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Short Communication

Phosphorus and Zinc Availability in Alkali Soils as Influenced by Application of Graded Levels of Gypsum

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Alkali soils occupy an area of 13.47 lakh hectares in Uttar Pradesh (Singh *et al.* 2010). These soils occurring in the Indo-Gangetic alluvial plains are highly dispersed in nature due to the presence of excess exchangeable sodium (Na^+) on the exchange complex. There is a stretch of low laying tract extending to the sub-humid parts of eastern Uttar Pradesh comprising the districts of Azamgarh, Mau and western part of Ballia where waterlogging conditions prevail. In low-laying areas water gets accumulated during wet season and as a result of evaporation soil solution becomes concentrated and sodium adsorption ratio (SAR) of water increases. This results in increased exchangeable sodium percentage (ESP) and high pH, causing nutritional imbalances and low levels of soil organic matter (SOM). The high Na content of soils also leads to dispersion of fine clay particles resulting into low permeability, crusting and hardening of the surface soil upon drying.

Phosphorus (P) exists in soils in both inorganic and organic forms. Inorganic P exists as primary and secondary P minerals. The primary P minerals such as apatites, strengite and variscite are quite stable and release the available P very slowly. Unlike primary minerals, secondary P minerals such as phosphates of calcium (Ca-P), iron (Fe-P) and aluminium (Al-P) are easily weatherable (Pierzynski *et al.* 2005; Oelkers and Valsami-Jones 2008). The solubility and dissolution rates of secondary P minerals depend largely upon pH.

Availability of P becomes low due to the precipitation as Ca-P in calcareous soil (Lindsay *et al.* 1989), or its adsorption on the surfaces of calcium carbonate (Larsen 1967) and clay minerals (Devau *et al.* 2010). Phosphate can precipitate with Ca, generating dicalcium phosphate (DCP) that is available to plants. As the pH increases, DCP becomes more stable and forms stable Ca-P compounds such as octocalcium phosphate and hydroxyapatite (Arai and Sparks 2007). Clay minerals and Fe or Al oxides provide large number of P adsorption sites because they have large specific surface areas. The occurrence of Zn deficiency is frequently observed in soils having high pH, alkalinity, free calcium carbonate, coarse texture and low organic matter contents (Katyal and Randhawa 1983). Availability of zinc (Zn) for plant uptake or movement down the soil profile depends on a range of soil properties.

The principle behind reclamation of alkali soil is to replace exchangeable Na^+ on soil complex by another cation Ca^{2+}. Among the calcium compounds, gypsum is considered as the best and cheapest for reclamation point of view. The gypsum requirement (GR) is calculated as the amount of gypsum needed for reclaimnation of the soil. The desired level of quantitative replacement of exchangeable Na^+ from the soil by Ca^{2+} is possible for calculating the doses of gypsum needed to reclaim a particular alkali soil. Application of gypsum reduces the pH and ESP, and increases exchangeable Ca^{2+} and Mg^{2+} in alkali soils (Patel and Singh 1991). The work on GR for release of P and Zn is lacking in alkali soils of eastern part of Uttar Pradesh. The objective of this incubation study was to assess the availability of P and Zn in alkali soils as influenced by application of graded levels of gypsum.

The bulk surface soil samples (0-15 cm) were collected from three alkali soils in the Azamgarh, Ballia and Mau districts of eastern part of Uttar Pradesh. The samples were air-dried and passed through 2-mm sieve. The release pattern of available P and Zn in soils was studied in an incubation experiments conducted during October, 2016 at the Institute of Agricultural Sciences, BHU, Varanasi. The

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experiment was laid out in a completely randomized design with three replications. Treatments consisted of three alkali soils amended with six levels of gypsum requirement (0, 25% GR, 50% GR, 75% GR and 100% GR). The GR of soils was determined as outlined by Schoonover (1952).

Two hundred seventy plastic bottles of 100 mL capacity each were used for the incubation study and filled with 50 g of processed air-dry soil. A known amount of gypsum for each level was mixed thoroughly into the soil. Moisture content in the soils was maintained at field capacity (20%, w/w) by addition of distilled water as and when required. The bottles were sealed tightly and incubated for 15, 30, 45, 60, 75 and 90 days at room temperature. After each incubation period, the samples were air-dried, ground and analyzed for available P and Zn contents.

Soil pH and electrical conductivity (EC) were determined in 1:2.5 (soil: water) suspension as described by Jackson (1973). Soil texture was determined by Bouyoucos hydrometer (Bouyoucos 1962). Water holding capacity (WHC) was measured by using Keen's box (Black 1965). Organic carbon (OC) was determined by wet oxidation method of Walkley and Black (1934). Available P in soil (pH>7.5) was extracted with 0.5 *M* $NaHCO_3$ at pH 8.5 (Olsen *et al*. 1954) and P content in the extract was determined by ascorbic acid method (Watanabe and Olsen 1965). The available Zn was extracted by using DTPA extract (0.005 *M* diethylene triamine penta acetic acid and 0.01 *M* $CaCl_2$ + 0.1 *N* triethanolamine at pH 7.3) in the ratio of 1:2. The concentration of available Zn in extracts was measured using atomic absorption spectrophotometer as outlined by Lindsay and Norvell (1978). Initial available P contents of untreated alkali soils of Azamgarh, Ballia and Mau were 3.87, 8.03 and 17.9 mg kg^{-1}, respectively. While available Zn contents of soils of Azamgarh, Ballia and Mau were 0.24, 0.41 and 0.38 mg kg^{-1}, respectively. The physicochemical properties of the soils used in the present study are presented in table 1. The data obtained from the incubation period of three different locations was subjected to statistical analysis as described by Gomez and Gomez (1984).

Application of graded level of GR in all three alkali soils increased the release of available P during incubation period over control (Table 2). Highest release of available P was obtained with 25% GR at 15 days after incubation (DAI) in alkali soil from Mau (59.5 mg kg^{-1}) followed by Ballia (54.0 mg kg^{-1}) and Azamgarh (53.1 mg kg^{-1}). The magnitude of release of available P decreased from 30 to 90 DAI at all levels of the GR in all three soils. Increase in the levels of GR decreased the release of available P during entire incubation period from 15 to 90 DAI in all three alkali soils.

The higher rate of release of available P in initial 45 days was due to solubilization of P bound by the colloidal complexes by reduction reaction that would have been released to the labile pool and made it available. The mineralization of organic P might also contribute to the pool of available P. The lower availability of P at the later phase (60 to 90 DAI)

Table 1. Physicochemical properties of three alkali soils collected from different districts of Uttar Pradesh used for the incubation study

Properties	District		
	Azamgarh	Ballia	Mau
Textural class	Sandy clay loam	Sandy clay loam	Clay loam
Bulk density (Mg m^{-3})	1.32	1.27	1.25
Water holding capacity (%, w/w)	31.0	25.9	28.8
pH (1:2 soil:water)	9.14	9.64	8.87
EC (dS m^{-1}) (1:2 soil:water)	0.06	0.08	0.04
Organic carbon (g kg^{-1})	5.80	6.60	4.10
Carbonate content (%)	0.24	0.33	0.15
Bicarbonate content (%)	1.28	1.95	0.37
Chloride content (mg $100g^{-1}$ soil)	35.5	63.9	17.8
Exchangeable Ca^{2+} (me $100g^{-1}$ soil)	5.12	4.16	4.64
Exchangeable Mg^{2+} (me $100g^{-1}$ soil)	5.12	4.32	5.92
Exchangeable Na^{+} (me $100g^{-1}$ soil)	42.0	53.0	36.0
SAR	18.6	25.6	15.7
Gypsum requirement (t ha^{-1})	9.78	12.2	5.50
Available P (mg kg^{-1})	3.87	8.03	17.9
Available Zn (mg kg^{-1})	0.24	0.41	0.38

Table 2. Periodic changes in available P (mg kg^{-1}) as affected by different levels of gypsum requirement in three alkali soils

Gypsum requirement (GR) (%)	Incubation period (Days)						
	15	30	45	60	75	90	Mean
				Azamgarh			
Control	11.1	10.1	12.1	9.17	8.41	7.00	9.65
25	53.1	48.7	26.8	18.9	18.4	17.6	30.6
50	47.5	46.8	24.6	14.4	17.9	12.4	27.3
75	45.3	41.5	24.9	13.7	17.8	12.0	25.6
100	44.5	41.3	23.4	12.8	16.6	7.90	24.4
Mean	40.3	37.2	22.4	13.8	15.8	11.4	
LSD (P=0.05)	9.7	5.81	5.00	4.46	4.34	2.33	
				Ballia			
Control	11.3	11.9	10.26	9.35	8.07	7.47	9.72
25	54.0	49.8	27.3	21.9	17.5	12.6	30.5
50	42.1	44.8	26.1	21.3	16.4	12.9	27.3
75	39.9	43.4	26.0	15.4	14.2	11.9	25.1
100	33.4	42.1	22.4	13.9	12.4	11.2	22.6
Mean	36.1	35.4	22.4	16.4	12.2	11.4	
LSD (P=0.05)	4.2	9.78	6.68	4.71	3.58	2.12	
				Mau			
Control	12.54	11.22	9.14	8.70	10.39	8.81	10.13
25	59.52	58.22	31.09	21.27	18.13	15.95	34.03
50	57.70	51.73	22.12	15.91	14.53	13.82	29.30
75	43.60	45.25	16.71	14.91	13.63	13.36	24.58
100	49.91	43.03	15.47	13.90	13.23	13.21	24.79
Mean	44.65	41.89	18.90	14.94	14.12	13.03	
LSD (P=0.05)	8.44	6.71	2.80	3.49	3.55	6.02	

could be attributed to formation of insoluble phosphate compounds (Fe-P, Al-P and Ca-P) (Kumaraswamy and Sreeramulu 1992) and immobilization of soluble P by soil microbial activities. Gypsum supplies a considerable amount of Ca to the soil, which increased with an increase in the amount of gypsum level. The reaction of Ca with P results into the formation of a crystalline basic calcium phosphate causing decrease in labile phosphate content (Larsen *et al*. 1965). Moore and Miller (1994) also indicated that P solubility might be reduced in the presence of gypsum by enhanced Ca-P precipitation in the form of Ca-phosphate.

Available Zn content decreased with advancement of incubation period up to 45 DAI in all three alkali soils and then increased at 60, 75 and 90 DAI with added GR level from 25 to 100% (Table 3). The similar trend in release of available Zn was recorded throughout the incubation period in non-amended control soil. The increase of available Zn was more in alkali soil of Ballia followed by Mau and Azamgarh. The OC was higher in Ballia. This could possibly be due the fact that decomposition of organic matter, gives rise to certain chelating agents which contribute towards greater availability of Zn in soil. The least release of available Zn was obtained at 45 DAI in all three alkali soils amended with 25% to 100% GR.

The decreased availability of Zn after 15 DAI may be attributed to antagonistic P-Zn interaction. The release of available P was enhanced significantly by application of gypsum at 15 DAI. This high level of soil available P may decrease Zn availability due to the dilution effect, widely termed as P-induced Zn deficiency (Cakmak and Marschner 1987). Mousavi (2011) has also stated the negative interaction between soil Zn and P, suggesting enhanced P utilization reduced the Zn absorption capacity.

The release of available Zn increased at 45 DAI. This increase in the Zn availability may be attributed to the lowered availability of P during the same period of incubation. Application of gypsum decreased the soil pH and thus enhanced the availability of soil Zn (Takkar and Singh 1978). This increase in the availability of Zn may also be attributed to the increased availability of SO_4^{2-}-S which in turn modifies the soil reaction and causes the dissolution of Zn-containing minerals (Lindsay 1979).

From the above results it is concluded that release of available P increased up to 15 DAI and then declined at 30 to 90 DAI in all three alkali soils. On the other hand, release of available Zn decreased

Table 3. Periodic changes in available Zn (mg kg^{-1}) as affected by different levels of gypsum requirement in three alkali soils

Gypsum requirement (GR) (%)	Incubation period (Days)						
	15	30	45	60	75	90	Mean
				Azamgarh			
Control	0.21	0.21	0.21	0.26	0.30	0.30	0.24
25	0.22	0.21	0.20	0.28	0.32	0.32	0.25
50	0.26	0.20	0.20	0.26	0.28	0.30	0.25
75	0.28	0.24	0.22	0.30	0.30	0.32	0.27
100	0.32	0.30	0.28	0.36	0.40	0.42	0.35
Mean	0.28	0.25	0.24	0.29	0.32	0.33	
LSD (P=0.05)	0.02	0.04	0.05	0.03	0.06	0.05	
				Ballia			
Control	0.40	0.38	0.32	0.40	0.43	0.46	0.39
25	0.52	0.40	0.38	0.32	0.62	0.62	0.46
50	0.58	0.40	0.36	0.40	0.66	0.66	0.51
75	0.80	0.50	0.34	0.38	0.56	0.56	0.52
100	0.86	0.82	0.48	0.60	0.72	0.72	0.70
Mean	0.66	0.54	0.37	0.40	0.60	0.60	
LSD (P=0.05)	0.04	0.04	0.07	0.03	0.04	0.03	
				Mau			
Control	0.38	0.36	0.32	0.42	0.42	0.42	0.38
25	0.54	0.36	0.26	0.36	0.38	0.54	0.41
50	0.56	0.34	0.20	0.28	0.34	0.38	0.34
75	0.58	0.30	0.20	0.28	0.42	0.46	0.35
100	0.60	0.36	0.22	0.24	0.28	0.36	0.31
Mean	0.53	0.35	0.26	0.32	0.37	0.43	
LSD (P=0.05)	0.04	0.03	0.03	0.03	0.04	0.04	

during initial 45 DAI and it increased thereafter from 60 to 90 DAI. Gypsum application at 25 to 50% of GR and 75 to 100% GR can be helpful in increasing the availability of native P and Zn, respectively in alkali soils of eastern part of Uttar Pradesh.

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