zn-0.60 $mgkg^{-1}$(Vertisol). Similarly soils of Entisol had pH-7.80, EC-0.89 dSm^{-1}, organic carbon-6.3 g kg^{-1}, $CaCO_3$-1.56%, CEC- 24.2 c mol(p^+) kg $^{-1}$, $KMnO_4$-N- 276 kg ha^{-1}, Olsen-P- 18.0 kg ha^{-1}, NH_4OAc-K- 293 kg ha^{-1} and DTPA-Zn-0.57 $mgkg^{-1}$. The treatment consists of two factors viz., Factor A – Zinc levels (mg kg^{-1}) Zn_0 – 0, Zn_1- 2.5,Zn_2- 5.0 and Zn_3- 7.5 and Factor B- Zinc sources S_1 – Zinc sulfate (Zn – 21%),S_2 – Zn-EDTA (Zn – 12%),S_3 – Zn humate (Zn – 9%). The design was FRBD with three replications. Twenty seven days old rice seedling var ADT 43 was transplanted in the main field. All the plots received uniform dose of 120 kg N ha^{-1}, 40 kg P_2O_5 ha $^{-1}$ and 40 kg K_2O ha^{-1} applied through urea, SSP and muriate of potash respectively. Grain and straw yield was recorded at harvest and expressed as kg ha^{-1}. In order to estimate various Zn fractions in soil, sequential extraction of soil samples (at harvest stage) was performed following the procedure of Sarkar and Deb (1982). Zinc present in different forms was analysed using atomic absorption spectrometer.

RESULTS

Rice yield

Analysis of variance in Table 1 showed significant impact of graded dose of zinc applied through different sources on grain and straw yield in both soils. Addition of 5.0 mg Zn kg^{-1} registered the highest grain yield 5556 and 5771 kg ha^{-1} and straw yield 7029 and 7120 kg ha^{-1} in Vertisol and Entisol respectively. The grain and straw yield declined at 7.5 mg Zn kg^{-1}. The per cent increase in grain yield due to $Zn_{5.0}$ over Zn_0 was 25.9 in Vertisol and 21.8 in Entisol, respectively. With respect to zinc sources, application of Zn through Zn-EDTA recorded the highest grain and straw yield (5307, 5546 kg ha) and (6691 and 6913 kg ha^{-1}) in Vertisol and Entisol respectively which was significantly superior to $ZnSO_4$ and Zn-humate. The interaction effect between zinc sources and Zn level was significant. At all levels of zinc, Zn-EDTA registered significantly higher grain and straw yield over other two sources. The highest grain and straw yield was obtained when 5.0 mg Zn kg^{-1} was applied through Zn-EDTA (5732, 5946 kg ha^{-1}) and (7234, 7302 kg ha^{-1}) in Vertisol and Entisol respectively. The per cent increase due to this treatments over control was 30.0 and 24.4(grain) and 26.7 and 20.4 (straw) in Vertisol and Entisol respectively. All though effect of zinc application on grain and straw yield was more in Entisol than Vertisol, the extent of impact was high in Vertisol than Entisol.

Zinc fraction

Total zinc in soil was sequentially fractionated to different form of zinc to assess the impact of zinc rates and sources. Analysis of variance on forms of zinc, showed that addition of graded dose of zinc applied through various sources caused significant influence on various forms of zinc over control (Table 2, 2a). Among various zinc fractions, largest amount of zinc was associated with residual zinc followed by occluded Zn, organic bound zinc, complexed zinc, exchangeable zinc and water soluble zinc. All forms of Zn increased with Zn levels and the highest water soluble Zn (0.350, 0.287 µg g^{-1}), exchangeable Zn (0.442, 0.432 µg g^{-1}), complexed Zn (2.79, 2.61 µg g^{-1}), organic bound Zn (3.01, 3.17 µg g^{-1}), occluded Zn (4.67, 4.31 µg g^{-1}) and residual Zn (90.04, 80.86 µg g^{-1}) in Vertisol and Entisol respectively was observed with 7.5 mg Zn kg^{-1} and it was significantly superior to rest of the levels. The per cent increase in different forms of Zn due to 7.5 mg Zn kg^{-1} over control was water soluble Zn (169.2, 105), exchangeable Zn (54.5, 78.5), complexed Zn (8.1, 16.5), organic bound Zn (21.2, 41.5), occluded Zn (38.5, 39.0) and residual Zn (27.4, 16.5) in Vertisol and Entisol respectively.

Percentage contribution of different forms of Zn to total zinc was residual Zn (88.5, 88.8), occluded Zn (4.53, 4.30), organic-Zn (2.98, 3.24), complexed-Zn (2.98, 2.85), exchangeable Zn (0.40, 0.43) and water soluble Zn (0.30, 0.27) in Vertisol and Entisol respectively. With respect to zinc sources, all forms of zinc was highest with Zn-EDTA and was comparable with $ZnSO_4$ but superior to Zn-humate. Interaction effect of Zn rates and sources was significant. All forms of zinc was highest when 7.5 mg Zn kg^{-1} was applied through Zn-EDTA and it was significantly superior to rest of the treatment combinations. Different forms of zinc was higher in Vertisol than Entisol.

DISCUSSION

Rice yield

Addition of graded dose of zinc increased the grain yield over control in both soils. Addition of 5 mg Zn kg^{-1} recorded the highest grain yield (5556, 5771 kg ha^{-1}) in Vertisol and Entisol respectively. The per cent increase in grain yield was 15.7, 25.9 and 22.6 (Vertisol) and 13.8, 23.8 and 19.5 (Entisol) due to 2.5, 5.0 and 7.5 mg Zn kg^{-1} over control (Fig.1) was noticed in the field experiments. Increase in these components led to increase in grain yield. Increase in grain yield due to zinc was the logical result due to increase in yield components. In the present study, number of panicles m^{-2}, number of grains $panicle^{-1}$, panicle length and 1000 grain weight increased with Zn levels and highest value was obtained with 5 mg Zn kg^{-1}. The above argument was ably supported by linear relationship between grain yield with number of panicles m^{-2} ($Y = 3628 – 0.703x + 0.010x^2$, x^2, $R^2 = 99$**), number of grains $panicle^{-1}$ ($Y = 4688- 83.49\ x – 9.322\ x^2$, R^2=99**), panicle length ($Y = -353.6 + 393.6x – 4.473\ X^2$, R^2= 0.99**) which showed that 99 per cent variation in grain yield are brought out by different yield attributes. Abbas *et al*. (2010) and Rahman *et al*. (2011) reported increase in grain yield due to improvement in yield components. Rahmatullah *et al*. (2007) reported application of 5 and 10 kg Zn ha^{-1} gave 39 and 45 per cent increase in rice yield over control, respectively. Rahman *et al*. (2011) reported highest rice yield with 10 kg Zn ha^{-1} in soils of Bangladesh. Khan *et al*. (2012) reported maximum grain yield at 9 kg Zn ha^{-1} and it was reduced at 12 and 15 kg Zn ha^{-1} in soils of Pakistan. Higher yield due to zinc is attributed to its involvement in many metallic enzymes systems, regulating functions and auxin production (Rajarajan, 1991) and enhanced synthesis of carbohydrates and their transport to the site of grain formation (Khan *et al*., 2009).Significant response to zinc fertilization might be attributed to the increased availability of zinc and increased uptake of major and micronutrients at various stages of crop growth (Sankaran *et al*., 2001).

Straw yield

Addition of 5 mg Zn kg^{-1} recorded the highest straw yield (7024, 7120 kg ha^{-1}) in Vertisol and Entisol respectively and declined at 7.5 mg Zn kg^{-1}. Per cent increase in straw yield ranged from 12.5 to 23.8 (Vertisol) and 11.0 to 17.2 (Entisol). Increase in straw yield due to zinc addition might be due to favourable effect of zinc on the proliferation of roots and thereby increasing the uptake of plant nutrients from the soil and supplying to the aerial part of the plant and ultimately enhancing vegetative growth of the plants. This was confirmed by significant and positive correlation between straw yield with DTPA-Zn (r=0.961**, r=0.901**, r=0.931**) and Zn uptake (r=0.981**, r=0.965**, r=0.987**) at tillering and panicle initiation stages respectively. Higher straw yield due to Zn fertilization was reported earlier by Mustafa *et al*. (2011).Addition of 5 mg Zn kg^{-1} through Zn-EDTA recorded the highest straw yield (7234, 7302 kg ha^{-1}) which caused 26.7 and 30.4 per cent increase over control in Vertisol and Entisol, respectively. It was higher than $ZnSO_4$ and Zn-humate. Increase in straw yield with the application of Zn-EDTA might be due to the relatively greater amount of Zn uptake compared with $ZnSO_4$ application (Naik and Das, 2008). The result is in agreement with the findings of Karak *et al*. (2006) who reported that chelated zinc was the most efficient source of zinc for lowland rice production in calcareous soil. Also, Zn mobilization efficiency was higher with Zn-EDTA than with $ZnSO_4$ for zinc uptake by grain and straw.

ZINC FRACTIONS IN SOIL

Analysis of variance on forms of zinc showed that addition of graded dose of zinc applied through various sources caused significant influence on zinc fractions in soils over control. Addition of 7.5 mg Zn kg^{-1} recorded the highest concentration of different forms of zinc. Knowledge of different chemical forms of zinc in the soil solution is necessary for evaluating their toxicity, mobility and bio-availability. The description of zinc from the exchangeable complex to solution, release of zinc from organic matter, crystalline minerals and other precipitates to the solution phase are the process to control the mobility of zinc in soils. Chemical fractionation of soil Zn has been viewed as a means of assessing sources of plant available zinc (Hazra *et al*., 1994). Different zinc fractions contribute to the pool of available zinc and play a significant role in the crop nutrition (Randhawa and Singh, 1995). Transformation of such zinc fractions depends on the physico-chemical properties of the soil and the associated environment conditions (Hazra *et al*., 1994). Increase in all fractions with Zn levels might be due to higher solubility and mobility of the added inorganic Zn sources (Chandni Patnaik *et al*., 2011). Distribution of total zinc among soil zinc fractions removed by different extractants indicated that residual zinc associated with mineral fractions formed the bulk of the soil zinc and very little per cent was distributed in other fractions. The greater percentage of residual zinc probably reflected the greater tendency for Zn to become unavailable once it was in soil (Kumar and Qureshi, 2012). Increase in the residual Zn content on submergence indicated considerable transformation of zinc to residual fraction. Addition of Zn-EDTA recorded higher soil Zn fractions compared to $ZnSO_4$ and Zn-humate could be due to greater efficiency of Zn-EDTA in providing improved higher concentration of zinc in soil compared to other sources. Kumar and Qureshi (2012) reported higher zinc fractions with Zn-EDTA.

CONCLUSION

The present study clearly indicated addition of 5.0 mg Zn kg^{-1} (Zn-EDTA) registered with the highest grain and straw yield was observed in both soils. However response of rice to graded dose of zinc through different sources was more prominent in Entisol than Vertisol. Addition of Zn-EDTA recorded higher soil Zn fractions compared to $ZnSO_4$ and Zn-humate could be due to greater efficiency of Zn-EDTA in providing improved higher concentration of zinc in soil compared to other sources.

Table 1. Effect of zinc sources and levels on grain and straw yield (kg ha^{-1})

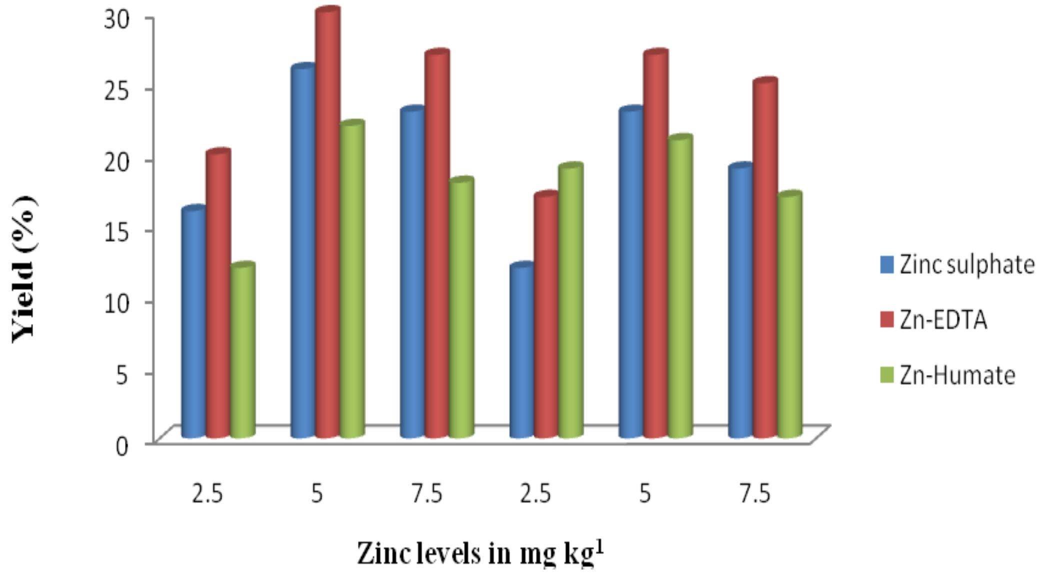
Zinc sources	Grain yield					Straw yield				
	Zn levels (mg kg^{-1})									
	0	2.5	5.0	7.5	Mean	0	2.5	5.0	7.5	Mean
	Vertisol									
Zinc sulfate	4409	5107	5550	5405	5118	5711	6365	6976	6763	6454
Zn-EDTA	4606	5284	5732	5607	5307	5831	6620	7234	7078	6691
Zn-Humate	4221	4921	5385	5221	4937	5489	6173	6876	6662	6300
Mean	4412	5104	5556	5411		5677	6386	7029	6834	
		S	L	SxL			S	L	SxL	
SE_d		38	44	75			27	31	54	
CD (p=0.05)		72	90	155			56	65	112	
	Entisol									
Zinc sulfate	4781	5379	5748	5623	5383	6066	6776	7155	7027	6756
Zn-EDTA	4845	5559	5946	5833	5546	6272	6915	7302	7162	6913
Zn-Humate	4580	5234	5618	5520	5238	5883	6541	6904	6748	6519
Mean	4737	5391	5771	5659		6074	6744	7120	6979	
		S	L	SxL			S	L	SxL	
SE_d		38	44	76			33	38	66	
CD (p=0.05)		79	91	158			69	79	138	

Table 2. Effect of zinc sources and levels on zinc fractions (μg g^{-1})

Zinc sources	Water soluble zinc					Exchangeable zinc					Complexed zinc					Organic bound zinc				
	Zn levels (mg kg^{-1})																			
	0	**2.5**	**5.0**	**7.5**	**Mean**	**0**	**2.5**	**5.0**	**7.5**	**Mean**	**0**	**2.5**	**5.0**	**7.5**	**Mean**	**0**	**2.5**	**5.0**	**7.5**	**Mean**
	Vertisol																			
Zinc sulfate	0.132	0.324	0.343	0.367	0.291	0.302	0.338	0.459	0.482	0.395	2.64	2.79	2.81	2.83	2.76	2.54	2.66	2.86	3.07	2.76
Zn-EDTA	0.135	0.326	0.344	0.369	0.293	0.304	0.339	0.468	0.489	0.400	2.65	2.80	2.82	2.84	2.77	2.55	2.75	2.91	3.09	2.81
Zn-Humate	0.125	0.260	0.288	0.314	0.246	0.262	0.295	0.334	0.355	0.311	2.45	2.68	2.70	2.72	2.63	2.34	2.52	2.70	2.89	2.59
Mean	0.130	0.303	0.325	0.350		0.289	0.324	0.420	0.442		2.58	2.75	2.77	2.79		2.47	2.64	2.82	3.01	
		L	S	LxS			L	S	LxS			L	S	LxS			L	S	LxS	
SE_d		0.003	0.007	0.008			0.004	0.007	0.01			0.04	0.05	0.06			0.04	0.05	0.07	
CD (p=0.05)		0.008	0.01	0.02			0.009	0.01	0.02			0.10	0.11	0.14			0.10	0.11	0.15	
	Entisol																			
Zinc sulfate	0.120	0.240	0.274	0.296	0.232	0.250	0.361	0.434	0.450	0.373	2.27	2.42	2.48	2.63	2.45	2.25	2.74	2.98	3.28	2.81
Zn-EDTA	0.122	0.242	0.275	0.297	0.234	0.253	0.365	0.436	0.452	0.376	2.28	2.43	2.49	2.68	2.47	2.27	2.85	3.10	3.38	2.90
Zn-Humate	0.100	0.223	0.258	0.270	0.212	0.224	0.335	0.390	0.395	0.336	2.13	2.28	2.34	2.53	2.32	2.20	2.39	2.60	2.87	2.51
Mean	0.140	0.235	0.269	0.287		0.242	0.352	0.420	0.432		2.24	2.37	2.43	2.61		2.24	2.66	2.89	3.17	
		L	S	LxS			L	S	LxS			L	S	LxS			L	S	LxS	
SE_d		0.003	0.004	0.007			0.004	0.007	0.01			0.04	0.04	0.06			0.05	0.05	0.08	
CD (p=0.05)		0.007	0.009	0.01			0.009	0.01	0.02			0.09	0.10	0.13			0.11	0.12	0.16	

Table 2a. Effect of zinc sources and levels on zinc fractions (μg g^{-1})

Zinc sources	Occluded zinc					Residual zinc					Total zinc				
	Zn levels (mg kg^{-1})														
	0	2.5	5.0	7.5	Mean	0	2.5	5.0	7.5	Mean	0	2.5	5.0	7.5	Mean
	Vertisol														
Zinc sulfate	3.37	4.12	4.43	4.69	4.15	72.01	78.16	85.09	90.55	81.60	81.13	89.03	96.30	102.11	92.14
Zn-EDTA	3.54	4.25	4.55	4.81	4.28	75.83	81.53	87.90	93.39	84.66	85.20	92.12	99.14	105.01	95.36
Zn-Humate	3.20	3.98	4.27	4.52	3.99	64.26	74.26	80.70	86.19	76.35	75.15	84.31	91.10	97.13	87.00
Mean	3.37	4.11	4.41	4.67		70.70	78.18	84.56	90.04		80.55	88.48	95.57	101.41	
		S	L	SxL			S	L	SxL			S	L	SxL	
SE_d		0.08	0.09	0.11			1.62	1.85	2.21			1.90	2.10	2.50	
CD (p=0.05)		0.17	0.19	0.24			3.42	3.890	4.65			4.10	4.60	5.25	
	Entisol														
Zinc sulfate	3.10	3.49	3.66	4.30	3.63	70.81	70.77	78.49	81.17	75.31	78.80	83.50	88.30	92.10	85.67
Zn-EDTA	3.12	3.52	3.75	4.38	3.69	71.44	74.99	79.24	83.00	77.16	79.50	84.40	89.30	94.20	86.85
Zn-Humate	3.09	3.48	3.64	4.26	3.61	66.03	70.08	74.45	78.43	72.24	73.80	78.80	83.70	88.80	81.27
Mean	3.10	3.49	3.68	4.31		69.42	71.94	77.39	80.86		77.40	82.23	87.10	91.70	
		S	L	SxL			S	L	SxL			S	L	SxL	
SE_d		0.03	0.04	0.10			0.96	1.15	1.93			1.04	1.49	2.08	
CD (p=0.05)		0.07	0.10	0.21			2.00	2.40	4.00			2.17	3.10	4.32	



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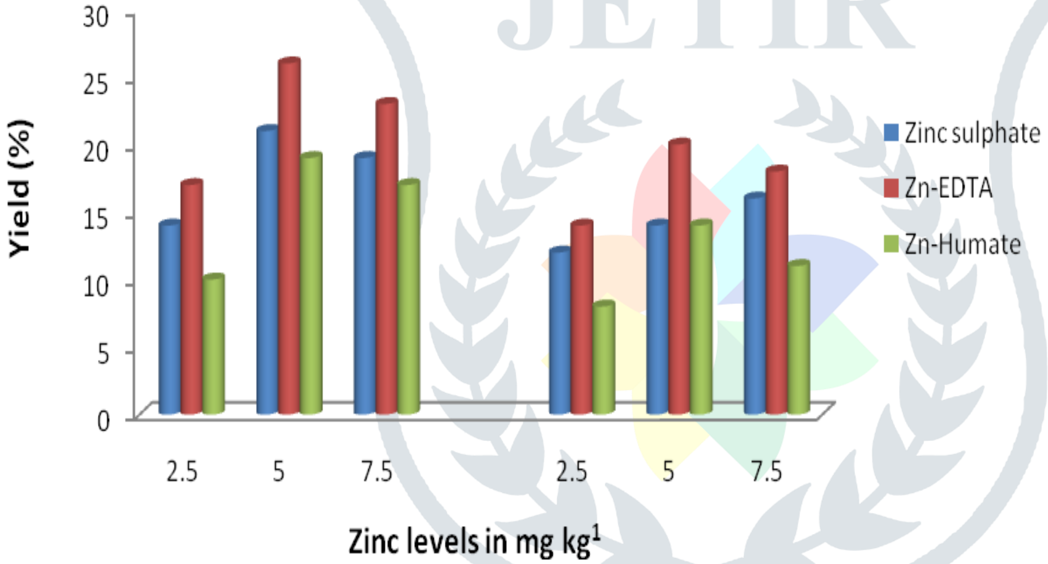

Fig. 1. Percentage increase in grain and straw yield due to zinc
A) Vertisol B) Entisol

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