



VARIATION IN SOIL PARENT MATERIALS AT VARIOUS STAGES OF DEVELOPMENT AND PHOSPHORUS IN CROPS

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ABSTRACT

The aims of this study were to determine the inorganic P fractions in chosen parent material soils and to build a link between the different P fractions and Zeamays's P absorption capacity. Samples were gathered from the surface and subsurface of three separate loess, alluvium, shale residuum, and sandstone residuum samples that were chosen at three different levels of development in each of the four soil types. pH, soil test P, total P, CaCO₃, dissolved and total organic carbon, dithionite extractable iron, and amorphous iron were all determined in the samples tested. Calcium 2-P, calcium 8-P, P adsorbed by Fe and Al, P occluded in iron oxide bodies, apatite-P were all identified in the soil P fractionation experiments. P was found in apatite in concentrations ranging from 33 to 71%, and secondary phosphates, such as occluded P, iron oxides surface adsorbed P, and aluminum oxides surfaces adsorbed P, were found in concentrations ranging from 0.8 to 4 percent, 2.6 to 14 percent, and 1.2 to 5 percent of total P, respectively. The absorption of phosphorus varied greatly depending on the soil parent material. The investigation of phosphatase enzyme activity in relation to P fractions, soil parent material, and plant growth was very valuable in determining which P pools are more accessible to plants, as well as the role of phosphatase in restricting P availability to plants.

Keywords: Aluminum Oxides, Phosphorus Fractions, Phosphatase Enzyme, Alluvium

INTRODUCTION

Chemical forms of phosphorus (P) assist understand P dynamics in soil. Soil solution P is a readily available supply of nutrients for agricultural plants. Maintaining the level of phosphorus in soil solution is accomplished by desorption and dissolution of solid-phase inorganic phosphorus and mineralization of soil organic components, such as nucleic acids



and phospholipids, to soluble P. Various phosphate minerals are formed when inorganic P forms combine with calcium, iron, and aluminium to produce phosphate minerals.

Inorganic P forms are also adsorbed on the surfaces of iron and aluminium oxides. Organic and inorganic P fractions may play a critical role in the availability of P to plants depending on the soil type. Olsen P is an extensively used method for determining the bioavailability of phosphorus and the connection between different P forms. Olsen P demonstrates that NaHCO_3 removes all of the water-soluble phosphorus as well as a little portion of the phosphorus bound to the surfaces of clay, organic materials, and iron and aluminium oxides, among other things. Unlike Olsen P, which is extracted using NaHCO_3 , which is unable of extracting P from goethite crystals that are occluded in their fringes, plant roots have the capacity to collect occluded P under severe P deficient conditions. Instead of Olsen P, it is possible that the link between P uptake and P fractions is a better explanation for phosphorus bioavailability. In order to better understand the behaviour of soil P and its bioavailability, it is necessary to fractionate the soil phosphorus.

For diverse soil types, a variety of sequential extraction strategies are available, each with its own advantages and disadvantages. "The P sequential extraction technique for calcareous soils was developed by Jiang and Gu, who also separated the Ca-bound P into three different fractions, called $\text{Ca}_2\text{-P}$, $\text{Ca}_8\text{-P}$, and $\text{Ca}_{10}\text{-P}$, respectively." The $\text{Ca}_2\text{-P}$ represents the equivalents of the monocalcium phosphate $[\text{Ca}(\text{H}_2\text{PO}_4)_2]$ and dicalcium phosphate $(\text{CaHPO}_4 \cdot n\text{H}_2\text{O})$ ions. In chemical structure, the $\text{Ca}_8\text{-P}$ is related to an alkaline phosphate group that includes the compounds $\text{Ca}_8\text{H}_2(\text{PO}_4)_6 \cdot n\text{H}_2\text{O}$ and $\text{Ca}_8\text{H}_2(\text{PO}_4)_6 \cdot n\text{H}_2\text{O}$, both of which are less accessible to plants than the Ca_2 phosphate group. With the $\text{Ca}_{10}\text{-P}$, we're talking about a group of phosphates that have chemical structures comparable to apatite $[\text{Ca}_{10}(\text{PO}_4)_6(\text{OH})_2]$, but they release P when they're exposed to the elements.

Additional phosphorus fractions have been proposed in addition to the Ca-bound P pools, including phosphorus adsorbed on the surfaces of aluminium and iron oxides (Al-P and Fe-P, respectively) and phosphorus trapped inside iron oxide bodies (Occluded P). Four morphological units on Uttar Pradesh plateau host the majority of the region's soils. Different source rocks have contributed sediments to the region, and these sediments can be interpreted as different soil parent materials. As a result of the diverse source rocks and levels of development within parent material, the soil P fraction and fundamental soil



properties varies. Aluminum, iron, and calcium, which are secondary P minerals, have low solubility values and are very stable in their natural environments.

The distribution of phosphorus fractions in the soil and the availability of phosphorus for absorption and use by plants are connected to the uptake and utilisation of phosphorus by plants. Organic phosphorus and inorganic phosphorus are the two most abundant types of phosphorus in soil, and they have quite distinct characteristics and behaviours. Soil inorganic mineral phosphorus may be found in a variety of calcium, iron, and aluminium compounds with varying solubilities, as well as in phosphorus soil solution and phosphorus adsorbed on exchangeable sites in diverse forms. Bioavailable phosphorus in soil is soluble and exchangeable, indicating that it is readily accessible. The fractionation of phosphorus in the soil may be used to anticipate the changes of phosphorus bioavailability. It is possible to determine the distinct types of inorganic phosphorus that are more common in the soil via the use of chemical fractionation.

MATERIALS AND METHODS

Sampling and characterization of the soil Soils were chosen to represent a range of clay, CaCO_3 , and free Fe oxides contents that resulted from variations in the source of the parent material as well as weathering and degradation (Table 1). The soils were collected from four different parent materials that were found on the Uttar Pradesh. For each of the selected soils in the parent materials, triplicate surface and subsurface horizon samples were collected at distal locations and air dried before being crushed to pass through a 2 mm sieve, as previously described. Each sample was tested for “texture, pH, CaCO_3 , Olsen-P, sodium dithionite extractable iron and aluminium, total and dissolved organic carbon, and total and dissolved organic carbon in the water. The particle size distribution of soil paste was determined after it was dispersed in $(\text{NaPO}_3)_6$ and pH of saturated soil paste was measured.” The amount of calcium carbonate in the soil was determined by acetic acid (CH_3COOH) consumption. Phosphorus was extracted with 0.5 M sodium bicarbonate (NaHCO_3) solution pH 8.5 and measured colorimetrically for the Olsen test P using a colorimetric method. Using wet digestion in potassium dichromate ($\text{K}_2\text{Cr}_2\text{O}_7$), researchers were able to determine total organic carbon (TOC). Consumption of $\text{K}_2\text{Cr}_2\text{O}_7$ allowed researchers to determine the amount of dissolved organic carbon (DOC) in a solution using potassium sulphate (K_2SO_4). In a NaHCO_3 buffer solution, soil iron oxide was dissolved with



sodium dithionite ($\text{Na}_2\text{S}_2\text{O}_4$) and sodium citrate ($\text{C}_6\text{H}_5\text{Na}_3\text{O}_7$), and the solution was then filtered. Atomic absorption spectroscopy was used to determine the presence of iron and aluminium in the extract, which were expressed as Fed and Ald, respectively. A total of three stages of development were observed in soils collected from the districts of Uttar Pradesh, and they were formed from four different parent materials: loess (a type of loam), sandstone (a type of sandstone), shale (a type of shale), and alluvium.

Table 1. Selected soil series

Parent material	Soil series
Alluvium	Mau, Mirzapur, firozpur
Loess	Tundla, Sahibabad, Agra
Shale	Kanpur, Aligarh, Ghaziabad
Sandstone	Amethi, Amroha, Auraiya

Table 2. Extraction steps for the inorganic P fractions by Jiang and Gu

Step	Extraction procedure	Extracted P form (and notation)
One	gram soil added in 50 mL 0.25 M NaHCO_3 (pH 7.5) solution and shaken for 60 min.	Surface complex of P on calcite or discrete dicalcium phosphate ($\text{Ca}_2\text{-P}$)
Residue	washed twice with 95% alcohol, added 50 mL 0.5 M $\text{NH}_4\text{CH}_3\text{COO}$ (pH 4.2), left soaking for 4 h and shaken for 60 min.	Octacalcium phosphate ($\text{Ca}_8\text{-P}$)
Residue	washed twice with saturated NaCl, added 50 mL 0.5 M NH_4F , shaken (orbital) for 1 h	Amorphous aluminum P (Al-P)
Residue	washed twice with saturated NaCl, added 1:1 ratio of 0.1 M NaOH and 0.1 M Na_2CO_3 solution (pH 8.2), shaken for 160 min, left unshaken for 16 h and shaken again for 160min	P adsorbed on surface of iron oxides (Fe-P)
Residue	washed twice saturated with NaCl,	P incorporated, trapped into iron oxide



added 40 mL 0.3 N Na-citrate plus 1 g Na-dithionate and heating at 80°C for 15 min.	coatings, or amorphous iron oxide P (Occl-P)
Residue added with 50 mL 0.5 M H₂SO₄, and shake for 60 min.	Hydroxylapatite (Ca₁₀-P)

Table 3. Soil properties derived from different parent materials

PM	Soil Series	pH	Clay	CaCO ₃	Fe _d	TOC	Fe _o	DOC	Olsen-P
Alluvium	Mau,	7.7	19	13.9	10.5	3.1	0.3	39	4.2
	Mirzapur,	7.7	25	7.0	9	3.5	0.4	40	9.1
	firozpur	7.3	21	0.9	12.8	3.1	0.6	51	5.7
Loess	Tundla,	8	23	16.4	7.7	3.1	0.5	48	6.8
	Sahibabad,	7.2	23	0.9	9.4	4.4	0.9	63	8.6
	Agra	7.5	34	1.1	9.5	3.9	0.7	38	5.8
Shale	Kanpur,	7.3	31	14.8	16.4	9.7	0.7	72	9.2
	Aligarh,	7.4	34	11.75	17.3	3.2	0.3	41	3.2
	Ghaziabad	6.4	30	1	21.3	10.7	1.9	83	6.5
Sandstone	Am	7.6	13	9.5	4.8	2.9	0.3	39	4.1
	ethi,	7.6	26	1.6	7.9	4.5	0.5	79	4.2
	Amroha,	6.9	21	0.6	8.1	3.2	0.6	42	6.0
	Auraiya								

RESULTS AND DISCUSSION

The Fundamental Characteristics of Soils, as Well as the P Fractions that they Contained Several chemical features of the selected soils, including those that impact P absorption and the P fractions in the soil, were found to be extremely different (Table 3). The soils at a relatively “higher stage of development (Alfisols and Mollisols) were decalcified, had a low pH, and contained high levels of oxalate and dithionite extractable iron, whereas the soils at a relatively lower stage of development (Entisols) were calcareous, had a high pH, and



contained low levels of oxalate and dithionite extractable iron.” It was discovered that the extractable iron in the shale-derived soils was greater than in the surrounding soils because of the presence of lithogenic hematite. During the growth of the soil inside of the parent material, the quantity of total and dissolved organic carbon in the soil altered. “With levels ranging from 3.25 to 9.20 mg kg⁻¹ in soil test P (Olsen P), almost all of the soils examined were found to be deficient. When comparing parent materials, soil P fractions varied with soil development, with apatite-P accounting for the highest proportion of soil P, ranging from 33 to 71 percent of total P in certain cases.” Apatite-P levels decreased as soil formation progressed, although organic P levels increased. Loess and alluvium parent materials had a lower concentration of apatite P than shale and sandstone parent materials, suggesting that the concentration of apatite P decreased as soil formation progressed. The mineral apatite is the most abundant form of phosphorus (P) in many parent materials, especially during the early stages of soil development. Apatite concentrations decreased from 503 mg kg⁻¹ in the least weathered greywacke to 3 mg kg⁻¹ in the most weathered greywacke, according to the findings. When it came to unweathered greywacke (sandstone) and mica schist samples, practically all of the samples analysed had P in the form of apatite. It was discovered that apatite P made up 70 percent of the total P created on basalt in weathered soil and about 95 percent in less weathered soil when total P formed on basalt was measured. The decrease of apatite P in soil grown on loess toposequence with weathering has been observed.

The amount of P adsorbed on aluminium oxide surfaces varied between 1.2 and 5 percent of total P. A significant rise in secondary phosphates was seen in all parent materials, with the exception of iron oxides, as the soil development continued. Furthermore, organic phosphorus represented a large proportion of total phosphorus, accounting for anything between 20 and 49% of total phosphorus. Apatite is the principal phosphorus mineral in soils at the beginning of their development. As a soil grows, the primary P mineral diminishes and is replaced by other phosphorus forms, such as organic P and occluded P, which are created by both biotic and adaphic processes. Organic P reservoirs are generated when soluble P released from primary minerals is taken up by biota or turned into organic P reservoirs. Soluble P released from primary minerals is also adsorbed onto the surface of secondary minerals in soils, resulting in the formation of non-occluded P. Organic P



reservoirs are generated as a result of soluble P released from primary minerals being taken up by biota or changed into organic P reservoirs, and/or adsorbed onto the surface of secondary minerals in soils to form non-occluded P. Advanced weathering causes the aluminium and iron adsorbed P to gradually turn into occluded P, while the non-occluded P is physically confined or ringed by the iron and aluminium oxides. The Uptake of Phosphorus and Its Relationship with Fraction of Phosphorus The quantity of phosphorus taken up by the plants was calculated based on the measured concentration and the amount of biomass produced by the plants. In alluvial soils, phosphorus intake increased with soil development, whereas in loess soils, phosphorus absorption was maximum in soils that were at an intermediate stage of development. In kanpur soil, it is conceivable that the high P absorption is due to the large amounts of iron oxides and organic matter sorbed P, both of which are present in significant proportions. Increased phosphorus intake was found to be associated with the intermediate stage of development, as opposed to the early stage of development, in shale and sandstone derived soils. Phosphorus intake was also found to be associated with the intermediate stage of development as opposed to the early stage of development. It has been shown that the absorption of phosphorus by maize plants is closely related with the labile P fractions, Olsen P, and organic phosphorus (Fig. 3). It is hypothesised that the bioavailability of the soil P fraction is organised in the following sequence: Ca_2 -P is followed by Org-P, Al-P, Fe-P, Ca_8 -P, Occluded P, and Apatite-P. Plants may be able to absorb phosphorus that has been desorbed from the surfaces of aluminium and iron oxide, according to research. With regard to soil phosphorus, the availability of labile phosphorus to plants is governed by the amount of labile phosphorus refilled from other P fractions, which is dictated by the quantity of labile phosphorus renewed from other P fractions. It has been shown that the absorption of P by plants is very marginally related to occluded P and apatite-P. The mineral apatite-P is a refractory mineral, which means that it cannot be taken up by plants. Apatite-P entrapped in iron oxide bodies is also difficult for plants to extract. Apatite-P is a mineral that cannot be absorbed by plants. We used stepwise multiple regression analysis to predict the quantity of P taken up by the body based on the Olsen P and the P fractions, and the results were promising. Multiple regressions with steps are produced as a result of this.



CONCLUSION

The quantity of labile phosphorus fractions, secondary phosphates, and apatite-P in parent materials varied with soil formation, and the amount of apatite-P changed with soil development. It is chemically related to dicalcium phosphates, aluminium oxides, and iron oxides, among other elements. It has been shown that the absorption of P by Zea mays is greatly influenced by surface adsorbed P and organic P. Zea mays intake of phosphorus was shown to be highly associated with phosphorus availability. Olsen P plus occluded P offered a superior prognosis for P uptake than Olsen P alone, according to the findings of stepwise multiple regressions. According to the soil development (class) and the supply material, phosphorus absorption differed significantly. Even though soil development enhanced alluvial soil phosphorus absorption, it peaked in loess soil during the intermediate stage of soil development, which indicates that the soil is in the process of becoming more developed. In sandstone derived soils, phosphorus intake remained constant with soil development; however, in shale derived soils, phosphorus intake was lowest in soils that were at an intermediate stage of development.

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