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EFFECT OF PHOSPHORUS AND VERMICOMPOST ON ZINC AVAILABILITY IN AN ACIDIC LATERITE SOIL OF WEST BENGAL, INDIA

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Abstract: Phosphorus (P) is the most important element interfering zinc availability in soil. The antagonism between phosphorus-zinc is observed mainly when both nutrients are deficient. The experimental soil was collected from Bankura having pH value 5.2, phosphorus content of 25.98 kg ha^{-1} and Zn content of 0.29 mg kg^{-1}. The laboratory incubation study for 15 and 30 days at 30^0C taking graded doses of Zn, P and vermicompost showed that DTPA-extractable Zn was higher in general in all treatment combinations receiving higher Zn addition. The application of P reduced the Zn extractability of soil and *vice-versa.* The application of vermicompost increased the availability of the P but decreased the DTPA extractable Zn in soil. The time of incubation period increased the P as well as Zn contents in soil.
Keywords: Zinc, Vermicompost, Phosphorus, Acid soil.

1. INTRODUCTION

Zinc (Zn) is an important micronutrient element which is essential for the normal growth and reproduction of crops. It is considered as the least toxic among the so called heavy metals. Like all other micronutrients zinc is present in soils in a number of forms, differing in their reactivity, solubility, and availability to plants [1]. Zinc mobility in soil is dependent on many factors such as soil acidity, zinc total value in the soil, organic matter and soil type. In India, the major Zn deficiency was found in the places like Madras, Ranchi, Maharasthra, Punjub, Ajmer, Paramour, Jalandhar, Ahmedabad and Bashri [2]. In West Bengal, out of eighteen districts, fourteen districts including Darjeeling, Jalpaiguri, Cooch Behar, Bankura, Purulia etc. have deficiency in zinc [3]. Zinc deficiency is also found in laterite zones of West Bengal. These soils are well drained and acidic with lower cation exchange capacity, organic matter and phosphorus [4].

Phosphorus is the most important element which interferes on zinc mobility in soil and uptake by plants and this was confirmed by a number of studies that excessive accumulation

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of phosphorus causes zinc deficiency in plants [5-7]. The interactive effect between phosphorus and zinc causes deficiency of both the nutrients possibly by forming less soluble zinc-phosphate compound in soil. The antagonism between phosphorus-zinc is observed mainly when both nutrients are deficient. The accumulation of high concentrations of P at low levels of Zn is considered to be responsible for the "phosphate enhanced zinc requirement syndrome" [3]. The antagonistic interaction of PO_4^- and Zn^{2+} for a range of plant species and soil types has been studied widely since 1936 [8]. The interaction often called "P induced zinc deficiency" is commonly associated with high levels of available soil P or with application of phosphorus to the soil [3].

The addition of organic manure may reduce the mobility of Zn in soil by forming stable chelates thereby may affect the formation of Zn-P complexes in soil. The vermicompost is one of the most widely used organic in the study area. Thus, the present study was undertaken to examine the zinc-phosphorus interaction on phyto-availability of both nutrients in presence of one organic namely vermicompost in controlled environment.

2. MATERIALS AND METHODS

A. Soil

The soil used in the experiment was collected from the surface layer (0-15 cm) from Gottoria village, Indpur Block and Khatra sub-division of West Bengal, India (23°9'49"N 86°47'32"E). The collected soils were air dried in shade at 35°C to constant weight, grounded with a wooden pestle and mortar and passed through a 2 mm nylon sieve. Coarse litter and plant material were removed, being careful to minimize soil losses in the process. The soil samples were stored in paper bags with proper labeling for further study. The soil was characterized for pertinent physico-chemical properties following standard procedures [9-10] and those were as follows: pH (1:2.5) 5.2, organic carbon 0.25%, water holding capacity 47.2%, CEC [5.97 Cmol $(P^+)Kg^{-1}$], clay 17.24%, texture silty loam, available P 12.99 mg kg^{-1}, DTPA-extractable Zn 0.47 mg kg^{-1}, and Fe_2O_3 4.6%. The taxonomic classification of this soil belongs to Typic Haplustalfs.

B. Laboratory incubation Study

30 gm soil sample was taken in a number of each incubation tube and incubated at 30^0C in a BOD incubator with two level of vermicompost, *viz.* VC_0 and VC_1 (0 and 1% vermicompost of the weight of soil), three levels of phosphorous *viz.* P_0, P_{50} and P_{100} (0, 50 and 100 mg P kg^{-1} soil) added as KH_2PO_4 and three level of zinc *viz.* Zn_0, Zn_5 and Zn_{10} (0, 5 and 10 mg Zn kg^{-1} soil) applied in the form of $ZnSO_4$, $7H_2O$. The vermicompost (containing

total P 0.69% and Zn trace) was added in soil as powder. Phosphorus and zinc were added in the form of solution which was mixed thoroughly with the soil. The moisture in the samples was maintained at maximum water holding capacity. The loss of water was compensated by periodic addition of double distilled water as and when required. These treatments were combined with all possible way and were replicated thrice. The incubated samples were kept inside in the incubator for 15 and 30 days maintaining the temperature of 30^0C ± 2^0C. On expiry of the incubation period the samples were extracted for P with Bray and Kurtz No-1 extractant and P was determined colorimetrically using a Systronics make digital spectrophotometer. The Zn was extracted with DTPA and was measured with atomic absorption spectrophotometer (PerkinElmer AAnalyst 200).

3. RESULTS AND DISCUSSION

A. Effect of zinc and vermicompost on the availability of phosphorus

The available phosphorus decreased with the increased application of the zinc (Table 1). The available P content reduced from 42.5 mg kg^{-1} (in control, *i.e.,* $P_0Zn_0VC_0$ treatment combination) to 35.8 mg kg^{-1} and 32.5 mg kg^{-1} with the increased dose of zinc @ 5 mg kg^{-1} and 10 mg kg^{-1}, respectively without vermicompost and phosphorus application in 15 days incubation. This had also same trend in case of 30 days incubation. This lowering of the P content with the application of Zinc may be attributed to the antagonistic interaction of P and Zn particularly in acid soil [11]. However the incubation period increased the extractability of phosphorus in all treatment combination may be due to the release of the sparingly soluble Zn-P complexes in longer time by the reduction of Zn in moist soil condition. The cations present in soil get reduced in anaerobic condition and become gradually more labile in the soil [12] particularly for the dissolution of iron oxides and release of phosphates that adsorbed on iron oxides. In control treatment combination available P increased from 42.5 mg kg-^{1} to 44.8 mg kg^{-1} with the increment of incubation period from 15 to 30 days. The data also revealed that available phosphorus content increased markedly with the increase of P application in all the cases. The available P increased from 42.5 mg kg^{-1} to 84.1 and 146.3 mg kg^{-1} with the application of P @ 0, 50 and 100 mg kg^{-1}, respectively, in 15 days of incubation whereas it was 44.8, 92.6 and 157.8 mg kg^{-1} in 30 days of incubation where zinc and vermicompost were not externally applied

The application of vermicompost increased the availability of the mean P from 91.0 mg kg^{-1} to 94.7 mg kg^{-1} in 15 days of incubation without the addition of zinc (Table 1). But the mean P content was lowered from 82.5 mg kg^{-1} to 78.2 mg kg^{-1}, and 77.0 to 72.6 mg kg^{-1} with the zinc addition @ 5 and 10 mg kg^{-1}. This may be due to the formation of more stable and less soluble Zn-P complexes which may hindered the formation of more soluble organic-P compounds in soil. The increase of incubation period also increased the availability of P in all treatment combinations. The increment of P content with the increase of incubation period may be attributed to some extent to the more release of the P from vermicompost itself through the decomposition of organics with the longer incubation period. The reduced ionic environment in moist soil condition may also be responsible for more discharge of the P from metal-P complexes in soil.

B. Effect of phosphorus and vermicompost on the availability of the zinc

DTPA extractable Zn increased in all treatment combinations with the application of Zn (Table 2). The longer incubation period increased the extractability of Zn where the vermicompost and P were not applied. This may be attributed to desorption for increased solubility of Zn from absorbing sites of clay surfaces with time under wet soil condition due to reduction. Phosphorous addition decreased Zn extractability by DTPA irrespective of the treatment and time of incubation period. This decrement may be attributed to formation of the reaction product of Zn of lower solubility with phosphorus [13]. Furthermore this experimental acid soil has high amount of Fe^{2+} and Mn^{2+} content which compete with Zn^{2+} for exchange sites leaving Zn^{2+} in soil solution phase making it susceptible to form organo-metal complexes of high stability and lower solubility [14]. In most of the cases the longer incubation period increased the availability of Zn with vermicompost addition also. This may due to the release of Zn from the once-complexed organo-Zn compound with the increased decomposition of the organic matter present in vermicompost in longer incubation period.

The addition of organic matter also further decreased the extractable Zn in soil. The average available Zn content decreased from 0.59 to 0.44 mg kg^{-1}, 3.34 to 2.73 mg kg^{-1} and 5.87 to 5.35 mg kg^{-1} with the addition of vermicompost @1% weight of soil at Zn addition of 0, 5 and 10 mg kg^{-1}, respectively in 15 days of incubation (Table 2). This decrement of Zn availability may be due to the formation organo-metal complexes of high stability and lower solubility [14). The longer incubation period increased the availability of Zn with vermicompost addition particularly for the soil received more P dose which may be attributed to the release of Zn from the once-complexed organo-Zn compound with the decomposition of the organic matter present in vermicompost in longer incubation period.

Significant positive interaction between phosphorus and vermicompost (P×VC) contrary to that between P and Zn (P×Zn) as well as between Zn and vermicompost (Zn×VC) was noted.

A further positive interaction between the three factors (P×Zn×VC) was also observed in this incubation study. This was in agreement with stepwise multiple regression equations given in tables 3 and 4 which clearly showed that the available P content was increased with the application of vermicompost as well as with incubation period in both the soil. The DTPA extractable Zn was markedly reduced with the application of P and *vice versa.*

4. Conclusion

These results clearly demonstrated that the antagonistic effect of phosphorus and zinc is prevailed in acid soil which affects the mobility of both nutrients in soil-plant systems. The addition of vermicompost can decrease this antagonism, to some extent, between these elements may by forming complexes with both.

References

[1] Shuman, L.M. "Effect of phosphorus level on extractable micronutrients and their distribution among soil fractions". Soil Science Society of America Journal **52 (1):** 136-141, 1988

[2] Roychoudhury, S.P. and Biswas, N.R. "Trace element status of Indian soils". Journal of the Indian Society of Soil Science **12 (3):** 207-214, 1964

[3] Das, D.K. "Introductory Soil Science. New Delhi'. Kalyani Publishers, 2008

[4] Panda, N., Prasad, R.N., Mukhopadhyay, Asit K. and Sarkar, A.K. "Managing soils for optimum productivity on red, Lateritic and associated soils in Eastern India". Bulletin of the Indian Society of Soil Science, **15 (1):** 20-28, 1991.

[5] Das, D.K., Dang, R., Shivananda, T.N. and Sur, P. "Interaction between phosphorus and zinc on the biomass yield and yield attributes of the medicinal plant stevia (*Stevia rebaudiana*)". The Scientific World Journal, **5:** 390–395, 2005.

[6] Khorgamy, A. and Farnia, A. "Effect of phosphorus and zinc fertilisation on yield and yield components of chick pea cultivars". African Crop Science Conference. Proceedings 9, 205-208, 2009.

[7] Salimpour, S.K., Khavazi, H., Nadian, H. and Besharati, M.M. "Enhancing phosphorous availability to canola (*Brassica napus* L.) using P solubilizing and sulfur oxidizing bacteria". Australian Journal of Crop Science, **4(5):** 330-334. 2010.

[8] Barnette, R.M., Camp, J.P., Warner, J.D., and Gall, O.E. "Use of zinc sulphate under corn and other field crops". Bulletin- 292. Unit of Florida Agricultural Experimental Station. USA, 1936.

[9] Jackson, M.L. "Soil Chemical Analysis". New Delhi: Prentice-Hall of India, 1967.

[10] Page, A.L., Miller, R.H., and D.R. Keeney. “Methods of soil analysis, Part 2: Chemical and microbiological properties”. 2nd Edition. Madison, Wisconsin: American Society of Agronomy and Soil Science Society of America, 1982.

[11] Marschner, H., Oberle, H., Cakmak, L. and Romheld, V. “Growth enhancement by silicon in cucumber (*cucumis sativus*) plants depends on imbalance in phosphorus and zinc supply”. Plant and Soil**, 124 (2):** 211-219, 1990.

[12] Mandal, L.N. and Mandal, B. “Transformation of Zinc fractions in rice soils”. *Soil Science,* **143 (3)**: 205-212, 1987.

[13] Mandal, B. and Mandal, L.N. “Effect of phosphorus application on transformation of Zinc fraction in soil and on the Zinc nutrition of lowland rice”. Plant and Soil, **121(1)**: 115-121. 1990.

[14] Banik, G.C. and Sanyal, S.K. A study on chromium-humic complexation; Part 2. Complexation equilibria of chromium-humic/fulvic complexes. *J. Indian Soc. Soil Sci.* **54 (2):** 170-173, 2006.

Table 1. Effect of Zn, vermicompost (VC) and P application on the extractable phosphorus (mg kg^{-1}) in soil in 15 and 30 days incubation

Zn level	VC level	15 Days P level				30 Days P level			
		P_0	P_{50}	P_{100}	**Mean**	P_0	P_{50}	P_{100}	**Mean**
Zn_0	VC_0	42.5	84.1	146.3	**91.0**	44.8	92.6	157.8	**98.4**
	VC_1	45.3	82.5	156.4	**94.7**	42.6	96.3	168.9	**102.6**
	Mean	**43.9**	**83.3**	**151.4**		**43.7**	**94.5**	**163.4**	
Zn_5	VC_0	35.8	78.4	133.4	**82.5**	40.2	85.6	146.8	**90.9**
	VC_1	32.7	75.2	126.8	**78.2**	45.8	78.9	152.3	**92.3**
	Mean	**34.3**	**76.8**	**130.1**		**43.0**	**82.3**	**149.6**	
Zn_{10}	VC_0	32.5	65.8	132.8	**77.0**	28.9	65.2	156.2	**83.4**
	VC_1	38.7	72.5	106.6	**72.6**	32.5	78.6	189.5	**100.2**
	Mean	**35.6**	**69.2**	**119.7**		**30.7**	**71.9**	**172.9**	
LSD (P = 0.05)		Zn:0.55 Zn×P:0.76 VC: 0.62 Zn: ×VC: 0.54 P: 0.61 VC×P: 0.38 Zn×VC×P:0.85				Zn:0.64 Zn×P:0.81 VC: 0.34 Zn: ×VC.: 0.44 P: 0.40 VC×P: 0.81 Zn×VC×P:0.93			

Where, Zn Level: Zn_o= without zinc, Zn_5 = 5 mg kg^{-1} zinc and Zn_{10} = 10 mg kg^{-1} zinc

P level: P_o = without P, P_{50}= 50 mg P Kg^{-1} of soil and P_{100} = 100 mg P Kg^{-1} of soil

Vermicompost level: VC_0 = without vermicompost and VC_1 = 1% vermicompost by weight of soil

Table 2. Effect of Zn, vermicompost and P application on the available Zn (mg kg^{-1}) in soil in 15 and 30 days incubation

Zn level / VC level		Period of Incubation							
		15 Days P level				30 Days P level			
		P_0	P_{50}	P_{100}	**Mean**	P_0	P_{50}	P_{100}	**Mean**
Zn_0	VC_0	0.37	0.43	0.98	**0.59**	0.79	0.19	0.17	**0.38**
	VC_1	0.33	0.05	0.95	**0.44**	0.10	0.13	0.16	**0.13**
	Mean	**0.35**	**0.24**	**0.97**		**0.45**	**0.16**	**0.17**	
Zn_5	VC_0	3.36	4.27	2.38	**3.34**	3.39	3.23	4.68	**3.77**
	VC_1	3.23	2.60	2.35	**2.73**	4.38	3.59	2.40	**3.46**
	Mean	**3.30**	**3.44**	**2.37**		**3.89**	**3.41**	**3.54**	
Zn_{10}	VC_0	8.38	4.95	4.27	**5.87**	8.65	7.98	6.75	**7.79**
	VC_1	5.36	5.16	5.53	**5.35**	5.88	6.88	6.99	**6.58**
	Mean	**6.9**	**5.1**	**4.9**		**7.27**	**7.43**	**6.87**	
LSD (P = 0.05)		Zn:0.062 Zn×P:0.078 VC: 0.062 Zn: ×VC: 0.078 P: 0.062 VC×P: 0.078 Zn×VC×P:0.079				Zn:0.064 Zn×P:0.081 VC: 0.064 Zn: ×VC: 0.081 P: 0.064 VC×P: 0.081 Zn×VC×P:0.089			

Where, Zn Level: Zn_o= without zinc, Zn_5 = 5 mg kg^{-1} zinc and Zn_{10} = 10 mg kg^{-1} zinc
P level: P_o = without P, P_{50}= 50 mg P Kg^{-1} of soil and P_{100} = 100 mg P Kg^{-1} of soil
Vermicompost level: VC_0 = without vermicompost and VC_1 = 1% vermicompost by weight of soil

Table 3. Stepwise multiple regressions showing the effect of different doses of Zn, P and vermicompost addition on the phosphorus availability

Multiple regression equation	R^2	Percent individual contribution
$Y= 0.0.683 + 0.623 X_1$	0.532	53.2
$Y= 0.654 + 0.623 X_1-0.762X_2$	0.657	12.5
$Y = 0.772 + 0.623 X_1-0.762X_2+ 0.291X_3$	0.714	5.7
$Y = 0.621 + 0.623 X_1-0.762X_2+ 0.291X_3+ 0.732X_4$	0.779	6.5

Y = extractable phosphorus; X_1 = phosphorus addition; X_2= zinc addition; X_3 = vermicompost addition; X_4 = Days of incubation

Table 4. Stepwise multiple regressions showing the effect of different doses of Zn, P and vermicompost addition on the available zinc

Multiple regression equation	R^2	Percent individual contribution
$Y= 0.0.683 + 0.623 X_1$	0.648	64.8
$Y= 0.654 + 0.623 X_1-0.0.762X_2$	0.785	13.7
$Y = 0.772 + 0.623 X_1-0.0.762X_2+ 0.291X_3$	0.862	7.7
$Y = 0.621 + 0.623 X_1-0.0.762X_2+ 0.291X_3+ 0.732X_4$	0.891	2.9

Y = zinc; X_1 = zinc addition; X_2 = phosphorus addition; X_3 = vermicompost addition; X_4 = Days of incubation