

## Transformation of native and applied zinc in alluvial soils under submerged condition

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### ABSTRACT

*Transformation of native and applied zinc in three alluvial soils under submerged condition was evaluated in laboratories of Department of Agricultural Chemistry and Soil Science, R. B. S. College, Bichpuri, Agra (U.P.). The results revealed that the water soluble plus exchangeable and the crystalline sesquioxides bound forms of soil zinc showed a gradual decline with incubation period. A small amount of added zinc was present in these forms after its application. Mn oxide bound zinc recorded an increase from the initial value in all the soils. About 8.2 to 12.0% of the applied zinc was found to be converted to this form. Organically bound zinc showed a gradual increase in all the soils. The mean amount of applied zinc found in this form was very small ranging from 2.6 to 6.6%. The AMOX-Zn in the soils increased over the initial content of the soils. About 3.6 to 9.3% of the applied zinc was found in this form. The amount of AMOX-Zn increased with increase incubation up to 45 days. Application of 5 mg Zn kg<sup>-1</sup> soil showed an increase in different zinc fractions under submergence.*

**Keywords:** Alluvial soil, submergence, transformation zinc fraction

### INTRODUCTION

Zinc deficiency is a serious problem for rice grown under wet land soil conditions in Uttar Pradesh. Zinc exists in soil in various chemical forms, in soil solution as ionic or organically complexed species, on exchange sites of reactive soil components, complexed with organic matter, occluded in oxides and hydroxides of Al, Fe and Mn, entrapped in primary and secondary minerals. Zinc in soluble organic complexes and exchange positions are of major importance in maintain of zinc level sufficient for wetland rice (Murthy 1982, Singh and Umashankar 2018). When a soil is submerged, a number of chemical and electro-chemical changes occur, such as adjustment of soil pH towards neutrality, increase in partial pressure of CO<sub>2</sub> and decrease in redox potential. These forms are in a state of dynamic equilibrium. The amount and rate of transformation of these forms of zinc determine the size of the labile zinc pool. So far no work has been done on transformation of native and applied zinc in alluvial soils of Agra region (Uttar Pradesh). The present investigation was, therefore undertaken to study the transformation of zinc, both native and applied, in alluvial soils under submergence.

### MATERIALS AND METHODS

The incubation studies were carried out in the laboratory of Department of Agricultural Chemistry and Soil Science, R.B.S. College Bichpuri, Agra. The soils were collected from upper (0-15 cm) layer from field at three different locations viz., Bichpuri, Kagarol and Tehu in Agra district. The soils were air dried, crushed, sieved through 2 mm sieve and homogeneously mixed before subjecting to different treatments. The soils were subjected to physical and chemical analyses. The chemical characteristics of the soil are given in Table 1. Five grams of each of the soil samples were taken in a number of incubation tubes of 50 ml capacity, submerged using deionised water, treated with two levels of zinc (0 and 5 mg kg<sup>-1</sup>) as ZnSO<sub>4</sub>.7H<sub>2</sub>O and then incubated in the laboratory at room temperature (25± 0.5°C). The soils were thereafter sequentially extracted with different sets of extractants for different forms of zinc following Iwasaka and Yoshikawa (1990) method with some modifications after different periods (15, 30, 45 and 60 days) of submergence. Zinc in the extracts was determined with the help of atomic absorption spectrophotometer.

Table 1: Important chemical characteristic of the soils

Characteristics	Bichpuri	Kagarol	Tehu
pH	8.5	7.7	7.2
EC (dSm <sup>-1</sup> )	0.4	0.33	0.32
Org. C (g kg <sup>-1</sup> )	4.5	4.0	4.5
CaCO <sub>3</sub> (g kg <sup>-1</sup> )	15.0	10.0	10.0
CEC (cmol(p <sup>+</sup> ) kg <sup>-1</sup> )	9.40	9.40	11.36
Available N (kg ha <sup>-1</sup> )	176.0	165.0	180.0
Available P (kg ha <sup>-1</sup> )	8.8	8.5	9.0
Available K (kg ha <sup>-1</sup> )	140.0	150.0	160.0
Total Zn (mg kg <sup>-1</sup> )	31.6	36.0	48.0
Total Fe (%)	1.85	1.80	2.0
Total Mn (mg kg <sup>-1</sup> )	180.0	200.0	220.0
DTPA Zn (mg kg <sup>-1</sup> )	0.54	0.86	1.06
WSES Zn (mg kg <sup>-1</sup> )	0.16	0.22	0.29
Mn OX- Zn (mg kg <sup>-1</sup> )	0.30	0.40	0.56
OC- Zn	1.05	1.20	1.25
AMOX- Zn (mg kg <sup>-1</sup> )	1.80	2.40	2.70
CRYOX- Zn (mg kg <sup>-1</sup> )	2.20	2.80	3.14
Residual Zn (mg kg <sup>-1</sup> )	26.09	28.98	40.06

## RESULTS AND DISCUSSION

**Water soluble plus exchangeable zinc:** A study of Table 2 reveals that the amount of water soluble plus exchangeable form of Zn in all the soils showed a gradual decrease up to 30 days followed by a slight increase after submergence of 45 days. The decrease might be due to the precipitation of soluble Zn as hydroxide and carbonates (Chatterjee *et al.* 1992), its adsorption on the surface of manganese oxides and amorphous sesquioxides and / or displacement of Zn from (Patnaik *et al.* 2011).

Table 2: Status of water soluble plus exchangeable zinc (mg kg<sup>-1</sup>) in soils as affected by zinc levels and incubation period

Treatments	Incubation period (days)			
	15	30	45	60
S <sub>1</sub> Zn <sub>0</sub>	0.14	0.11	0.10	0.11
S <sub>1</sub> Zn <sub>5</sub>	0.16	0.13	0.12	0.13
S <sub>2</sub> Zn <sub>0</sub>	0.21	0.18	0.16	0.17
S <sub>2</sub> Zn <sub>5</sub>	0.24	0.22	0.20	0.21
S <sub>3</sub> Zn <sub>0</sub>	0.27	0.24	0.21	0.23
S <sub>3</sub> Zn <sub>5</sub>	0.29	0.28	0.25	0.26

S<sub>1</sub> = Bichpuri soil    S<sub>2</sub> = Kagarol soil    S<sub>3</sub> = Tahu soil

Exchange sites by Fe<sup>2+</sup> and Mn<sup>2+</sup> followed by its subsequent precipitation. As regards the applied Zn, a small proportion was found to be present in the water soluble plus exchangeable form

immediately after application in all the three soils. This amount gradually decreased with the advancement of incubation period, the cause of decrease being the same as described above. Similar results were reported by Kamli *et al.* (2011).

**Manganese oxide bound Zn:** The amount of Zn in MnO<sub>2</sub> bound form recorded (Table 3) an increase in all the soils, attained peak value at 45 days of submergence and declined thereafter. Under anaerobic condition, some amount of higher oxides of manganese are converted to the lower valent compounds (Chatterjee *et al.* 1992), which on diffusion to the oxic region gets re-oxidised with subsequent formation of mangantic hydroxide having large specific surface area and hence high adsorption capacity. The Zn released from other bound forms might have been held by the manganic hydroxide resulting in an increase in the content of manganese oxide bound form of zinc. During the latter period of incubation, the redox potential of soils decreased which caused the reduction of the freshly formed manganic hydroxide resulting in the release of the adsorbed zinc. As regards the applied Zn, 8.2 to 12.0 percent of the applied amount was found to be converted to this form immediately after application. The amount recorded a gradual increase with the progress of incubation and attained peak values after 45 days and thereafter more or less constant. The low Eh developed in soils after prolonged submergence favours dissolution of the oxides and hydroxides of higher valent Mn resulting in release of Zn occluded by them making it available to rice plants. Chatterjee *et al.* (1992) reported similar results. Among the soils higher values were recorded in Tehu soil at all the incubation periods.

Table 3: Effect of zinc levels incubation period on Mn occluded zinc (mg kg<sup>-1</sup>) in soils

Treatments	Incubation period (days)			
	15	30	45	60
S <sub>1</sub> Zn <sub>0</sub>	0.32	0.50	0.55	0.46
S <sub>1</sub> Zn <sub>5</sub>	1.70	1.95	2.11	1.90
S <sub>2</sub> Zn <sub>0</sub>	0.43	0.63	0.69	0.60
S <sub>2</sub> Zn <sub>5</sub>	1.85	2.26	2.45	2.31
S <sub>3</sub> Zn <sub>0</sub>	0.58	0.80	0.84	0.75
S <sub>3</sub> Zn <sub>5</sub>	2.00	2.35	2.57	2.40

**Organically bound Zn:** Data on organically bound Zn are presented in Table 4. The amount of Zn in the organically bound form showed (Table 4) an increase in all the soils immediately after submergence, attained a peak value at 45 days of submergence and thereafter showed a declining trend. Such increase is possible due to the release of Zn bound by crystalline sesquioxides on their reduction under submerged condition and its subsequent chelation by organic compound resulting from anaerobic decomposition of soil organic matter. The declining trend towards the later period might be due to the decrease in stability of Zn-organic complexes at the lower Eh of the soils attained after prolonged submergence. Patnaik *et al.* (2011) observed that at low reduction potential; Zn and Cu chelates were highly unstable. A very small proportion (1.7 to 3.6%) of the applied Zn was found to be present in the organic complexed form immediately after its application.

Table 4: Effect of zinc levels and incubation period on organically complex zinc ( $\text{mg kg}^{-1}$ ) in soils

Treatments	Incubation period (days)			
	15	30	45	60
S <sub>1</sub> Zn <sub>0</sub>	1.05	1.25	1.37	1.00
S <sub>1</sub> Zn <sub>5</sub>	1.90	2.17	2.36	1.98
S <sub>2</sub> Zn <sub>0</sub>	1.20	1.43	1.55	1.14
S <sub>2</sub> Zn <sub>5</sub>	2.05	2.39	2.57	2.10
S <sub>3</sub> Zn <sub>0</sub>	1.25	1.49	1.60	1.19
S <sub>3</sub> Zn <sub>5</sub>	2.17	2.65	2.82	2.45

It showed an increasing trend with the progress of incubation period. The mean amount of applied Zn found in this form after the 45 days period of incubation was very small ranging from 2.6 to 6.6 percent of the applied amount. The water soluble plus exchangeable and organically bound forms of Zn in soil are known to play important role in Zn nutrition of lowland rice (Mandal and Mandal, 1986 and Chatterjee *et al.* 1992). Since very small proportion of the applied Zn was transformed to these two forms in lateritic soils, the efficiency of applied Zn for Zn nutrition of rice is likely to be low in such soils.

**Amorphous sesquioxide bound zinc:** The native soil zinc in this form recorded (Table 5) an

increased in all the soil, attained maximum values after 30 or 45 days period of submergence and thereafter showed a decreasing trend. The magnitude of increase ranged from 13.0 to 29.4% of the initial amount after 15 days period of submergence. With the progress of incubation period up to 15 days, the amount of amorphous Fe-oxides gradually increased in all the soils. Such oxides of Fe have highly specific surface area and therefore high adsorption capacity. So the Zn released from other bound forms in soils on submergence might have been adsorbed by such freshly formed amorphous Fe oxides resulting in an increased in the content of zinc bound by them. About 3.6 to 9.3 percent of the applied Zn was found to be transformed to this form immediately after application. The amount recorded a gradual and continuous increase up to 45 days of incubation in all the soils, at 60 days indicated a decrease. The transformation of Zn to the amorphous sesquioxides bound form appears to be closely related to the amount of amorphous Fe oxide which increased due to submergence in these soils as suggested by Chatterjee *et al.* (1992).

Table 5: Amorphous sesquioxide bound zinc ( $\text{mg kg}^{-1}$ ) in soils as affected by zinc levels and incubation period

Treatments	Incubation period (days)			
	15	30	45	60
S <sub>1</sub> Zn <sub>0</sub>	1.80	1.95	2.75	2.70
S <sub>1</sub> Zn <sub>5</sub>	4.50	4.92	5.75	5.55
S <sub>2</sub> Zn <sub>0</sub>	2.40	2.60	3.47	3.35
S <sub>2</sub> Zn <sub>5</sub>	5.22	5.75	6.66	6.37
S <sub>3</sub> Zn <sub>0</sub>	2.70	3.00	3.90	3.78
S <sub>3</sub> Zn <sub>5</sub>	5.35	5.90	6.82	6.55

**Crystalline sesquioxides bound Zn:** The amount (Table 6) of native soil Zn in this form decreased gradually in all the soils after submergence, the magnitude of such decrease after 30 days was marked at 60 days of submergence. Such decrease may be attributed to the reduction of crystalline Fe oxides and the subsequent release of Zn held by them. The rate of decrease of soil Zn by crystalline sesquioxide followed a pattern more or less similar to that of the decrease of these oxides in such soils on submergence. The amount of applied Zn

Table 6: Effect of zinc levels and incubation period on crystalline sesquioxide Zn (mg kg<sup>-1</sup>) in soils

Treatments	Incubation period (days)			
	15	30	45	60
S <sub>1</sub> Zn <sub>0</sub>	2.20	2.10	1.95	1.88
S <sub>1</sub> Zn <sub>5</sub>	5.50	5.38	5.10	4.79
S <sub>2</sub> Zn <sub>0</sub>	2.80	2.75	2.57	2.49
S <sub>2</sub> Zn <sub>5</sub>	6.00	5.71	5.48	5.31
S <sub>3</sub> Zn <sub>0</sub>	3.14	3.05	2.97	2.88
S <sub>3</sub> Zn <sub>5</sub>	6.18	5.92	5.81	5.69

transformed to this immediately after application ranged from 5.4 to 10.5 percent of the applied amount, the magnitude of such transformation

was closely related to the initial content of crystalline Fe oxides of the soils. The amount, however, gradually decreased due to reasons as explained earlier. Chatterjee *et al.* (1992), Prasad *et al.* (1995) described in CRYOX- Zn due to reduction of crystalline Fe oxides under anaerobic condition and subsequent release of Zn held by them.

The results of transformation of native and applied Zn in laterite soils show that the potentially available forms of Zn (organically bound, MnO<sub>2</sub> bound and amorphous sesquioxide bound) remain at the highest level between 7-15 and 15-30 days period after submergence and Zn application, although the readily available form (water soluble plus exchangeable) is slightly lower during these periods.

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