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Zinc Content in Different Forms of Paddy Growing Soils in Selected Villages of Gangavati Taluka in North Karnataka

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Sixty surface (0-20 cm) soil samples were collected each from the paddy fields of villages in Gangavati taluka in North Karnataka during 2010. Distributions of different forms of zinc in paddy growing soils were studied. The results showed that more than 75% (79.38%) in Herura village and more than 90% (99.35%) in Maralanahalli village of total zinc occurred as residual zinc, whereas water soluble + exchangeable Zn accounted for only 0.11% in Maralanahalli village and 6.71% in Sanapura village soil samples. The water soluble + exchangeable zinc status varied from 0.13 to 1.93 ppm, organically bound zinc from 0.16 to 5.32 ppm, manganese oxide bound zinc from 1.00 to 5.89 ppm, amorphous sesquioxides bound zinc from 0.09 to 2.16 ppm, crystalline sesquioxides bound zinc form 1.21 to 9.94 ppm and residual zinc from 53.29 to 277.99 ppm. Among the Zn fractions water soluble + exchangeable zinc was low in all the soils when compared to other fractions, which is a very important for the plant nutrition. Amorphous sesquioxide bound form of zinc is the seat for zinc adsorption because of its high specific surface area. Crystalline sesquioxide bound form of zinc dominated when compared to water soluble + exchangeable, organically bound, manganese oxide bound and amorphous sesquioxide bound zinc fractions in selected village soils in Gangavati taluka.

Key words: Zinc fractions, paddy soil, water soluble and exchangeable zinc, organically bound zinc, amorphous sesquioxide bound zinc, residual zinc, total zinc

Zinc is one of the essential plant micronutrients and its importance for crop productivity is similar to that of major nutrients. Zinc is soluble organic complexes and exchange positions are of major importance in maintaining of zinc at sufficient level for wetland rice (Murthy, 1982). Crops require only small amount of zinc for their normal growth but its application rate is high due to very low fertilizer use efficiency. Micronutrients and their fractions have an important role in increasing the productivity and quality of crops. Their availability in soil is dependent on parent material, landform, climatic condition, natural vegetation and land use pattern (Deka *et al.,* 1996). Water soluble plus exchangeable and organically complexed forms are considered to be available; amorphous sesquioxide bound form is potentially available and crystalline sesquioxide bound residual zinc forms are unavailable to plants (Mandal *et al.,* 1992).

Sarkar and Deb (1982) explained that complexed zinc was found to be the most important fraction for plant nutrition. Residual fraction considered bulk of the native zinc fraction. But exchangeable and organically bound forms are considered to be the most available. About 5% or less of total zinc present in soil is available to plants at any given time. Contribution of these forms to the available pool of zinc may vary depending upon the physical and chemical properties of the soils. Further, zinc applied to the soil reacts with the soil constituents forming a number of sparingly soluble to insoluble components which together determine the concentration of zinc in soil solution and availability to plants (Iyengar and Deb, 1977). Knowledge on distribution of zinc fractions in soils and various soil properties influencing its availability might prove to be the best approach for obtaining reliable information about the need of zinc. Such information is lacking in the base unsaturated soils of selected villages in Gangavati taluka, North Karnataka. Hence, an attempt was made to study the distribution of different zinc fractions of paddy-growing soils of this area.

Materials and Methods

Sixty surface (0-20 cm) soil samples were collected from the paddy field of different villages in Gangavati taluka in North Karnataka during 2010. From one village five farmers were selected and soil samples were collected from each farmer's field. Soil samples collected from Vadratti, Basapatna, Karatagi, Mallapura, Marali, Siddhapura, Maralanahalli, Herura, Sangapura, Anegunti, Sanapura and Rampura villages in Gangavati taluk. The soils were analyzed for pH, EC, Organic carbon and $CaCo_3$ by following standard methods. Fractionation of soil zinc was carried out by following procedure outlined by Chatterjee et al. (1992). The fractionation of soil zinc is presented in Table 1. Total zinc was determined by digesting the soil sample with hydrofluoric acid-

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aqua-regia mixture in closed polypropylene bottles as given by Page et al. (1982). Available zinc in the soil was extracted by DTPA extractant (Lindsay and Norvell, 1978). Concentration of zinc in the filtrate was determined by Atomic Absorption Spectrophotometer (Varian AA 240FS).

Results and Discussion

Chemical properties of soils

The chemical properties of soil, such as pH, electrical conductivity, organic carbon and $CaCO_3$ were estimated. Soil pH value varied from 7.12 (slightly alkaline soil) in Mallapura village to 8.54 (strongly alkaline soil) in Karatagi village sample with a mean of pH 7.72. The Electrical conductivity ranged between 0.10 dSm^{-1} in the soils of Vadratti and Karatagi villages and 0.32 dSm^{-1} in Rampura village soil sample with a mean value 0.21 dSm^{-1}. All the soil samples collected from Gangavati taluka had shown low electrical conductivity indicating that soils are non-saline in nature.

The organic carbon content varied from 1.02 g kg^{-1} in Sanapura village to 9.46 g kg^{-1} in Rampura village with a mean value of 7.23 g kg^{-1}. The higher content of organic carbon in surface soil could be attributed to *in situ* incorporation of rice stubbles and addition of organic manures. Higher content of organic carbon, better aeration as well as finer fractions of soil loading to increase in the surface area for ion exchange (Sharma and Choudhry, 2007). The $CaCO_3$ values ranged between 2.11 per cent (Basapatna village) and 9.97 per cent (Vadratti village) with a mean value of 7.82 per cent. It might be due to downward movement of calcium and its subsequent precipitation as carbonate and / or decomposition of calcium carbonate.

Available Zinc

DTPA zinc varied from 1.49 ppm in Basapatna village to 4.97 ppm in Herura village with a mean value of 3.11 ppm. Considering 0.6 ppm as the critical limit of available zinc in soil, soil samples in all the villages were having sufficient zinc status. Sharma *et al*. (2003) explained that the higher values might be due to highest content of organic carbon as well as finer fraction of soils leading to increase in the surface area for ion exchange and hence contributed to the higher amount of DTPA- Zn in soil (Table 2).

Table 1. Sequential fractionation procedure of soil zinc

Fraction	Extraction	Ratio of Soil(g) : solution (mL)	Condition	Reference
Water soluble + Exchangeable	1 M Mg $(NO_3)_2$ (pH 7.0)	5:50	2 h shaking	Chatterjee and Khan (1992)
Organically bound zinc	0.05M Cu $(OAc)_2$	5:50	30 min. shaking	Chatterjee and Khan (1992)
Manganese oxide bound zinc	0.1M NH_2 OH.HCl (pH 2.0)	5: 50	30 min shaking	Chatterjee and Khan (1992)
Amorphous sesquioxides bound Zn	0.2 M $(NH_4)_2$ C_2O_4 (pH 3.0)	5: 50	4 h shaking	Chatterjee and Khan (1992)
Crystalline sesquioxides bound Zn	0.1M Ascorbic acid in the acidified ammonium oxalate	1:10	Soil and solution boiling for 30 min. in water bath	Chatterjee and khan (1992)
Residual Zinc	Total Zn – Sum of all the other fraction	---	---	---

Distribution of Zinc fractions

Different fractions in soils in selected villages were given in Table 2.

Water soluble + Exchangeable zinc

Water soluble + Exchangeable zinc differed in the range between 0.13 ppm in Mallapura village and 1.93 ppm in Sanapura village. The mean value of this form of zinc in selected soil samples was 0.82 ppm. The per cent contribution of this form to total Zn was 0.11% in Maralanahalli village and 6.71% in Sangapura village (Table 7). Higher values indicate that high zinc buffering capacity of soil which resulted in higher amounts of water soluble + exchangeable zinc (Deb, 1997). Similar findings were reported by many workers (Iyengar and Deb, 1977; Edwardraja and Iyengar, 1986 and Pal *et al.,* 1997). The variation in the content of this fraction in different village samples may be due to soil reaction which determines solubility of zinc (Hazra *et al.,* 1987).

Organically bound zinc

Organically bound zinc was ranged from 0.16 ppm in Rampura field to 5.32 ppm in Basapatna with mean a value of 2.25 ppm. The per cent contribution of this form to total zinc was ranged between 0.08 in Rampura village and 4.09 in Siddhapura village. This fraction is known to play a significant role in zinc nutrition of lowland rice (Mandal and Mandall, 1986). Similar values (0.3 – 6%) of organically complexed zinc have been reported by Prasad and Shukla (1996). Highest organically complexed zinc was recorded in Siddhapura soil sample which might be due to addition of FYM and $ZnSO_4$. Lowest content of organically complexed zinc was recorded in Rampura village soil sample, as this sample did not receive either FYM or $ZnSO_4$.

Manganese oxide bound zinc

Manganese oxide bound zinc ranged from 1.00 ppm in Sangapura village to 5.89 ppm in Maralanahalli village with a mean value of 2.39 ppm. The per cent contribution of this form to the total Zn was in the range between 0.47 and 5.0 in Sangapura village. This can be attributed to higher amount of zinc adsorption on the surface of the oxides (Edmund Marshall, 1977) as these soils reported to be relatively higher in total manganese content (Ananthanarayana and Ravindra, 1998).

Table 2. Zinc fractions and total zinc in Paddy growing soils of selected villages in Gangavati taluka

Samples	DTPA Exchangeable Zn	Water soluble + Exchangeable Zn	Organically Bound Zn	Manganese oxide bound Zn	Amorphous Sesquioxides bound Zn	Crystalline sesquioxide bound Zn	Residual Zn	Total Zn
Vadratti village								
1	3.88	0.35	3.64	1.82	0.50	5.60	120.38	132.29
2	4.40	0.98	2.14	2.47	0.33	4.74	235.97	246.63
3	3.97	1.08	3.91	3.92	0.82	1.83	190.05	200.61
4	5.87	0.25	2.19	2.12	0.93	7.75	142.40	155.64
5	4.73	0.98	2.09	2.66	1.34	2.92	53.29	63.28
Basapatna village								
6	2.33	0.73	1.56	2.13	0.75	3.65	269.17	277.99
7	2.55	0.45	5.32	1.86	0.62	1.62	188.10	197.97
8	1.49	1.08	3.05	3.15	0.66	5.65	122.93	136.52
9	3.31	2.53	2.56	2.16	0.94	3.95	219.86	232.00
10	3.58	1.47	2.37	2.18	2.16	1.25	189.95	199.38
Karatagi village								
11	3.17	0.98	2.23	2.50	0.49	7.36	120.70	134.26
12	2.02	1.07	1.04	1.78	1.31	1.21	120.06	126.47
13	4.81	1.45	3.52	2.75	0.92	1.96	215.97	226.57
14	2.37	1.36	3.22	1.27	0.81	1.66	123.42	131.74
15	2.28	0.60	2.16	1.99	0.61	2.19	136.98	144.53
Mallapura village								
16	3.91	1.59	1.19	3.01	0.66	1.76	139.29	147.50
17	2.67	0.63	2.18	1.90	0.24	1.39	144.38	150.72
18	3.28	0.18	1.54	2.41	0.56	1.44	217.33	223.46
19	1.68	0.13	1.60	1.63	0.15	1.36	207.54	212.41
20	2.05	0.17	1.68	0.93	0.14	1.45	118.82	123.19
Marali village								
21	2.84	0.22	2.73	1.73	0.16	1.75	140.18	146.77
22	2.13	0.51	1.17	2.66	0.13	1.92	205.28	211.67
23	2.81	0.33	1.25	4.15	0.97	2.02	119.45	128.17
24	3.31	0.43	1.94	2.22	0.86	1.62	109.12	116.19
25	3.76	0.18	1.45	1.41	0.41	1.53	227.82	232.80
Siddhapura village								
26	3.21	0.63	2.67	2.27	0.09	1.62	231.86	239.14
27	1.99	0.18	4.69	3.53	0.33	6.89	99.04	114.66
28	2.81	0.70	1.89	4.10	0.82	2.11	104.69	114.31
29	3.75	0.19	2.14	3.25	0.63	2.03	151.81	160.05
30	3.01	0.25	2.18	2.24	0.55	1.92	109.88	117.02
Maralanahalli village								
31	2.81	0.45	2.43	2.01	0.22	1.65	120.37	127.15
32	3.81	0.32	1.56	2.98	0.23	4.24	102.90	112.23
33	3.54	1.22	1.81	3.22	0.16	8.72	120.22	134.35
34	2.60	0.25	2.45	4.22	0.38	4.65	203.68	215.63
35	3.33	1.66	2.39	5.89	0.38	1.75	208.06	220.13
Herura village								
36	2.56	0.40	1.55	2.52	0.36	6.92	140.57	152.32
37	3.26	1.79	1.84	2.68	0.39	5.37	110.82	122.89
38	4.97	1.54	3.00	2.34	0.46	4.57	106.80	118.71
39	2.64	0.48	1.53	1.95	0.50	9.45	101.68	115.59
40	2.45	1.15	1.87	1.11	0.59	1.67	111.01	117.40
Sangapura village								
41	2.02	0.15	1.86	1.00	0.44	4.65	105.18	113.28
42	2.11	1.66	1.43	1.99	0.35	6.57	207.59	219.59
43	2.51	0.57	1.01	2.89	1.92	5.73	204.07	216.19
44	6.51	2.13	4.86	3.25	0.83	8.94	77.06	97.07
45	2.63	0.15	1.98	1.36	0.77	8.82	53.51	66.59
Anegunti village								
46	2.85	1.17	2.75	2.14	0.86	2.16	111.18	120.26
47	3.34	1.19	3.10	3.07	0.56	1.93	204.72	214.57
48	3.31	1.16	2.10	2.57	0.88	1.60	119.89	128.20
49	2.82	0.18	1.98	1.58	0.25	6.82	108.25	119.06
50	2.75	0.20	1.89	1.00	0.75	1.43	111.30	116.57
Sanapura village								
51	2.46	1.29	1.22	1.82	0.63	1.33	120.44	126.73
52	2.91	0.25	2.83	1.93	0.35	1.47	130.74	137.57
53	2.52	1.93	1.43	2.66	0.44	1.92	159.13	167.51
54	3.84	0.43	2.33	3.01	0.49	1.73	175.40	183.39
55	4.63	1.45	4.43	2.93	0.25	4.12	193.00	206.18
Rampura village								
56	2.64	0.84	1.45	1.82	0.87	6.74	124.20	135.97
57	4.50	0.94	3.22	1.23	0.73	6.12	206.06	218.30
58	2.26	0.73	2.47	2.62	0.89	8.38	198.81	213.90
59	3.83	0.83	1.61	1.53	0.56	8.53	191.86	204.92
60	2.29	0.25	0.16	2.01	0.96	9.94	193.40	206.72
Mean	3.11	0.82	2.25	2.39	0.62	3.87	151.59	161.62
S.Em±	0.38	0.29	0.31	0.43	0.19	0.72	76.57	46.52
CD at 5%	0.57	0.34	0.75	1.14	0.56	2.11	92.12	97.46

Highest content of manganese sesquioxide zinc content was recorded in Sangapura village soil sample which might be due to the addition of ZnSO4 and FYM. This can be occluded are co-precipitated with hydrous oxide of manganese and iron and form a principal matrix with abundant held zinc (Jene, 1968).

Amorphous sesquioxide bound zinc

Amorphous sesquioxide bound zinc varied from 0.09 ppm in Siddhapura village to 2.16 ppm in Basapatna village with a average value of 0.62 ppm. The per cent contribution of this fraction to total zinc was from 0.04 in Siddhapura village soil sample to 1.16 in Herura soil sample. The highest content of amorphous sesquioxide bound zinc than crystalline sesquioxide bound zinc could be attributed to greater ability of amorphous sesquioxide to adsorb zinc because of their high specific surface area (Devis and Leckie, 1978).

Highest content of amorphous sesquioxide bound zinc was noticed in Herura soil sample. This might be due to addition of $ZnSO_4$ and FYM. Vasudeva and Ananthanarayana (2002) observed that soils rich in oxides of iron and aluminium contain much of their zinc in the amorphous iron oxide bound forms.

Crystalline sesquioxide bound zinc

This form of zinc ranged between 1.21 ppm in Karatagi village to 9.94 ppm in Rampura village with overall average value of 3.87 ppm. The per cent contribution to total Zn was between 0.64% in Mallapura village sample and 13.25% in Herura village sample. This fraction was dominant compared to water soluble + exchangeable, organically bound zinc fractions. This might be due to chemical affinity or specific adsorption and also due to predominance of crystalline iron oxide content. Similar results obtained by Pal *et al.* (1997). This fraction is more stable particularly in upland condition. The crystalline oxide exhibit soil structure (Schwertman *et al.,* 1985) in which Zn^{2+} is incorporated to compensate change in values, thereby Zn^{2+} gets bound / adsorbed.

Residual zinc

The Residual zinc content varied from 53.29 ppm in Vadratti village to 269.17 ppm in Basapatna village with a mean residual zinc of 151.59 ppm. Residual zinc fraction constituted the largest proportion of total zinc content *viz.,*79.38% in Herura soil and 99.35% in Maralanahalli soils.

Iyengar and Deb (1977) reported that in some red soils of Karnataka, residual zinc fraction was the most dominant fraction ranged from 42.5 to 208.2 ppm and constituted 96.8% of total zinc. Whereas, in the calcareous soils of India it was 25.1 to 80.6 ppm with a mean of 55.7 ppm, and accounts for 73.4 to 88.0% of the total zinc (Singh *et al.,* 1988).

Total zinc

The total zinc varied from 63.28 ppm in Vadratti village to 277.99 ppm in Basapatna village with an average total zinc content of 161.62 ppm. The total zinc content of the soils depends on the parent material. Although, total Zn content is considered as a poor indicator of zinc supplying capacity of soil for long term management practices in crop cultivation.

Based on the study it was concluded that different fractions of soil Zn have been contributed in soil formation. The content of different zinc fractions differed between soils of selected villages in Gangavati taluka. However, water soluble and exchangeable forms of Zn were less compare with other fractions of Zinc. Depletion of water soluble and exchangeable and complexed forms of Zn occurred with a build-up of organic, occluded and residual fractions of Zn occurred.

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