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Interaction between P and Zn on the Changes in Different Inorganic Phosphorus Fractions under Waterlogged Soil Treated with and Without Organic Matter

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ABSTRACT

Background: Phosphorus and zinc are two essential nutrients which are required for normal plant growth. These nutrients are mutually antagonistic in certain circumstances which can cause yield reductions in many crops due to either P or Zn deficiencies. Organic matter causes soil to clump and form soil aggregates, which improves soil structure. With better soil structure, permeability improves, in turn improving the soil's ability to take up and hold water. 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, the present study was undertaken to find the interaction between P and Zn on the changes in different inorganic phosphorus fractions under waterlogged soil treated with and without organic matter.

Methods: An incubation experiment has been conducted in the laboratory of Department of Agricultural Chemistry and Soil Science, University of Calcutta to find the interaction between P and Zn on the changes in different phosphorus fractions under waterlogged soil treated with and without organic matter. Treatments details: P_0Zn_0 - No Phosphorus + No Zn, P_0Zn_1 - No Phosphorus + Application of Zn at 2.5 mg/kg soil, P_0Zn_2 - No Phosphorus + Application of Zn at 5 mg/kg soil , P_1Zn_0 - Application of P at 10 mg/kg soil + No Zn, P_1Zn_1 - Application of P at 10 mg/kg soil + Application of Zn at 2.5 mg/kg soil,P_1Zn_2 - Application of P at 10 mg/kg soil + Application of Zn at 5 mg/kg soil, P_2Zn_0 - Application of P at 15 mg/kg soil + No Zn, P_2Zn_1 - Application of P at 15 mg/kg soil + Application of Zn at 2.5 mg/kg soil, P_2Zn_2 - Application of P at 15 mg/kg soil + Application of Zn at 5 mg/kg soil. The same treatment combination was studied with application of organic matter where organic matter was applied @1% by soil weight basis and another set of treatment combination were conducted in absence of organic matter. After application of all treatments, maintaining waterlogged condition, the soils were allowed to incubate at room temperature (30±2)°C for a period of 10, 20, 30, 40, 50 days interval and analyzed for different fractions of P.

Result: The amount of Soluble and Loosely bound P fractions has been recorded highest (47.50 mg kg^{-1}) in the treatment P_2OM_2 at 30 days of incubation in presence of organic matter. As regards to the interaction effect between P and organic matter it was observed that the amount of Al-P was recorded enhanced, being highest with their highest level of application. The individual application of P increased the amount of Fe-P content, being highest (56.96 mg kg^{-1}) at 30 days of incubation with its highest level, while the application of organic matter at its highest level recorded highest amount of Fe-P (55.30 mg kg^{-1}) content. The absolute amount of Reductant soluble P was recorded a lower value than Fe-P. The results suggest that Ca-P fraction was the dominant inorganic P fraction among other fractions and there is a synergistic effect was found between P and organic matter where there is an antagonistic effect found between P and Zn.

Key words: Interactions, Organic matter, Phosphorus fractions, Waterlogged, Zinc.

INTRODUCTION

Interaction can be defined as the influence of an element upon another in relation to growth and crop yield. There are mainly two types of interactions effect viz. antagonistic and synergistic effects. Antagonistic effect means an increase in concentration of any nutrient element will decrease the activity of another nutrient (negative effect). While synergistic effects means an increase of concentration of any one nutrient element will influence the activity of another nutrient element (Positive effect). Nutrient antagonism occurs when an excess of a particular element blocks the absorption of another element the plant needs and can happen with elements of a similar size and charge (positive or negative) (Bhardwaj *et al*., 2019). Phosphorus and zinc are two essential nutrients which are required for normal plant

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growth. These nutrients are mutually antagonistic in certain circumstances which can cause yield reductions in many crops due to either P or Zn deficiencies. Deficiencies typically happen when a nutrient is available in small amounts. In this phenomenon, the nutrient is present in marginal to normal levels but the antagonizing nutrient is available in such a large amount that it induces the deficiency of the other. The Zn induced P deficiency is a very rare phenomenon because growers commonly apply large amounts of P fertilizer as compared to Zn fertilizer. Organic matter causes soil to clump and form soil aggregates, which improves soil structure. With better soil structure, permeability (infiltration of water through the soil) improves, in turn improving the soil's ability to take up and hold water. 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 (Banik and Samat 2016). The FYM is one of the most widely used organic in the study area. Thus, the present study was undertaken to find the interaction between P and Zn on the changes in different inorganic phosphorus fractions under waterlogged soil treated with and without organic matter.

MATERIALS AND METHODS

An incubation experiment has been conducted in the laboratory of Department of Agricultural Chemistry and Soil Science, University of Calcutta to find the interaction between P and Zn on the changes in P content under waterlogged soil treated with and without organic matter. For this experiment, the surface soil was collected (0-15 cm depth) from the cultivated field of Baruipur Experimental Farm of University. Before analysis, the soil was air dried ground and passed through 2mm sieve. The surface soil samples were analyzed for various soil properties such as pH and EC (Jackson, 1973), organic carbon (Walkley and Black, 1934), Cation exchange capacity (Harada and Inoko, 1980) and available P_2O_5 by Olsen's method (Olsen *et al.*, 1954) Available K_2O by Flame photometric method (Jackson, 1973), Available N by modified Kjeldahl's method (Jackson, 1973). The physico-chemical properties of the soil were: pH 6.46, EC: 0.05 dSm^{-1}; Organic Carbon: 6.5 g kg^{-1}; CEC: 15.76 cmol (p+) kg^{-1}; Available N: 0.2508 g kg^{-1}; Available P by Olsen method : 0.0153 g kg^{-1}; Available K: 0.29008 g kg^{-1}; Available Zn: 0.00055 g kg^{-1}. In this present investigation, the source of P used was Potassium dihydrogen phosphate (22% P_2O_5) and the source of organic matter was Farm Yard Manure (FYM) in which Total N content was 9.6g kg^{-1}, Total P content was 6.5 g kg^{-1}, Total K content was 10.2 g kg^{-1} and Total Zn content was 1.5 g kg^{-1}. After application of all treatments, maintaining waterlogged condition, the soils were allowed to incubate at room temperature (30±2)°C for a period of 10, 20, 30, 40, 50 days interval and analyzed for different fractions of P by following the procedure of Kuo, (1996).

Details of experiments

Moisture regime: Waterlogged.

Replication: Three.

Design: 2 Factor Factorial CRD.

Treatments details

P_0Zn_0 - No Phosphorus + No Zn.
P_0Zn_1 - No Phosphorus + Application of Zn at 2.5 mg/kg soil.
P_0Zn_2 - No Phosphorus + Application of Zn at 5 mg/kg soil.
P_1Zn_0 - Application of P at 10 mg/kg soil + No Zn.
P_1Zn_1 - Application of P at 10 mg/kg soil + Application of Zn at 2.5 mg/kg soil.
P_1Zn_2 - Application of P at 10 mg/kg soil + Application of Zn at 5 mg/kg soil.
P_2Zn_0 - Application of P at 15 mg/kg soil + No Zn.
P_2Zn_1 - Application of P at 15 mg/kg soil + Application of Zn at 2.5 mg/kg soil.
P_2Zn_2 - Application of P at 15 mg/kg soil + Application of Zn at 5 mg/kg soil.

Under this experiment, organic matter has been applied @ 1% by weight of the soil in one set of all treatments and another set of all treatment have been conducted without organic matter.

RESULTS AND DISCUSSION

The results (Table 1a, 2a, 3a, 4a and 5a) show that the pattern of changes in the amount of loosely bound P, Al-P, Fe-P, Reductant soluble P and Ca-P fractions under waterlogged soil without amended with organic matter showed a consistent decrease in the amount throughout the incubation period. This lowering of phosphorus content with the application of zinc may be attributed to the antagonistic interaction of P and Zn. Due to absence of organic matter, no counter effect of decreasing trend was observed with respect to each P fraction. The data also revealed that all inorganic fraction of phosphorus content increased markedly with the increase of P application in all the cases where zinc was not applied and showed the lowest value of loosely bound P, Al-P, Fe-P, RS-P and Ca-P where zinc and phosphorus were applied at their highest doses.

The results (Table 1b) show that the amount of loosely bound P due to organic matter application under waterlogged condition showed a consistent decrease throughout the period of incubation irrespective of treatments with the exception of slight increase at 20 days period of incubation, being varied with different treatment combination. Mandal *et al*. (1973) reported that the application of organic matter increased the release of added P which confirms the results of present investigation. The decrease of loosely bound P due to individual application of both P and Zn varied and followed a similar trend to that of loosely bound P, being showed a significantly lower amount of this fraction at the later period when Zn was applied, while relatively greater amount was recorded with treatment when P was applied at its increasing level which is obvious in presence of organic matter under waterlogged condition. As regards to the interaction between P and Zn in presence of organic matter, it was observed that although the amount decreases but at a slower rate which might explained by counter effect of added organic matter restricting the antagonistic effect between P and Zn (Das, 2018). Das *et al*. (2005) also reported similarly who showed that the amount of available P increased initially and decreased at the later period. The results (Table 2b) reveal that the amount of Al-P fraction showed a slight initial increase and thereafter the amount of the same decreased consistently throughout the incubation period irrespective of treatments in presence of organic matter. However, the amount varied with treatments. The individual application of both P and Zn and their combinations although increased initially but at the later period of incubation, the amount of Al-P fraction showed a consistent decrease. However, the magnitude of such decrease has been found to be much higher in the treatment where higher level of Zn (5 mg kg^{-1}) was applied compared to individual application of P at its higher level (15 mg kg^{-1}). Comparing the results of their interaction effects, it was found that the amount of such decrease was much less which might be attributed to the counteracting the negative effect of P × Zn interaction in presence of organic matter. The results of the present investigation also find support from the findings of Patel *et al*. (1992) who reported that the application of graded doses of P significantly increased various fractions of P including Al-P fraction. The application of organic matter at 2.5 and 5 per cent significantly increased the content of occluded P and Olsen's P. The results (Table 3b) reveal that the amount of Fe-P fraction showed a slight initial increase and thereafter, the amount of the same decreased consistently throughout the incubation period irrespective of treatments in presence of organic matter. However, the

Table 1a: Interaction between P and Zn on the periodic changes in Loosely bound P (mg kg^{-1}) content under waterlogged soil treated without organic matter.

Treatments	Days after incubation					Mean	% Over control
	10	20	30	40	50		
P_0Zn_0	13.25	14.02	13.88	12.25	11.50	12.98	
P_0Zn_1	12.56	12.38	12.10	11.28	10.86	11.84	-8.81
P_0Zn_2	12.80	12.16	11.48	11.28	10.90	11.72	-9.68
P_1Zn_0	14.48	14.28	13.86	12.80	12.25	13.53	4.27
P_1Zn_1	12.88	12.38	12.10	11.65	11.18	12.04	-7.26
P_1Zn_2	11.60	11.26	11.02	10.98	10.18	11.01	-15.19
P_2Zn_0	16.58	15.08	14.98	14.26	13.98	14.98	15.38
P_2Zn_1	15.75	14.55	13.80	13.28	12.54	13.98	7.73
P_2Zn_2	13.45	12.65	11.80	11.26	10.97	12.03	-7.35
Mean	13.71	13.20	12.78	12.12	11.60	12.68	
LSD (0.05)							
P	0.048	0.027	0.051	0.039	0.042		
Zn	0.048	0.027	0.051	0.039	0.042		
P × Zn	0.080	0.048	0.089	0.068	0.071		

Table 1b: Interaction between P and Zn on the periodic changes in Loosely bound P (mg kg^{-1}) content under waterlogged soil amended with organic matter.

Treatments	Days after incubation					Mean	% Over control
	10	20	30	40	50		
P_0Zn_0	15.25	16.02	15.88	14.25	12.50	14.78	
P_0Zn_1	13.96	14.58	14.10	13.28	11.86	13.56	-8.28
P_0Zn_2	13.10	13.96	13.48	12.98	12.50	13.20	-10.66
P_1Zn_0	17.48	19.98	17.86	16.80	15.85	17.59	19.04
P_1Zn_1	14.88	17.08	16.46	16.25	14.98	15.93	7.78
P_1Zn_2	14.60	16.96	17.02	15.98	14.28	15.77	6.68
P_2Zn_0	22.58	23.08	22.98	21.66	21.10	22.28	50.74
P_2Zn_1	19.75	19.15	18.96	17.88	17.24	18.60	25.82
P_2Zn_2	18.85	18.05	17.98	16.96	16.67	17.70	19.77
Mean	16.72	17.65	17.19	16.23	15.22	16.60	
LSD (0.05)							
P	0.039	0.039	0.024	0.024	0.030		
Zn	0.039	0.039	0.024	0.024	0.030		
P × Zn	0.068	0.065	0.059	0.042	0.053		

Table 2a: Interaction between P and Zn on the periodic changes in Al-P (mg kg^{-1}) content under waterlogged soil treated without organic matter.

Treatments	Days after incubation					Mean	% Over
	10	20	30	40	50		control
P_0Zn_0	18.25	19.02	18.88	17.25	16.50	17.98	
P_0Zn_1	17.96	17.18	16.80	16.28	15.86	16.82	-6.47
P_0Zn_2	17.60	17.16	16.48	16.28	15.40	16.58	-7.76
P_1Zn_0	19.48	18.98	18.16	17.88	17.25	18.35	2.06
P_1Zn_1	17.88	16.68	16.10	15.85	15.18	16.34	-9.13
P_1Zn_2	16.60	15.96	15.02	14.68	14.28	15.31	-14.86
P_2Zn_0	23.58	22.98	22.28	21.66	20.70	22.24	23.69
P_2Zn_1	20.75	20.25	20.10	19.88	19.24	20.04	11.48
P_2Zn_2	18.95	17.65	17.10	16.96	16.17	17.37	-3.41
Mean	19.01	18.43	17.88	17.41	16.73	17.89	
LSD (0.05)							
P	0.048	0.030	0.042	0.042	0.042		
Zn	0.048	0.030	0.042	0.042	0.042		
P × Zn	0.083	0.053	0.071	0.071	0.071		

Table 2b: Interaction between P and Zn on the periodic changes in Al-P (mg kg^{-1}) content under waterlogged soil treated with organic matter.

Treatments	Days after incubation					Mean	% Over
	10	20	30	40	50		control
P_0Zn_0	19.25	20.02	19.88	18.25	16.50	18.78	
P_0Zn_1	17.36	18.58	18.10	17.28	15.86	17.44	-7.16
P_0Zn_2	17.10	17.96	17.48	16.98	16.50	17.20	-8.39
P_1Zn_0	21.48	23.98	21.86	20.82	19.95	21.62	15.11
P_1Zn_1	18.78	21.08	20.46	20.25	18.98	19.91	6.02
P_1Zn_2	18.60	20.96	21.02	19.98	17.68	19.65	4.62
P_2Zn_0	26.58	27.08	26.68	25.66	25.10	26.22	39.62
P_2Zn_1	23.75	23.15	22.86	21.88	21.24	22.58	20.21
P_2Zn_2	22.85	22.05	21.98	20.96	20.57	21.68	15.45
Mean	20.64	21.65	21.15	20.23	19.15	20.56	
LSD (0.05)							
P	0.033	0.033	0.027	0.027	0.042		
Zn	0.033	0.033	0.027	0.027	0.042		
P × Zn	0.053	0.056	0.048	0.048	0.071		

Table 3a: Interaction between P and Zn on the periodic changes in Fe-P (mg kg^{-1}) content under waterlogged soil treated without organic matter.

Treatments	Days after incubation					Mean	% Over
	10	20	30	40	50		control
P_0Zn_0	38.85	38.02	37.88	37.15	36.50	37.68	
P_0Zn_1	37.96	37.88	37.10	36.28	35.86	37.02	-1.76
P_0Zn_2	37.90	37.26	36.48	36.28	35.40	36.66	-2.70
P_1Zn_0	39.98	39.02	38.86	37.80	37.15	38.56	2.34
P_1Zn_1	37.88	36.68	36.10	35.25	35.18	36.22	-3.88
P_1Zn_2	36.60	35.96	35.02	34.78	34.18	35.31	-6.30
P_2Zn_0	33.58	34.08	33.98	32.66	31.70	33.20	-11.89
P_2Zn_1	31.75	30.55	30.10	29.28	28.64	30.06	-20.21
P_2Zn_2	28.95	28.35	27.10	26.66	25.96	27.40	-27.27
Mean	35.94	35.31	34.74	34.02	33.40	34.68	
LSD (0.05)							
P	0.033	0.027	0.059	0.048	0.045		
Zn	0.033	0.027	0.059	0.048	0.045		
P × Zn	0.056	0.048	0.059	0.080	0.077		

amount varied with treatments. The individual application of both P and Zn and their combinations although increased initially, but at the later period of incubation, the amount of Fe-P fraction showed a consistent decrease. However, magnitude of such decrease has been found to be much higher in the treatment when higher level of Zn (5 mg kg^{-1}) was applied compared to individual application of P at its higher level (15 mg kg^{-1}). Such initial increase might be explained by the added effect of organic matter which contributes P in the soil solution. Comparing the results of their interaction effects, it was found that the amount of such decrease was much less which might be attributed to the presence of organic matter counteracting the negative effect of P X Zn interaction. Agrawal *et al*. (1987) reported that Fe-P showed the highest increase over control among other fractions. The results (Table 4b and Table 5b) show that the trend of changes in the amount of reductant soluble P and Ca-P fractions showed a similar pattern to that of Fe-P fraction. But the absolute amounts of those fractions were varied with other fractions. The absolute amount of reductant soluble P was lower than that of both Fe-P and Ca-P fractions in presence of organic matter. The results also show that Ca-P fraction was the dominant inorganic phosphorus fraction which can play a major role for P nutrition of rice in addition to Fe-P and Al-P fractions. Sihag *et al*. (2005) reported that the amount of P recovered in Ca-P form increased significantly with the application of organic matter over control.

Table 3b: Interaction between P and Zn on the periodic changes in Fe-P (mg kg^{-1}) content under waterlogged soil treated with organic matter.

Treatments	Days after incubation					Mean	% Over control
	10	20	30	40	50		
P_0Zn_0	22.25	23.02	22.88	21.25	19.50	21.78	
P_0Zn_1	20.36	21.58	21.10	20.28	18.86	20.44	-6.17
P_0Zn_2	19.10	19.96	19.48	18.98	18.50	19.20	-11.83
P_1Zn_0	24.48	26.98	24.86	23.82	22.95	24.62	13.03
P_1Zn_1	21.78	24.08	23.46	23.25	21.98	22.91	5.19
P_1Zn_2	21.60	23.96	24.02	22.98	20.28	22.57	3.62
P_2Zn_0	29.58	30.08	29.68	28.66	28.10	29.22	34.16
P_2Zn_1	26.75	26.15	25.86	24.48	24.84	25.62	17.61
P_2Zn_2	25.85	25.05	24.98	23.96	23.17	24.60	12.96
Mean	23.53	24.54	24.04	23.07	22.02	23.44	
LSD (0.05)							
P	0.033	0.030	0.039	0.033	0.045		
Zn	0.033	0.030	0.039	0.033	0.045		
P × Zn	0.056	0.051	0.065	0.053	0.077		

Table 4a: Interaction between P and Zn on the periodic changes in Reductant soluble P (mg kg^{-1}) content under waterlogged soil treated without organic matter.

Treatments	Days after incubation					Mean	% Over control
	10	20	30	40	50		
P_0Zn_0	38.25	37.80	37.28	36.25	35.50	37.02	
P_0Zn_1	39.96	38.58	37.70	37.28	36.86	38.08	2.86
P_0Zn_2	43.55	43.60	43.10	41.28	40.20	42.35	14.40
P_1Zn_0	44.48	44.08	43.86	42.80	41.85	43.41	17.28
P_1Zn_1	40.88	40.18	39.70	38.75	37.18	39.34	6.27
P_1Zn_2	41.60	40.96	40.02	39.48	38.28	40.07	8.25
P_2Zn_0	45.58	44.08	43.98	43.26	42.40	43.86	18.49
P_2Zn_1	36.95	36.45	35.10	34.88	34.24	35.52	-4.03
P_2Zn_2	34.95	34.15	33.10	32.96	31.87	33.41	-9.75
Mean	40.69	39.99	39.32	38.55	37.60	39.23	
LSD (0.05)							
P	0.030	0.051	0.042	0.039	0.065		
Zn	0.030	0.051	0.042	0.039	0.065		
P × Zn	0.051	0.089	0.074	0.065	0.116		

Table 4b: Interaction between P and Zn on the periodic changes in Reductant soluble P (mg kg^{-1}) content under waterlogged soil treated with organic matter.

Treatments	Days after incubation					Mean	% Over control
	10	20	30	40	50		
P_0Zn_0	18.95	19.48	19.08	18.45	17.80	18.75	
P_0Zn_1	19.16	19.88	18.60	18.38	17.96	18.80	0.23
P_0Zn_2	17.10	17.96	17.48	16.98	16.50	17.20	-8.26
P_1Zn_0	22.48	23.98	22.86	21.82	20.95	22.42	19.55
P_1Zn_1	20.78	22.08	21.46	21.25	19.98	21.11	12.57
P_1Zn_2	19.60	21.96	22.02	20.98	18.88	20.69	10.32
P_2Zn_0	26.58	27.08	26.68	25.66	25.10	26.22	39.82
P_2Zn_1	24.75	24.15	23.86	22.88	22.24	23.58	25.73
P_2Zn_2	23.85	23.05	22.98	21.96	21.57	22.68	20.96
Mean	21.47	22.18	21.67	20.93	20.11	21.27	
LSD (0.05)							
P	0.027	0.030	0.050	0.042	0.045		
Zn	0.027	0.030	0.050	0.042	0.045		
P × Zn	0.044	0.051	0.086	0.071	0.077		

Table 5a: Interaction between P and Zn on the periodic changes in Ca-P (mg kg^{-1}) content under waterlogged soil treated without organic matter.

Treatments	Days after incubation					Mean	% Over control
	10	20	30	40	50		
P_0Zn_0	53.9 5	53.02	52.88	52.25	51.50	41.93	
P_0Zn_1	52.96	51.88	51.10	50.98	50.26	51.44	22.67
P_0Zn_2	51.10	50.96	50.28	49.98	48.96	50.26	19.86
P_1Zn_0	48.48	47.98	47.26	46.50	46.25	47.29	12.79
P_1Zn_1	46.88	45.88	45.10	44.95	44.18	45.40	8.27
P_1Zn_2	45.60	44.96	43.98	43.48	42.28	44.06	5.08
P_2Zn_0	43.58	42.08	41.98	40.66	40.00	41.66	-0.64
P_2Zn_1	39.75	38.55	38.10	37.68	36.24	38.06	-9.22
P_2Zn_2	37.95	36.65	36.10	35.96	35.27	36.39	-13.22
Mean	40.70	45.77	45.20	44.72	43.88	44.05	
LSD (0.05)							
P	0.036	0.033	0.045	0.051	0.036		
Zn	0.036	0.033	0.045	0.051	0.036		
P × Zn	0.059	0.056	0.077	0.089	0.065		

Table 5b: Interaction between P and Zn on the periodic changes in Ca-P (mg kg^{-1}) content under waterlogged soil treated with organic matter.

Treatments	Days after incubation					Mean	% Over control
	10	20	30	40	50		
P_0Zn_0	42.25	43.02	42.88	41.25	39.50	18.75	
P_0Zn_1	40.36	41.58	41.10	40.28	38.86	18.80	0.23
P_0Zn_2	39.10	39.96	39.48	38.98	38.50	17.20	-8.26
P_1Zn_0	44.48	46.98	44.86	43.82	42.95	22.42	19.55
P_1Zn_1	41.78	44.08	43.46	43.25	41.18	21.11	12.57
P_1Zn_2	41.60	43.96	42.02	41.98	40.28	20.69	10.32
P_2Zn_0	41.58	40.68	39.68	38.56	38.10	26.22	39.83
P_2Zn_1	40.75	39.15	38.96	38.28	37.84	23.58	25.73
P_2Zn_2	39.85	38.05	37.98	37.26	36.85	22.68	20.96
Mean	21.47	22.18	21.67	20.93	20.11	21.27	
LSD (0.05)							
P	0.033	0.030	0.086	0.039	0.051		
Zn	0.033	0.030	0.086	0.039	0.051		
P × Zn	0.056	0.051	0.149	0.068	0.089		

CONCLUSION

These results clearly demonstrated that the antagonistic effect of phosphorus and zinc is prevailed in soil which affects the mobility of both nutrients in soil-plant systems. The addition of organic matter can decrease this antagonism, to some extent, between these elements may by forming complexes with both. Significant positive interaction between phosphorus and organic matter (P×FYM) was also noted. The results also show that Ca-P fraction was the dominant inorganic phosphorus fraction which can play a major role for P nutrition of rice in addition to Fe-P and Al-P fractions.

Conflict of interest: None.

REFERENCES

Agrawal, S., Singh, T.A. and Bhardwaj, V. (1987). Inorganic soil phosphorus fractions and available phosphorus as affected by long term fertilization and cropping patteren in Nainital tarai. Journal of the Indian Society of Soil Science. 35: 25-28.

Banik, G.C. and Samat, S. (2016). Effect of phosphorus and vermicompost on zinc availability in an acidic lateritic soil of West Bengal, India. International Journal of Science, Environment and Technoogy. 5(4): 1903-1911.

Bhardwaj, G., Sharma, U. and Brar, P.S. (2019). A review on interactive effects of phosphorus, zinc and mycorrhiza in soil and plant, International Journal of Current Microbiology and Applied Sciences. 8(4): 2525-2530.

Das, D.K. (2018). In: Introductory Soil Science. 4th edition revised and enlarged. Kalyani publishers, New Delhi.

Das, K., Dang, R., Shivananda, T.N. and Sur, P. (2005). Interaction effect between phosphorus and zinc on their availability in soil in relation to their contents in stevia (*Stevia rebaudiana*). The Scientific World Journal. 5: 490-495.

Harada, Y. and Inoko, A. (1980). The measurement of cation exchange capacity of compost for the estimation of the degree of maturity. Soil Science and Plant Nutrition. 26: 127-134.

Jackson, M.L. (1973). Methods of soil chemical analysis. Prentice Hall of India Pvt. Ltd., New Delhi.

Kuo, S. (1996). Phosphorus. In: Methods of Soil Analysis: Chemical Methods. [Sparks, D.l. (ed.)], Part 3.SSSA No.5.ASA-CS SA-SSSA, Madison, WI. PP. 869-919.

Mandal, L.N. and Mandal, K.C. (1973). Influence of organic matter and lime on the transformation of applied phosphate in acidic lowland rice soils. Journal of the Indian Society of Soil Science. 21(1): 57-62.

Olsen, S.R., Cole, C.V., Watanabe, F.S. and Dean, L.A. (1954). Estimation of available phosphorus in soil by extraction with $NaHCO_3$, USDA and Circ. 3: 19-33.

Patel, M.S., Patil, R.G., Zalawadia, N.M. and Sutaria, G.S. (1992). Effect of phosphorus, moisture and organic matter on phosphorus availability and its fractions in calcareous clay soil at different incubation periods. Journal of the Indian Society of Soil Science. 40: 705-710.

Sihag, D., Singh, J.P., Mehla, D.S. and Bhardwaj, K.K. (2005). Effect of integrated use of inorganic fertilizers and organic materials on the distribution of different forms of nitrogen and phosphorus in soil. Journal of the Indian Society of Soil Science. 53(1): 80-84.

Walkley, A.J. and Black, I.A. (1934). Estimation of soil organic carbon by the chromic acid titration method. Soil Sciences. 37: 29-38.