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ZINC-PHOSPHOROUS INTERACTION IN PRESENCE OF VERMICOMPOST ON RICE GROWN IN AN ACID SOIL OF COOCH BEHAR, WEST BENGAL, INDIA

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ABSTRACT

The interactive effect of zinc and phosphorus in presence of vermicompost was investigated in laboratory incubation study and green house experiment growing rice. The incubation study taking graded doses of Zn, P and vermicompost showed that Zn reduced P extractability of soil (mean P content was reduced from 77.43 mg kg^{-1} in control to 61.9 mg kg^{-1} in soils with 10 mg kg^{-1} added Zn and no vermicompost in 15 days of incubation period) and *vice-versa*. The vermicompost increased availability of P but decreased DTPA extractable Zn in soil. Incubation period increased P as well as Zn extractability in soil. Green house experiment revealed that the addition of Zn reduced P content in all the plant parts of rice at harvest and *vice-versa*. This negative effect of Zn in P uptake was reduced by the addition of vermicompost. The higher accumulation of P ranging from 7.22 to 9.67 mg kg^{-1} and 10.16 to 10.63 mg kg^{-1} was observed in rice grains without and with application of vermicompost, respectively. The combined addition of P, Zn and vermicompost increased the yield of rice. Study suggests the improvement of Zn and P nutrition along with yield of rice by addition of vermicompost.

KEY WORDS
Phosphorous- zinc interaction
Acid soil
Rice
Zinc-vermicompost interaction

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INTRODUCTION

Rice is the main staple food for the Indian subcontinent and also for the South-Eastern Asian countries. India is the second largest producer of rice after china covering 44.01 million ha land with 105.30 million tons production and an average productivity of 23.93 q ha^{-1} (Meena *et al*., 2015). Zinc (Zn) and Phosphorus (P) both are essential for the yield of rice.

Among the micronutrients, zinc is the most limiting nutrient whose deficiency is a wide spread nutritional disorder of wetland rice (Oryza sativa L.) causing *khoira* disease. Zinc deficiency in rice appears right from seedling stage in nursery and three weeks after transplanting in transplanted plots. Zn is essential for several biochemical processes in rice plant, such as chlorophyll production, auxin metabolism, cytochrome and nucleotide synthesis, enzyme activation etc. (Jat *et al*., 2008).

In India 50% of soil is zinc deficient (Suvarna *et al*., 2015). The major Zn deficiency was found in the places like Madras, Ranchi, Maharasthra, Punjub, Ajmer, Paramour, Jalandhar, Ahmedabad and Bashri (Roychaudhuri and Datta, 1964). In West Bengal, out of seventeen districts, fourteen districts including Darjeeling, Jalpaiguri, Cooch Behar, Bankura, Purulia etc. have deficiency in zinc. Zinc deficiency was also found in extremely leached acidic light soils of *terai* agro-ecological region of West Bengal and this may be attributed to higher content of Fe-P and complex Zn-P formation. In Cooch Behar district 49.88 % soils samples were deficient in Zn out of 1560 soil samples analyzed (Das, 2008).

Phosphorus is the most important element which interferes on zinc uptake by plants and this was confirmed by a number of studies that excessive accumulation of phosphorus causes zinc deficiency in plants (Khorgamy and Farnia, 2009; Salimpour *et al*., 2010). The antagonism between phosphorus-zinc is observed mainly when both nutrients are deficient.

Nearly 98 per cent of the soils in India are in need of phosphorus for better crop productivity (Hasan, 1996). Phosphorus and zinc deficiencies are widespread nutritional constraint on crop production in many parts of the world particularly in acid soils of India. Wagar *et al*. (1986) stated that although yield was increased significantly by P and Zn application but Zn uptake was reduced at higher dose of P.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. Thus may reduce down the antagonistic relationship between zinc and phosphorus. The vermicompost is one of the most widely used organic in the study area.

Realizing the above facts, the present investigation was undertaken to examine the zinc-phosphorus interaction on availability of both nutrients in presence of one organic namely vermicompost in the acidic soils of *terai* region deficient in both zinc and phosphorus.

MATERIALS AND METHODS

The soil used in the experiment was collected from the surface layer (0-15 cm) from teaching and instructional farm, Uttar Banga krishi Viswavidyalaya at Pundibari, District- Cooch Behar of West Bengal, India. The collected soils were air dried in shade, grounded with a wooden pestle and mortar and passed through a 2 mm nylon sieve. 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 as described by Jackson (1967) and Page *et al.* (1982) and those were as follows: pH (1:2.5) 5.6, organic carbon 0.28%, water holding capacity 48.2%, CEC [6.10 Cmol $(P^+)Kg^{-1}$], clay 13.14%, texture silty loam, available P 10.3 mg kg^{-1}, DTPA-extractable Zn 0.145 mg kg^{-1}, and Fe_2O_3 2.6% . The taxonomic classification of this soil belongs to Typic Fluvaquents.

Laboratory incubation Study

30 gm soil sample was taken in a number of each incubation tube and was incubated at 30ºC 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 30ºC ± 2ºC. 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 (Page *et al.,* 1982) and was measured with atomic absorption spectrophotometer (PerkinElmer AAnalyst 200).

Green house experiment with rice

The pot-culture experiment was designed taking rice (var. *Annada*) as the crop. Six kg soil sample was filled in each earthen pot having 30 cm height and 25 cm diameter. The soil of each pot was mixed properly without and with vermicompost @ 1% by weight of soil and different dose of phosphorus @ 0, 50, and 100 mg P kg^{-1} of soil in the form of KH_2PO_4 and different dose of zinc @ 0, 5, 10 mg Zn kg^{-1} of soil in the form of $ZnSO_4$, $7H_2O$ were applied in the pot soil (same treatment combinations as in the incubation study). The potassium was applied in recommended dose in the form of muriate of potash as basal taking into consideration the amount of K added through KH_2PO_4 used as P source. The nitrogen was applied in the form of urea. The treatments were replicated thrice. The soils in the pots were irrigated with double distilled water periodically to maintain the moist soil condition. The plant samples were collected at maturity. The roots were collected from plant and as well as from soil and was thoroughly washed with tap water. The roots and above ground plant parts (*i.e.,* shoots and grains) were then dried in air followed by oven drying at 60ºC. These were then powdered and digested with tri-acid mixture (HNO_3:H_2SO_4:$HClO_4$ = 10:1:4). The P and Zn content in the digested samples were measured using standard analytical procedures. The plant extractable P and Zn content of the soils at the harvest of rice crop was also measured. The data obtained was analyzed using three factor factorial randomized block design by INDOSTATE statistical package.

RESULTS AND DISCUSSION

Findings from the laboratory incubation studies

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 28.4 mg kg^{-1} (in control, *i.e.,* $P_0Zn_0VC_0$) to 21.8 mg kg^{-1} and 17.5 mg kg^{-1} with dose of zinc @ 5 mg kg^{-1} and 10

Table 1: Effect of zinc (Zn), vermicompost (VC) and phosphorus (P) application on the Bray and Kurtz No. 1– extractable phosphorus (mg kg^{-1}) in soil in 15 and 30 days incubation

Zn level*	VC level*	Period of Incubation 15 Days (P level) P_0	P_{50}	P_{100}	Mean	30 Days (P level) P_0	P_{50}	P_{100}	Mean
Zn_0	VC_0	28.4	68.5	135.4	77.43	34.6	72.7	138.6	81.97
	VC_1	30.1	72.6	141.2	81.30	35.9	75.2	144.9	85.33
	Mean	29.25	70.55	138.3		35.25	147.9	283.5	
Zn_5	VC_0	21.8	61.5	112.9	65.4	25.6	65.9	132.5	74.67
	VC_1	27.9	63.2	146.8	79.3	27.5	65.9	139.7	77.70
	Mean	24.85	62.35	129.85		26.55	65.9	136.1	
Zn_{10}	VC_0	17.5	55.8	112.4	61.9	21.6	60.5	132.6	71.57
	VC_1	14.8	56.5	115.6	62.3	22.8	61.5	120.5	68.27
	Mean	16.15	56.15	114		22.2	61	126.55	
LSD (P = 0.05)	Zn:0.53 Zn×P:0.92VC: 0.62 Zn×VC: 0.52P: 0.85 VC×P: 0.24Zn×VC×P:0.68					Zn:0.78 Zn×P:0.83VC: 0.64 Zn: ×VC: 0.32P: 0.22 VC×P: 0.41Zn×VC×P:0.46			

Where, Zn Level: Zn_o = without zinc, Zn_5 = 5 mg Zn kg^{-1} zinc and Zn_{10} = 10 mg Zn 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 zinc (Zn), vermicompost (VC) and phosphorus (P) application on the DTPA- extractable Zn (mg kg^{-1}) in soil in 15 and 30 days incubation

Zn level*	VC level*	15 Days		Period of Incubation			30 Days		
		P level				P level			
		P_0	P_{50}	P_{100}	Mean	P_0	P_{50}	P_{100}	Mean
Zn_0	VC_0	1.0	0.78	0.19	0.65	0.9	0.3	1.1	0.76
	VC_1	0.21	0.28	0.24	0.24	0.1	0.2	0.4	0.53
	Mean	0.60	0.53	0.21		0.5	0.25	0.7	
Zn_5	VC_0	2.17	2.62	2.09	2.29	3.4	2.7	2.3	2.8
	VC_1	2.23	2.25	1.42	1.96	4.5	3.0	2.6	3.36
	Mean	2.2	1.93	2.19		3.7	2.85	2.45	
Zn_{10}	VC_0	6.79	6.25	5.35	6.13	6.4	6.3	7.0	6.56
	VC_1	7.88	4.65	5.42	5.98	6.2	6.8	6.2	6.4
	Mean	7.33	5.45	5.38		6.3	6.5	6.6	
LSD (P = 0.05)		Zn:0.62 Zn×P:0.78VC: 0.58 Zn×VC: 0.55P: 0.27 VC×P: 0.18Zn×VC×P:0.79				Zn:0.64 Zn×P:0.82VC: 0.32 Zn×VC: 0.61P: 0.22 VC×P: 0.41Zn×VC×P:0.86			

Table 3: Stepwise multiple regressions showing the effect of different doses of zinc, phosphorus and vermicompost addition on the Bray and Kurtz No-1 extractable phosphorus of the experimental soils in the incubation studies

Multiple regression equation	R^2	Percent individual contribution
$Y = 0.725 + 0.417 X$	0.641	64.1
$_{1}Y = 0.528 + 0.417X_1 - 0.853X_2$	0.724	8.3
$Y = 0.631 + 0.417X_1 - 0.853X_2 + 0.341X_3$	0.772	4.8
$Y = 0.502 + 0.417X_1 - 0.853X_2 + 0.341X_3 + 0.324X_4$	0.817	4.5

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 zinc, phosphorus and vermicompost addition on the DTPA extractable zinc of the experimental soils in the incubation studies

Multiple regression equation	R^2	Percent individual contribution
$Y = 0.832 + 0.317 X$	0.532	53.2
$_{1}Y = 0.651 + 0.317 X_1 - 0.687X_2$	0.774	24.2
$Y = 0.667 + 0.317 X_1 - 0.687X_2 + 0.472X_3$	0.816	4.2
$Y = 0.665 + 0.317 X_1 - 0.687X_2 + 0.472X_3 + 0.324X_4$	0.852	3.6

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

Table 5: Phosphorus content (mg kg^{-1}) in the root of the rice plant at harvest under the influence of different doses of phosphorus, zinc and vermicompost in pot-culture study

Zn level*	VC level*		P level		
		P_0	P_{50}	P_{100}	Mean
Zn_0	VC_0	2.04	3.41	4.49	3.31
	VC_1	3.57	3.59	4.75	3.97
	Mean	2.80	3.50	4.62	
Zn_5	VC_0	3.46	2.60	3.22	3.09
	VC_1	2.88	4.66	2.35	3.29
	Mean	3.17	3.63	2.78	
Zn_{10}	VC_0	1.21	2.76	3.41	2.46
	VC_1	1.46	4.46	4.06	3.32
	Mean	1.33	3.61	3.73	
LSD(P = 0.05)			P: 1.25, Zn: 0.92, VC: 0.69P×Zn : 0.97, P×VC: 0.44, Zn×VC:0.87P×Zn×VC: 1.12		

mg kg^{-1} with without vermicompost and phosphorus application in 15 days of incubation. This had also same trend in case of 30 days of 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 as reported by Marschner *et al.* (1990). 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 (Mandal and Mandal, 1987) particularly for the dissolution of iron oxides and release of phosphates that adsorbed on iron oxides. In control treatment combination available P increased from 28.4 mg kg^{-1} to 34.6 mg kg^{-1} with the increment of incubation period from 15 to 30 days. The

Table 6 : Phosphorus content (mg kg-1) in the grain of the rice plant at harvest under the influence of different doses of phosphorus, zinc and vermicompost in pot-culture study

Zn level*	VC level*	P level			
		P_0	P_{50}	P_{100}	Mean
Zn_0	VC_0	7.78	7.79	8.47	8.01
	VC_1	9.90	9.38	11.26	10.18
	Mean	8.84	8.58	9.86	
Zn_5	VC_0	8.78	9.06	11.18	9.67
	VC_1	10.44	12.04	9.41	10.63
	Mean	9.61	10.55	10.29	
Zn_{10}	VC_0	5.78	8.91	6.97	7.22
	VC_1	10.25	9.35	10.9	10.16
	Mean	8.01	9.13	8.93	
LSD(P = 0.05)		P: 2.21, Zn: 1.28, VC : 0.54P×Zn : 1.44, P×VC: 0.18, Zn×VC:0.62P×Zn×VC: 2.63			

Table 7: Zinc content (mg kg-1) in the root of the rice plant at harvest under the influence of different doses of phosphorus, zinc and vermicompost in pot-culture study

Zn level*	VC level*	P level			
		P_0	P_{50}	P_{100}	Mean
Zn_0	VC_0	4.16	3.83	3.66	3.88
	VC_1	5.07	4.0	3.94	4.33
	Mean	4.61	3.91	3.8	
Zn_5	VC_0	3.26	5.42	5.03	4.57
	VC_1	7.29	4.22	3.8	5.10
	Mean	5.27	4.82	4.41	
Zn_{10}	VC_0	5.62	4.45	1.58	3.88
	VC_1	4.96	3.94	3.96	4.28
	Mean	5.29	4.19	2.77	
LSD(P = 0.05)		P: 0.76, Zn: 1.52, VC : 02.12P×Zn : 1.86, P×VC: 0.15, Zn×VC:1.39P×Zn×VC:2.63			

Table 8: Zinc content (mg kg-1) in the grain of the rice plant at harvest under the influence of different doses of phosphorus, zinc and vermicompost in pot-culture study

Zn level*	VC level*	P level			
		P_0	P_{50}	P_{100}	Mean
Zn_0	VC_0	0.37	0.83	0.74	0.64
	VC_1	1.30	0.81	0.63	0.91
	Mean	0.83	0.82	0.68	
Zn_5	VC_0	0.43	0.72	0.59	0.58
	VC_1	0.61	0.68	0.45	0.58
	Mean	0.52	0.70	0.52	
Zn_{10}	VC_0	0.74	0.79	0.46	0.66
	VC_1	0.61	0.63	0.52	0.58
	Mean	0.67	0.71	0.49	
LSD(P = 0.05)		P: 1.25, Zn: 0.92, VC : 0.69P×Zn : 0.97, P×VC: 0.44, Zn×VC:0.87P×Zn×VC: 1.12			

data also revealed that Bray and Kurtz No. 1 extractable phosphorus content increased markedly with the increase of P application in all the cases.

The application of vermicompost increased the availability of the P in all treatment combinations. The increment of P with the application of the vermicompost may be due to the release of some amount of available P from this organic manure itself as well as may also be attributed to the formation vermicompost-Zn complex which hinders the formation of the Zn-P compounds by decreasing the availability of Zn to P which is normally responsible for the less availability of P in Zn containing acid soils. 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 more decomposition of organics with the longer incubation period.

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). In most of the cases the longer incubation period increased the extractability of Zn where the vermicompost and P were not applied. This may due to desorption of Zn from the once-sorbed Zn absorbing sites of clay surfaces with time under wet soil condition. 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 (Mandal and Mandal, 1990). 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

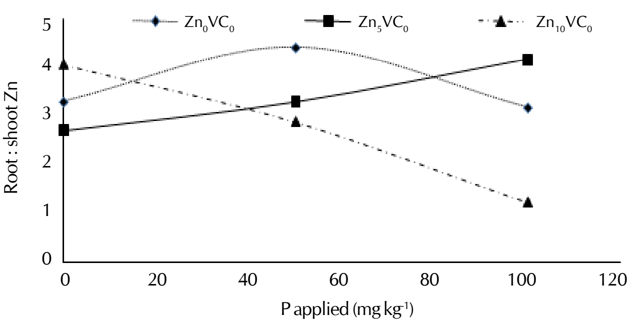

Figure 1: Effect of P application on the ratio of Zn concentration in rice, root and shoot

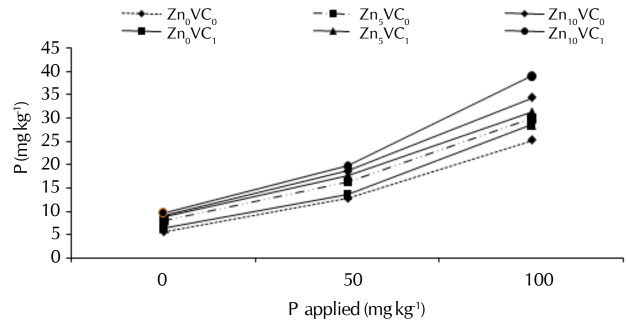

Figure4 : Effect of Zn and vermicompost on the residual P content of pot soil

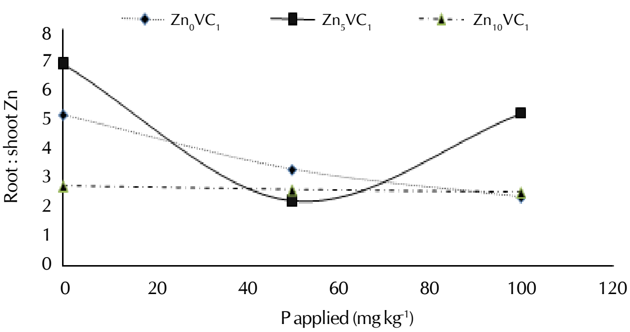

Figure 2: Effect of P application on the ratio of Zn concentration in rice, root and shoot

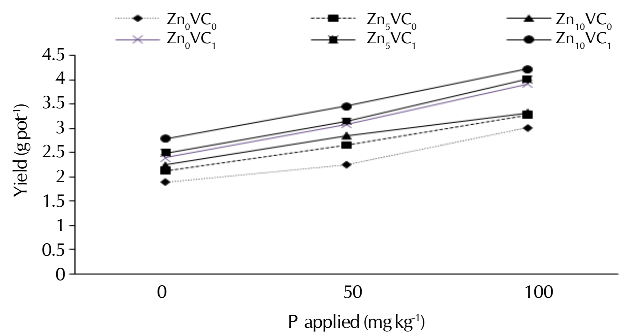

Figure 5: Effect of P, Zn and vermicompost on yield of rice

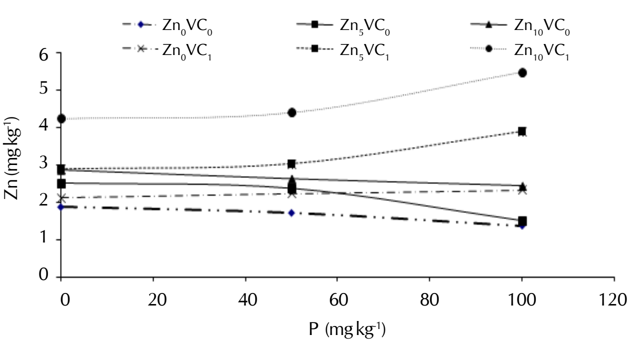

Figure 3: Effect of P and vermicompost on the residual Zn content of pot

of high stability and lower solubility (Mortvedt *et al.,* 1972; Banik and Sanyal, 2006). 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 these soils may due to the formation organo-metal complexes of high stability and lower solubility (Banik and Sanyal 2006). 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*.

Findings from the green house experiment

Phosphorus content in different plant parts in pot culture

The P content increased markedly with the increase of the P application in the root of the rice plant. Total P content increased from 2.04 to 3.41 and 4.49 mg kg^{-1} with the addition of P @ 0, 50 and 100 mg kg^{-1} in the roots where Zn and vermicompost were not applied (Table 5). The addition of Zn reduced the P content in root of the plant. The increase dose of Zn application from 0 to 10 mg kg^{-1} reduced the P uptake by rice roots from 4.49 to 3.41 mg kg^{-1}where the vermicompost was not added and P applied @ 100 mg kg^{-1}. Similar negative interaction between Zn and P was also obtained by other several workers (Haldar and Mandal, 1981; Mandal and Mandal, 1990; Bandara *et al.*, 2004). This negative effect of Zn in P uptake by plant was reduced by the addition of vermicompost as because manure may had formed complex with the applied Zn which has reduced the mobility of Zn thereby reducing the chance of formation of sparingly soluble Zn-P compounds. Moreover the addition of vermicompost increased the P uptake by rice roots in almost all treatment combinations. This may due to the inherent P content in vermicompost itself as well as the increased mobility of P due to presence of organic matter. The edible part of rice *i. e.,* grain was observed (Table 6) to be more accumulator of P than root and shoot may possibly for the greater translocation of P in plant body (Das 2008). In grain also similar results were noticed as in root. The addition of P increased the P content whereas Zn application significantly reduced the P content in all treatments. Although, the grain of rice was observed to be more accumulator of phosphorus than the root irrespective of the treatment combinations may due to the lower mobility of P in plant.

Zinc content in different plant parts in pot culture

The Zn content in roots shows that it also had the negative effect with P application in the soil (Table 7). The increase in the phosphorus content progressively reduced the Zn content in root. More the P was added Zn was decreased more. The Zn content obviously increased with the increased doses of Zn application in pot. The addition of vermicompost further increased the Zn content in rice roots. The mean Zn content increased from 3.88 to 4.33, 4.57 to 5.10 and 3.88 to 4.28 mg kg^{-1} with the addition of vermicompost @ 1% by weight of soil in the pots which received Zn @ 0, 5 and 10 mg kg^{-1}, respectively. In grain, the Zn content increased with the addition of Zn as fertilizer (Table 8). The addition of P decreased the Zn content in grain also. Whereas the addition of vermicompost further increased the Zn content in grain.

The ratio of Zn concentration in roots and shoots (Fig. 1) decreased progressively with the increase in the levels of P application at the lower and higher Zn concentration *i.e.*, at 0 and 10 mg Zn kg^{-1} of soil which suggest that P application favorably affected translocation of Zn from root to shoot. The value of such ration decreased with increasing Zn application, which indicates that Zn × P interaction in roots may be overcome to some extent with higher levels of Zn application. There was little deviations in this observation where vermicompost was applied (Fig. 2) suggesting the ameliorative power of organics in antagonistic effect of zinc and phosphorus. Similar result was observed by Mandal and Mandal (1990). Thus the application of manures may increase the uptake of both the nutrients under study by rice. Figure 3 represents the Zn content in pot soil after the harvest of rice. The soil Zn content after harvest increased to some extent with the addition of P may because it forms sparingly soluble Zn-P complexes in soil. The addition of vermicompost further increased the Zn content in soil. This may attribute to the formation of Zn-organic chelates as well as Zn-P compounds in soil so that Zn may be bounded in the soil. The residual phosphorus content in pot soil after the harvest of rice increased with the addition of vermicompost and Zn both (Fig. 4). This may attributed to the release of some phosphorus by mineralization through decomposition of the organic manure, vermicompost, during the crop growth period and formation of less soluble Zn-P complexes in soil which hinders the P from losses from soil.

Effect of phosphorus, zinc and vermicompost on the yield of rice in pot culture

The yield was observed to be progressively increased with addition of P addition @ 50 and 100 mg kg^{-1} over control (Fig. 5). The zinc also helped to increase the yield of rice. The effect of Zn on yield was more from in the addition of Zn @ 5 mg kg^{-1} over control than 10 mg kg^{-1} over 5 mg kg^{-1}. Similar increase of rice yield with zinc was also reported by Rahaman *et al.* (2011). The vermicompost addition was also helpful to increase the yield. The increase of yield with addition of phosphorus coupled with bio-organic sources was also reported by Meena *et al.* (2015). The results obtained in the pot culture study strongly conformed the findings observed in the laboratory incubation studies. The application of phosphorus reduced the uptake of Zn by plant. The addition of vermicompost increased the p uptake by rice but reduced the Zn uptake by rice. This inverse relationship between Zn concentration in plants and level of P application in soil was also observed by Mandal and Mandal (1990).

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