Annals of Plant and Soil Research 20(2): 148–152 (2018)

Zinc fractions in paddy soils and their relationship with soil properties

VINAY SINGH AND SINGH RENUKA UMASHANKAR

Department of Agricultural Chemistry and Soil Science, Raja Balwant Singh College (Dr. B.R.A. University) Bichpuri, Agra (U.P.)-283105

Received: December, 2017; Revised accepted: March, 2018

ABSTRACT

Status of various fractions of soil Zn and their relationship with soil properties in paddy soils of Agra (U.P.) were studied with soil samples (0-23 cm) with variable Zn status from Agra district of Uttar Pradesh. The results revealed that water soluble and exchangeable Zn fraction in soils ranged from 0.12 to 0.35, Mn occluded Zn 0.25 to 0.67, organically complexed Zn from 0.33 to 1.45, amorphous Fe oxide bound Zn 1.54 to 2.80 and Crystalline Fe bound Zn from 1.62 to 3.24 mg kg^{-1} with mean values of 0.22, 0.41, 1.13, 2.09 and 2.41 mg kg^{-1}, respectively. Residual Zn was the dominant fraction among all Zn fractions studied, which ranged from 21.48 to 50.40 mg kg^{-1} with a mean value of 29.19 mg kg^{-1}. Water soluble plus exchangeable (WS Ex-Zn) Mn occluded Zn (Mn OX-Zn), organically complexed (OC-Zn) Zn, amorphous Fe oxide bound Zn, crystalline Fe bound Zn (Cry OX-Zn) and residual Zn constituted 0.5, 1.05, 2.88, 5.48, 6.32 and 76.67 per cent of total Zn, respectively. Soil organic carbon $CaCO_3$ and clay content were the important soil characteristics that governed the status of soil Zn in different fractions. Dynamic equilibrium existed among various fractions of zinc.

Keywords: Zinc fractions, paddy soils, soil properties

INTRODUCTION

Zinc is an essential element in plant growth and metabolism and exists in soil in different forms such as primary and secondary minerals, insoluble organic and inorganic precipitates, soluble organic complexes and exchangeable and adsorbed forms. Zinc in soluble organic complexes and exchange positions are of major importance in maintaining of zinc level sufficient for wetland rice (Murthy 1982). Widespread occurrence of zinc deficiency in paddy soils suggests that both native and applied Zn react with the inorganic and organic phases in the soil and thereby affect its availability. When zinc is applied to the soil from external sources to correct its deficiency it undergoes transformation to various chemical forms, the nature and magnitude of which, however may differ in different soils depending upon their properties and associated environmental conditions. Water soluble plus exchangeable and organically complexed forms are considered to be available, amorphous sesquioxide bound form is potentially available and crystalline sesquioxide bound and residual zinc forms are unavailable to plants (Mandal *et al.* 1992). Rice in Agra region is grown in soils under upland condition. Information regarding the distribution of different pools of Zn in rice soils which are very pertinent to zinc nutrition of upland rice are limited in soils of Agra region of Uttar Pradesh. An experiment was, therefore conducted to study the status of different Zn fractions in rice growing soils of Agra region and their relationship with soil properties and various fractions of zinc.

MATERIALS AND METHODS

For the present study, in all 10 surface (0-20) soil samples were collected from cultivated fields of Agra district. The sites selected for this study fairly cover the entire areas of this district. The soil samples were drawn from 0-23 cm depth with the help of a soil auger. The soils were put in polythene bags, labeled properly and carried to the laboratory. The soil samples were air-dried and the Kankar nodules were removed there from. The samples were crushed with wooden hammer and sieved through cloth. The powdered samples, thus obtained were stored in the stoppard wide mouth bottles properly labeled. The samples were subjected to chemical analysis (pH, EC, organic carbon, calcium carbonate, CEC and sand, silt and clay) by adopting standard procedures (Jackson, 7973). Total zinc was extracted from soil by digesting with 60% perchloric acid. The soil was shaken with a mixture of 0.005M DTPA, 0.01M $CaCL_2$ and 0.1M triethanolamine (pH 7.3) to extract DTPA-Zn as suggested by Lindsay and Norvell (1978). Different forms of zinc were determined by Sequential fractionation method outlined by Iwasaka and Yoshikawa (1990). Zinc extracted by above methods was determined by atomic absorption spectrophotometer. Residual Zn was calculated subtracting a some of the fractions from the total zinc.

RESULTS AND DISCUSSION

Physico-chemical properties of soils

A perusal of the data given in (Table 1) indicates that all the soils under study were generally alkaline in reaction, the variation in pH being from 7.2 to 8.5. The electrical conductivity of soil - water suspension (1:2.5) ranged between 0.26 and 0.40 dSm^{-1} (Table 1). The higher content of soluble salts appeared due to irrigation with -saline water and insufficient leaching during rainy season. It is apparent that soluble salts do not appear to pose any problem for successful cultivation on these soils. The $CaCO_3$ content varied from 5.0 to 30.0 g kg^{-1} soil. The maximum and minimum values of calcium carbonate were noted in Tantpur and Sewala soils, respectively.The organic carbon content in the soil samples under reference varied from 3.9 to 5.0 g kg^{-1} soil. This variation in the organic carbon content of the soils may be attributed to variation in the texture of the soils and differences in the management practices. The cation exchange capacity of the soils under study varied from 7.40 to 11.36 c mol (p^+) kg-^{1}. The value of CEC was higher in Jagner soil in comparison to other soils. On the other hand, minimum value was recorded in Tantpur soil. Texturally, the soils of Agra district varied from loamy sand to sandy clay loam thus, showing a wide range of variation. The content of sand separate of these soils ranged from 41 to 80 percent. The ranges of silt and clay content were from 11 to 35 percent and 6 to 25 percent, respectively.

Table 1: Physico-chemical characteristics of the soils of Agra district

Location	pH	EC (dSm^{-1})	Org. C (g kg^{-1})	$CaCO_3$ (g kg^{-1})	CEC Cmol (p^+) kg^{-1})	Mechanical comp sition (%)			Textural class class
						Sand	Silt	Clay	
Akola	8.0	0.34	4.0	10.0	10.40	61	20	9	SL
Bichpuri	8.5	0.40	4.5	15.0	9.40	45	34	21	L
Etmadpur	8.1	0.26	4.1	10.0	8.60	75	19	6	LS
Jagner	8.2	0.28	4.9	10.0	11.36	70	12	18	SL
Kagarah	7.7	0.33	4.0	10.0	9.40	68	15	17	SL
Nadau	7.2	0.35	5.0	5.0	11.30	59	16	25	SCL
Raibha	7.5	0.35	4.0	10.0	10.00	57	25	18	SL
Sewala	7.9	0.30	4.0	5.0	8.50	59	23	18	SL
Tantpur	7.8	0.30	3.9	30.0	7.40	80	11	9	LS
Tehu	7.2	0.32	4.5	10.0	11.36	41	35	24	L

SL = sandy loam, L = loam, LS = loamy sand, SCL = sandy clay loam

Status of zinc

The total Zn content in these soils ranged from 26.0 to 59.0 mg kg^{-1} with an average value of 38.1 mg kg^{-1}. The soil of Etmadpur had relatively lower content of total zinc than the other soils of the district. The maximum amount of total zinc was recorded in Nadau soil which had high clay content and high organic matter content as well. The available zinc content in the soils of district Agra varied from 0.54 to 1.16 mg kg^{-1} (Table 2) with a mean value of 0.78 mg kg^{-1}. Using 0.60 ppm DTPA extractable zinc as deficient, 40 percent samples in the present investigation are classified as deficient. Singh and Singh, (1996) reported that available Zn content of the soils growing different crops in Mathura district varied from 0.3 to 2.4 mg kg^{-1}. Singh (2017) reported 50% zinc deficiency in soils of Allahabad, Uttar Pradesg.

Zinc fractions in soils

Water soluble plus exchangeable zinc: The water soluble plus exchangeable zinc in these soils was found very low, ranging from 0.12 to 0.35 mg kg^{-1} and constituted approximately 0.5% of the total zinc in soils. The maximum value (0.35 mg kg^{-1}) was recorded in Nadau soil while minimum (0.12 mg kg^{-1}) in Raibha soils. The soils of Sewala and Tehu had more or less similar values of water soluble + exchangeable zinc. The amount of water soluble + exchangeable Zn is largely controlled by soil pH. Low soil pH favours solubility of zinc and simultaneously prevents its adsorption by soil exchange complex. Almost similar values of water soluble + exchangeable zinc in low land rice soils were reported by Patnaik *et al.* (2011) and Kandali *et al.* (2016).

Table 2: Status of zinc fractions in soils of Agra district

Location	Total	DTPA	Zn Fractions (mg kg^{-1})					
			WSEX	Mn OX	OC	AMOX	CRYOX	Residual
Akola	39.0	0.66	0.20	0.40	1.25	2.20	2.32	32.63
Bichpuri	31.6	0.54	0.16	0.30	1.05	1.80	2.20	26.09
Etmadpur	26.0	0.56	0.15	0.30	0.91	1.54	1.62	21.48
Jagner	46.0	0.98	0.24	0.46	1.31	1.80	2.20	39.99
Kagarah	36.0	0.86	0.22	0.40	1.20	2.40	2.80	28.98
Nadau	59.0	1.16	0.35	0.67	1.45	2.80	3.24	50.49
Raibha	30.0	0.55	0.12	0.27	0.92	1.70	2.04	24.95
Sewala	38.0	0.85	0.28	0.50	1.20	2.32	2.52	31.18
Tantpur	27.0	0.59	0.16	0.25	0.73	1.70	2.00	22.16
Tehu	48.0	1.06	0.29	0.56	1.25	2.70	3.14	40.06

WSEX = Water soluble + Exchangeable, Mn OX = Mn- Oxide bound OC = organically complexed, AMOX = Amorphoux Fe-oxides bound, CRYOX = Crystalline Fe-oxides bound

Mn occluded Zn: The Zn content in Mn occluded pool varied from 0.25 to 0.67 mg kg^{-1} soil with a mean value of 0.41 mg kg^{-1}. The percentage of Mn oxide occluded Zn fraction was found 1.07%. The Mn oxide occluded Zn fractions, on an average, was similar to values reported by Wizebandara *et al.*(2011). The values of Mn oxide occluded Zn was lower than the values reported by Murthy (1982). The maximum and minimum values of MnOx-Zn were noted in Nadau and Tantpur soil, respectively.

Organically complexed Zn: The amount of organically complexed Zn ranged from 0.73 to 1.45 mg kg^{-1} soil with an average of 1.10 mg kg^{-1}. The percentage of organic matter occluded zinc fraction was 2.88% of total zinc. Kandali *et al.*(2016) also reported similar values of organically bound zinc in soils of Andhar Pradesh. The organically zinc was lower than AMOX and CRYOX forms but higher than WSEX Zn. This low value of OC-Zn in these soils may be attributed to their low organic matter content. The soil of Nadau and Tantpur had maximum and minimum values of OC-Zn, respectively.

Amorphous sesquioxide bound Zn: The amosphous Fe occluded Zn ranged from 1.54 to 2.80 mg kg^{-1}, with a mean of 2.09 kg mg^{-1}. On an average, 5.48 percent of total Zn was extracted in amorphous sesquioxide bound Zn. The maximum and minimum values of AMOX-Zn were noted under Nadau and Etmadpur soil, respectively. Dhane and Shukla (1995) also reported similar results. Considering the larger amount of Zn content in Fe oxide fraction compared with Mn oxide may be more important than the Mn oxide fraction in zinc chemistry of the soils used for the present study. The occurrence of higher proportion of Zn in the amorphous than in the crystalline sesquioxide bound form is due to the fact that amorphous sesquioxide have greater ability to adsorb more Zn because of their relatively large specific surface area.

Crystalline sesquioxide bound Zn: The crystal Fe occluded Zn fraction ranged from 1.62 to 3.24 mg kg^{-1} with an average of 2.41 mg kg^{-1}. The percentage of CRYOX-Zn fraction was 6.32 percent of total zinc. The maximum and minimum values of CRYOX-Zn were recorded in Nadau and Etmadpur soil, respectively. Mandal *et al.* (1992) also reported similar results.

Residual Zn: The residual Zn fraction ranged from 21.48 to 50.40 mg kg^{-1} with an average of 29.19 mg kg^{-1}. On an average, 76.62 percent of total Zn was extracted in the residual fraction. This also indicated that most of the applied zinc as fertilizer is reverted to the residual fraction.

Distribution of native and applied Zn predominantly in residual fraction has been confirmed by several investigations (Dhane and Shukla, 1995).

Relationship among forms of zinc

The different forms of zinc in these soils showed significant and positive correlations amongst one and other. Existence of a dynamic equilibrium among different pools of Zn in soil was confirmed from the correlation data (Table 3), which indicate that any change in soil management practices may affect Zn equilibria and thus Zn availability in soil. The state of dynamic equilibrium was found from the fact that water soluble plus exchangeable Zn (Table 3), and Mn occluded Zn (0.38), and residual Zn (r = 0.99) have high 'r' values with total Zn. Organically bound zinc also showed significant positive correlation with clay fraction as reported by Wijebandata *et al.* (2011). Iron oxide bound. Residual and total Zn had the highest correlation values indicating that the residual and total Zn was depended on each other. Operation of dynamic equilibrium among different soil fraction indicates that the depletion of Zn concentration in one pool readily available to plants in replenished form the other pools of soil Zn. Similar observations have also been reported by Dhane and Shukla (1995) and Pal *et al.* (1997). The AMOX form of Zn showed positive correlation with CRYOX and their initial contents in soil. The positive and significant correlations between DTPA extractable Zn and water soluble plus exchangeable Zn as well as organic matter bound Zn, indicated that DTPA has the ability to extract Zn from solution, exchangeable and organic matter associated pools existing in the soils. However, positive though not statistically significant relationship between total Zn and DTPA extractable Zn indicates that the availability of Zn may possibly be directly related to the amount of total zinc. This indicates that soils rich in oxides of iron contain much of their Zn in AMOX and CRYOX forms. Prasad *et al.* (1996) reported similar results.

Table 3: Correlation coefficients amongst different fractions of soil zinc

Zn Fractions	WSEX	Mn OX	OC	AMOX	CRYOX	Residual	DTPA
Mn OX	0.31						
OC	0.23	0.27					
AMOX	0.25	0.39*	0.27				
CRYOX	0.16	0.20	0.13	0.23			
Residual Zn	0.44**	0.36*	0.19	0.16	0.14		
DTPA	0.51**	0.16	0.35	0.21	0.19	0.19	
Total Zn	0.45**	0.38*	0.11	0.18	0.12	0.99**	0.60**

**Significant at 5% level ** Significant at 1% level, WSEX = Water soluble + Exchangeable, Mn OX = Mn- Oxide bound OC = organically complexed, AMOX = Amorphoux Fe-oxides bound, CRYOX = Crystalline Fe-oxides bound*

Zinc fractions Vs. Soil properties

Inverse relationship of pH with water soluble plus exchangeable zinc is supported by several other workers (Kandali *et al.* 2016). Positive and significant relationships of water soluble zinc and exchangeable zinc with organic carbon and clay indicated that the available zinc increased with increase in organic matter and clay content.

Table 4: Correlation coefficients between zinc fractions and soil properties

Fraction of zinc	pH	$CaCO_3$	Org. C	Clay	CEC
WSEX	-0.57*	-0.22	0.41 **	0.17	0.13
Mn OX	-0.31	-0.51**	0.19	0.21	0.26
OC	0.16	-0.15	0.47**	-0.41**	0.11
AMOX	0.11	-0.03	0.13	0.05	0.15
CRYOX	0.21	-0.25	0.11	0.11	0.11
Residual Zn	0.04	-0.58 **	0.34	0.45 **	0.37 *
Total Zn	-0.51 **	-0.59 **	0.36 *	0.38 *	0.39*

WSEX = Water soluble + Exchangeable, Mn OX = Mn- Oxide bound, OC = organically complexed, AMOX = Amorphoux Fe-oxides bound, CRYOX = Crystalline Fe-oxides bound

It is observed from Table 4 that the soil pH was found to be non-significantly related with total and available Zn. The values of correlation coefficient were, however, low and it was found to be statistically non significant. Clay fraction recorded significantly positive correlation with residual Zn. Organically complexed Zn had significant and positive correlation with organic carbon and clay content. AMOX and CRYOX-Zn did not show any significant relationships with soil properties (Wijebandara *et al.*, 2011).

REFERENCES

Dhane, S.S. and Shukla, L.M. (1995) Distribution of different forms of zinc in benchmark and other established soil series of Maharashtra. *Journal of the Indian Society Soil Sciency* **43**: 594-596.

Iwasaki, K. and Yoshikawa, G. (1990) Fractionation of copper and zinc in greenhouse soils. Trans. 14th Int. Congr. Soil Sci. vol II. Kyoto, Japan, pp 363-364.

Jackson, M.L. (1973) *Soil Chemical Analysis*. Prentice Hall of India Private Limited, New Delhi

Kandali, G.G., Barua, N.G., Basumatary, A. Medhi, B.K. and Kurmi, K. (2016) Zinc fractions and their availability in wetland rice in acidic soil of Assam. *Journal of the Indian Society of Soil Science* **64**(1): 58-65.

Lindsay, W.L. and Norvell, W.A. (1978) Development of a DTPA soil test for zinc, iron, manganese and copper. *Soil Science Society of America Journal* **42:** 421-428

Mandal, B., Chatterijee, J., Hazra, G.C. and Mandal, L.N. (1992) Effect of preflooding on transformation of applied zinc and its uptake by rice in lateritic soils. Soil Science **153** 250-257

Murthy, A.S.P. (1982) Zinc fractions in wetland rice soils and their availability to rice. Soil Science **133** 150-054.

Pal, A.K; Das, P.R; Patnaik, S.K; and Mandal, B (1997) Zinc fractions in some rice growing soils of Orissa. *Journal of the Indian Society Soil Science* **45**(4): 734-738

Patnaik, M.C., Sreenivasa Raju, A. and Bhupal Raj, G. (2011) Zinc requirement of hybrid rice-bhendi and its influence on zinc fractions in an Alfisol of Hyderabad, Andhra Pradesh *Journal of the Indian Society of Soil Science* **59**(4): 368-375.

Singh, R. (2017) Status of available sulphur and micronutrients in soils of Allahabad, Uttar Pradesh. *Annals of Plant and Soil Research* **19** (2): 237-239.

Singh, V. and Singh, Sandeep (1996) Relation of available micronutrient in soils and plants. *Journal of the Indian Society Soil Science* **44**: 800-802.

Wijebandara, D.M.D.I., Dasog, G.S., Patil, P.L. and Hebbar, M. (2011) Zinc fractions and their relationship with soil properties in paddy growing soils of northern dry and hill zones of Karnataka. *Journal of the Indian Society of Soil Science* **59**(2): 141-147.