Original Research Article

Study of correlation between soil chemical properties, zinc fractions and yield of rice under long term fertilization in Chromustert soil

Abstract

A long-term experiment entitled "Study of correlation between soil chemical properties, zinc fractions and yield of rice under long term fertilization in Chromustert soil" was conducted at IGKV Raipur experimental farm during kharif 2019-20. This study comprised of ten treatments: control (no fertilizer),50% NPK (sub-optimal dose), 100% NPK (optimal dose), 150% NPK (super optimal dose) and 100%NPK along with$ZnSO_4$ @ 10kg ha^{-1}, 100% NP, 100% N alone, 100% NPK along withfarmyard manure @ 5t ha^{-1}, 50% NPK along with blue green algae @ 10 kg ha^{-1} and 50% NPK along with green manure @ 40kg h^{-1}. The experiment was laid out at a randomized complete block design which was replicated four times. The variations in Zn uptake by grain, straw and total (bothgrain and straw) varied from 17.29-129.73 gha^{-1}, 27.19 to 196.54 gha^{-1} and 44.48 to326.27 gha^{-1}, respectively. Amongst various treatments 100% NPK+ $ZnSO_4$ hadsignificantly higher values of Zn uptakes by grain, straw and total as compared to thecontrol plot.The grain and straw yield of rice varied from 2430 to 6970 kg ha^{-1} and 3110-8364 kg ha^{-1}, respectively with the application of various treatments of inorganic fertilizers and manures.From the statistical analysis it was observed that a correlation coefficient was computedbetween Zn fractions with respect to soil chemical properties and yield of rice that couldpossibly differ in imbalance and balance applications of varying doses of fertilizer. In thiscontext, the significant correlation coefficient values (r) were obtained with all the parametersthat showed organic carbon content in soil predominantly affected almost all individualfractions that ultimately maintain the pool of total Zn in soil for uptake by crop plants.

Keywords: Correlation, LTFE, uptake, yield,zincfractions

Introduction

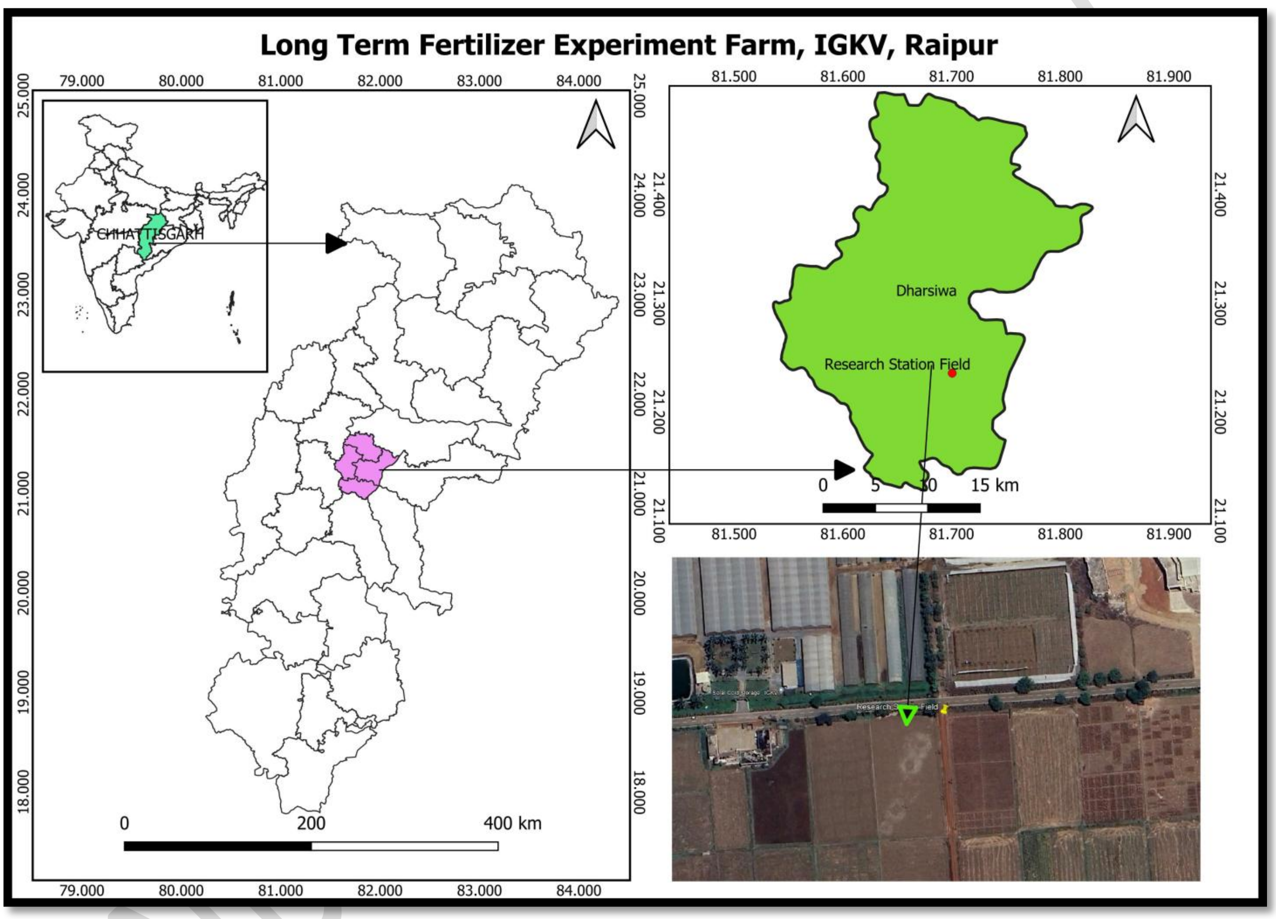
Zinc (Zn) is the most important trace element for the growth of rice especiallyin submerged soil. Zinc deficiency are common in both tropical and temperate climates(Fageria et al. 2011; Prasad 2006;Slaton et al. 2005). There is a critical need to enhance food production in developing (thirdworld) countries, where zinc shortages are most prevalent. Reducing zinc deficiency in the soil is necessary to meet crop productivity goals, but low Zn content in grains and straw is also low for humans and animals with inadequate Zn uptake.The transformation of zinc in soils and plants is linked to its bioavailability through various mechanisms, including adsorption by clay surfaces, hydrous oxide minerals, organic matter, and other factors that influence crop uptake of Zn.For a better understanding, total soil Zn can be divided into five mechanistic fractions using sequential fractionation schemes (Saffari *et al.*, 2009). These fractions consist of a water-soluble pool that is present in the soil solution, an exchangeable pool with ions bound to soil particles by electrical charges, an organically bound pool with ions adsorbed, chelated, or complexed with organic ligands, a pool of zinc non-exchangeably sorbed onto clay minerals and insoluble metallic oxides, and a pool of weathering primary minerals. (Alloway, 2008).Understanding complex interactions between plant, soil, climate, management techniques, and their consequences on soil over extended time periods is a key goal of long-term fertilizer experimentation (LTFE). As a result, these studies have gained recognition as important examples of knowledge about sustainability, especially in the context of intensive farming. (Singh et al. 2014). The first goal is to determine and assess how input management affects the usage of chemical fertilizers, sustainable soil fertility, and subsequent crop productivity(Dwivedi and Dwivedi 2015).It is crucial to accurately measure the various forms of zinc and their relationships to soil characteristics and crop Zn uptake in order to enhance farming profitability over the long run. Although the amount of zinc needed for crop development is significantly less than that of macronutrients, Zn deficiency in soil has typically been accounted for from diverse regions of the world.Therefore, the present investigation was carried out to“Study of correlation between soil chemical properties, zinc fractions and yield of riceunderlong term fertilization in Chromustert soil”.

Materials and Methods

Study Site Description

A long–term field experiment was conducted at the research farm of Indira Gandhi Krishi Vishwavidyalaya, Raipurduring Kharif 2019-20. The site comes under the sub-humid zone, located at 22^{o} 33’ N to 21^{o} 14’ N latitude and 82^{o} 6’ E to 81^{o} 38’ E longitude with an altitude of 293m above Mean Sea Level which receives approximately 1200 – 1300mm (51”) of rainfall, mostly in the monsoon season from late June to early October. The soil of the study areaclassified underVertisol order, having fine Montmorillonite clay also locally called as Kanhar and identified as Arang II series, with pH = 7.5, EC = 0.23 ds m^{-1}and OC = 0.60%, available nitrogen 212.39, phosphorus 21.31 kg ha^{-1}, potassium 386.25kg ha^{-1}sulphur 25.98kg ha^{-1}and DTPA extractable zinc 1.2mg kg^{-1}.

Map 1 : Map showing study location



Experimental details

The field experiment was carried out in randomized block design with ten treatments which were replicated four times. The ten treatments comprised of various inorganic and organic sources namely control (no fertilizer),50% NPK (sub-optimal dose), 100% NPK (optimal dose), 150% NPK (super optimal dose) and 100%NPK along with $ZnSO_4$ @ 10kg ha^{-1}, 100% NP, 100% N alone, 100% NPK along withfarmyard manure @ 5t ha^{-1}, 50% NPK along with blue green algae @ 10 kg ha^{-1} and 50% NPK along with green manure @ 40kg h^{-1}. The rice variety Rajeshwari R-1 was selected as a test crop and various organic sources applied in this experiment*viz*., FYM, green manure (*Sesbaniaaculeta*) and blue green algae. The recommended dose of NPKfertilizer for rice crop was 120:60:40 kg ha^{-1}, respectively. TheN, P and K were applied through urea, SSP and MOP, respectively and nitrogen was applied in split doses. The in-situ green-manure crop (Sunhemp) cultivated for a period of 45 days during kharif season, chopped into small pieces (5-7 cm) and incorporated into the soil with the help of a power operated rotavator at the time of puddling before thetransplantation of rice crop.

Results and Discussion

1. Zinc uptake by rice crop

Nutrient intake was calculated by multiplying the nutrient content of the grain and grassby their respective yields. The total amount of grain and straw was considered to be totaluptake of the rice crop. The data on uptake of zinc by rice crops is presented in Table 1. The variations in Zn uptake by grain, straw and total (bothgrain and straw) was varied from 17.29-129.73 gha^{-1}, 27.19 to 196.54 gha^{-1}and 44.48 to326.27 gha^{-1}, respectively. Amongst various treatments 100% NPK+ Zn hadsignificantly higher values of Zn uptakes by grain, straw and total as compared to thecontrol plot. On persual of data presented in table indicated that the highest Zn uptake bygrain (129.73 gha^{-1}), straw (196.54 gha^{-1}) and total (326.27 gha^{-1}) was recorded in 150%NPK, respectively. While, the lowest zinc uptake by grain (17.29 gha^{-1}), straw (27.19 gha^{-1})and total (44.48 gha^{-1}) was recorded in control plot. On the other hand Zn uptake by grainand straw in optimal dose of 100% NPK treatment was significantly lower than 100% NPK along with Znand100% NPK+FYM.The application of soil applied zinc (5 kgha^{-1}) + one foliar spray (0.5%) which lead tosignificant raise in Zn content of straw and seed and also total uptake. This may be becauseof that an increase in Zn concentration in the soil solution resulted in the absorption ofnutrients from the soil solution and thus increased Zn content in the seeds and straw (Katyalet al. 1997). Since, total absorption is a function of the nutrient content of the seed and thegrass and their proper yield, thus, leading to a significant increase in zinc absorption. Thesealso be finding by Mali et al. (2003), Saini (2003) in mothbean, Sharma and Jain (2004) in fenugreek. The increase in Zn absorption isdue to their additional mechanism can be attributed to changes in Zn availability in the rootzone and their role in plant growth and development.Moreenzymatic and hormonal activity increase assimilates translocation in plant biomass whichprogress highest straw yield. Zn may have helped to stimulate vegetative growth due to theabsorption of other essential nutrients influenced by the absorption of Zn. These findingsare matched with

Wijebandara and Iranie (2008), Khan et al. (2012) and Rajkumar et al. (2002).62Total dry weight and grain yield also increase by Zn under alternate wetting and dryingregimes (Wang et al. 2014), reliable based on earlier research showing that applying Zn could considerably boost plant growth and grain output in both lowand high-Zn status (Wissuwa et al. 2008).

Table 1: Effect of various treatments on Zn uptake by rice

S. No.	Treatment	Zinc uptake (gha^{-1})		
		Grain	**Straw**	**Total**
T_1	Control	17.29	27.19	44.48
T_2	50% NPK	48.87	61.59	110.46
T_3	100% NPK	97.80	145.67	243.47
T_4	150% NPK	129.73	196.54	326.27
T_5	100% NPK + $ZnSO_4$ @ 10kg ha^{-1}	100.40	151.24	251.64
T_6	100% NP	91.24	126.28	217.82
T_7	100% N	31.20	44.06	75.26
T_8	100% NPK + FYM @ 5 tha^{-1}	113.41	170.50	283.91
T_9	50% NPK + BGA @ 10 kg ha^{-1}	51.63	77.31	128.94
T_{10}	50% NPK + Green Manure	62.43	90.20	152.63
	SEm (±)	2.74	5.95	8.31
	CD (α = 5% level of significance)	7.84	17.01	23.77

2. Effect of different inorganic and organic treatments on grain and straw yield of rice

This experiment was very important from the point of view in order tounderstand the complex interaction between soil, plants, climate, and management practice ultimately reflecting crop productivity. The data on grain and straw yield of rice is given in Table 2. The various treatments significantly influenced the grain and straw yield of rice.

The grain yield of rice varied from 2430 to 6970 kg $ha^{-1}$and the straw yield of rice varied from 3110-8364 kg ha^{-1}among different treatments of continuous application of chemical fertilizers and manures. The grain yield of rice was significantly influenced by the balanced application of nutrients alone as well as organic manures over the imbalanced application of nutrients and no fertilizer application. The highest grain yield (6970 kg ha^{-1}) of rice was obtained with the application of super optimal dose (150% NPK) which was significantly superior over all the treatments except 6890 (kg ha^{-1}) grain yield obtained in optimal dose (100% NPK + FYM), whereas, the lowest yield was recorded in control plot (2430 kg ha^{-1}). Similarly, zinc sulphate also increased the grain and straw yields in 100% NPK + $ZnSO_4$ over the sole application of nitrogen fertilizer and control. The optimal dose of 100% NPK + FYM showed significantly higher yields as compared to control on par with 150% NPK. Only imbalance and/or sole application of nitrogenous fertilizer and control treatment was recorded lowest yields because of low fertility status of available nutrients.

Table 2: Effect of fertilization on grain and straw yields of rice

S.No.	**Treatment Name**	**Yield (kgha^{-1})**	
		Grain	**Straw**
T1	Control	2430	3110
T2	50% NPK	4580	5496
T3	100% NPK	6625	7950
T4	150% NPK	6970	8364
T5	100% NPK + $ZnSO_4$ @ 10kg ha^{-1}	6565	7878
T6	100% NP	6500	7800
T7	100% N	3535	4596
T8	100% NPK + FYM	6890	8268
T9	50% NPK + BGA	4600	5520
T10	50% NPK + GM	4920	5904
	SEm (±)	173	208
	CD (α = 5% level of significance)	496	594

3. Correlation between soil chemical properties, zinc fractions and yield of rice

From the statistical analysis it was observed that correlation coefficient was computed between Zn fractions with respect to soil chemical properties and yield of rice that could possibly be differ in imbalance and balance applications of varying doses of fertilizer. In this context, the significant correlation coefficient values (r) were obtained with all the parameters showed that organic carbon content in soil predominantly affected almost all individual fractions that ultimately maintain the pool of total Zn in soil for uptake by crop plants. This directly contributed to the available fraction in the root zone. (Narwal 2010 and Zang *et al*. 2014). Moreover, the correlation study also revealed the direct contribution of Org-Zn fraction with available Zn (Dhiman 2007 and Dwivedi and Dwivedi 2015). The complexity of Zn availability in black soil (Dwivedi *et al*. 2007) also suggested that there is a dynamic equilibrium of Org-Zn amongst the Zn fractions with the Zn availability in soil for plant utilization. Similar observations have been explained as wellby Mishra *et al.* 2009, Narwal *et al*. 2010, and Obrador *et al*. 2007.

The WSEX-Zn fraction tabulated in Table 3(a)and 3(b) showed a positive relationship with soil pH (r=0.06), positive as well as significant relationship with organic carbon (r=0.66*), available Zn (r=0.79*), grain (r=0.72*), and straw yields (r=0.73*) of rice. The WSEX-Zn fraction is of great importance in plant nutrition. Findings were also obtained by (Behra*et al.* 2008, Agbenin 2010 and Kandali*et al*. 2016).

The Org-Zn fraction arranged in Table 3(a) and 3(b)demonstrated a positive and significant correlation with OC (r=0.89**), available phosphorous (r=0.82**), grain (r=0.83**) and straw (r=0.84**) yields, respectively. A positive and significant relationship with available nitrogen (r=0.79*), available potassium (r=0.61*) and available Zn (r=0.64*) was also observed amongst different treatments. More exchange sites for the adsorption of Zn are provided by organic matter. Similar results were also observed by Prasad and Sakal (1988). The results are in conformity with that of Murthy *et al.*(1987) and Mandal and Mandal (1986).

The AMOX-Zn fraction in Tables3(a) and 3(b)showed a negative relationship with soil pH (r= -0.08) a reduction in AMOX-Zn fraction with the increase in pH can be explained by the natural reduction in oxide solubility and concentration as pH increases (Ramzan *et al*. 2014 and Shiowatana*et al*. 2005).While a positive correlation with electrical conductivity (r=0.16) and a positive with a significant relationship with available Zn (r=0.89**) was recorded amongst various treatments.

The CRYOX-Zn fraction tabulated in Tables3(a) and 3(b) showed a negative relationship with soil pH (r= -0.23) and a positive and significant relationship with organic carbon (r=0.48) and available phosphorous (r=0.56). While a positive and significant relationship with available Zn (r=0.86**) was observed with CRYOX-Zn. These results suggest that the use of organic fertilizers may play a major role in the availability of Zn in the soil system as a bound fraction (El- Foulyet *al*. 2015 andShrotri*et al*. 1980)

The residual Zn fraction arranged in Table 3(a) and 3(b) showed a positive and significant relationship with OC (r=0.81**), available nitrogen (r=0.84**), available phosphorous (r=0.86**), grain (r=0.85**) and straw (r=0.86**) yields, respectively and a positive and significant relationship with available potassium (r=0.0.69*) was also observed. The increase in soil Zn availability with an increase in organic matter content has been demonstrated by the positive correlation between organic carbon and soil Zn availability(Shambhavi, 2011). The results were in conformity with the findings of Mishra *et al*. 2009, Behra*et al*. 2008 and Rupa *et al*. 2003who accounted that greater association between available Zn and sesquioxide explain the influence of oxides associated nutrient elements on the available pool of Zn.

The total Zn fraction in Table 3(a) and 3(b)showed a positive and significant relationship with organic carbon (r=0.80**), available nitrogen (r=0.82**), available phosphorous (r=0.85**), grain (r=0.84**) and straw (r=0.85**) yields while a positive and significant relationship with available potassium (r=0.67*) and available Zn (r=0.62*) was also observed. This could probably by reason of the fact that the OC directly involved in the availability of almost all fractions of Zn in soil system that directly contributed to pool of Zn (Zang *et al*. 2014 and Wijebandra*et al*. 2011) and prevent the conversion into a non-available form there by promoting the availability of Zn to a optimum level (Kandali*et al*. 2016 andVerma *et al*. 2012).

Table 3(a): Effect of fertilization on correlation coefficient between soil chemical properties, yield of rice and Zn fractions (n = 40)

Parameters	Zn fractions at surface (0-15 cm)					
	WSEX-Zn	Org-Zn	AMOX-Zn	CRYOX-Zn	Residual Zn	Total Zn
Soil pH	0.06	0.31	-0.08	-0.23	0.23	0.20
EC	0.31	0.49	0.16	0.06	0.55	0.52
OC	0.66*	0.89**	0.59	0.48	0.81**	0.80**
Avail. N	0.71*	0.79*	0.54	0.42	0.84**	0.82**
Avail. P	0.75*	0.82**	0.64*	0.56	0.86**	0.85**
Avail. K	0.61*	0.61*	0.38	0.27	0.69*	0.67*
Avail. Zn	0.79*	0.64*	0.89**	0.86**	0.58	0.62*
Grain Y	0.72*	0.83**	0.63*	0.56	0.85**	0.84**
Straw Y	0.73*	0.84**	0.64*	0.56	0.86**	0.85**

***. Correlation is significant at the 0.05 level, **. Correlation is significant at the 0.01 level**

Table 3(b): Effect of fertilization on correlation coefficient values between soil chemical properties, yield of rice and Zn fractions (n = 40)

Parameters	Zn fractions at sub soil (15-30 cm)					
	WSEX-Zn	Org-Zn	AMOX-Zn	CRYOX-Zn	Residual Zn	Total Zn
Soil pH	0.02	0.08	0.14	0.28	0.39	0.36
EC	0.33	0.33	0.41	0.49	0.52	0.51
OC	0.67*	0.68*	0.72*	0.78*	0.91**	0.90**
Avail. N	0.68*	0.73*	0.79*	0.85**	0.84**	0.84**
Avail. P	0.75*	0.76*	0.81**	0.76*	0.85**	0.85**
Avail. K	0.53	0.61*	0.64*	0.65*	0.62*	0.62*
Avail. Zn	0.91**	0.88**	0.85**	0.76*	0.73*	0.75*
Grain Y	0.74*	0.75*	0.79*	0.78*	0.85**	0.85**
Straw Y	0.74*	0.75*	0.80**	0.79*	0.86**	0.86**

***. Correlation is significant at the 0.05 level, **. Correlation is significant at the 0.01 level**

Conclusion

The yield and uptake of zinc by the rice crop are strongly influenced by the continuous application of organic manures and inorganic fertilizers. In comparison to the control plot, the 150% NPK (super optimum dose) treatment had significantly greater Zn uptake values by grain, straw, and overall. With the exception of grain yield attained in optimal dose of NPK with farm yard manure (100% NPK + FYM), application of 150% NPK resulted in the highest grain yield of rice, which was significantly higher than all other treatments. Conversely, control had the lowest yield. Different zinc fractions showed a substantially positivecorrelation, and a long-term fertilizer experiment revealed that the residual Zn fraction alone greatly affected the production of rice.

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