Original Research Article

Phosphorus Fractions in Contrasting Soil Orders in Central India

Jayshive Patidar¹, Y.M. Sharma¹ and G.S. Tagore¹*

Dept. of Soil Science and Agricultural Chemistry, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur, India

*Corresponding author

Abstract

In present study, phosphorus fractions in representative agricultural soils belonging to three soil orders Vertisol, Inceptisol and Alfisol JNKVV, Farm, Jabalpur were investigated. Result revealed that the highest soil pH analysed in Vertisols with the range 7.57 to 7.68 followed by Alfisols range 6.37 to 7.18 and low pH found in Inceptisols, which 6.27 to 6.72 soil orders, respectively. The EC was existed as normal in all the orders < 1 dS m⁻¹ at 25°C. The organic carbon content was recorded in different soil orders ranged from 4.60 to 6.60 g kg⁻¹. The CaCO₃ content was found to be ranged from 40 to 70 g kg⁻¹. Overall, the soils are non-calcareous in nature. Vertisols have the highest CEC value followed by Inceptisols and Alfisols, which have minimum CEC value. The available N content in soils varied from 239.14 to 302.70 kg ha⁻¹ in different soil orders. The available phosphorus content in three soils orders varied from 11.24 to 30.79 kg ha⁻¹. The available K ranged from 308.32 to 345.60 kg ha⁻¹ in Vertisols, 289.76 to 336.08 kg ha⁻¹ in Inceptisols and it was ranged from 276.96 to 322.80 kg ha⁻¹ in Alfisols. The available N, P and K were low to medium in different soil orders. Vertisols and Inceptisols were found to be in order of Ca-P>Al-P>Occluded-P>Fe-P>Saloid-P. Whereas, Alfisols in order of Ca-P>Fe-P>Al-P>Occluded-P>Saloid-P. The Ca-P was found high in the Vertisols. But Fe-P and Al-P were recorded maximum under Alfisols.

Keywords
Phosphorus, Vertisol, Inceptisol, Alfisol, Ca-P, Fe-P, Al-P, Saloid P, Occluded P

Article Info
Accepted: 26 December 2018
Available Online: 10 January 2019

Introduction

Phosphorus (P) is essential element for plant growth as well as an important component in the developmental processes of agricultural crops (Withers et al., 2008). Approximately two-thirds of inorganic P and one third of organic P are not available in soil, especially in soils of variable charges. The rate of P use during crop growth is very low. Phosphates fixed by Fe, Al, and Ca in soils is a major cause of low phyto-availability (McBeath et al., 2005), because at least 70 to 90% of P that enters the soil is fixed, making it difficult for plants to absorb and use (Lei et al., 2004).

Organic inputs have been reported to increase P availability in P-fixing soils and humic substances enhance the bioavailability of P fertilizers in acidic soils (Hua et al., 2008). Decomposition products from manure such as humic acids and citrate were reported to have greater affinity for Al oxides than for PO₄. The term available-P is often used to describe

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the amount of soil P that can be extracted from solution or taken up by plant roots and utilized by the plant to growth and develop during its life cycle.

The concentration of available-P is always low because of continuous plant uptake. Phosphorus fertilizer efficiency in acid soils is less than 20% due to P fixation through P precipitation by soluble Fe and Al, and adsorption by Fe oxides.

The P is a critical element in agricultural ecosystem given its complex transformation in soil thus making its availability to plant difficult especially in tropics. Its deficiency is one of the major nutritional constraints to crop production in Indian vertisols (Bansal and Sekhon, 1994). Muralidharudu et al., (2011) reported only 8 and 11% districts as high P in India and Madhya Pradesh, respectively. Soil phosphorus exists in inorganic P and organic P forms.

These P forms differ in their behavior and fate in soils (Turner et al., 2007). The organic P can be released through mineralization processes mediated by soil organisms and plant roots in association with phosphates secretion. These processes are highly influenced by soil moisture, temperature, surface physical chemical properties, and soil pH and Eh. Organic P transformation has a great influence on the overall bioavailability of P in soil (Turner et al., 2007).

It is therefore important to consider both organic and inorganic P fractions for soil P fertility evaluation. It can serve as an indicator for proper nutrient management. Shen et al., 2004 concluded that fractions of P can provide an effective approach for investigating soil P availability and P inter conversion among soil P fractions from different P pools. Hence, the study was made to assess the fraction of P in different soil orders.

Materials and Methods

Description of study area and sites

Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur, is situated 23°12'57” latitude and 79°56'49” longitude and altitude of 383.3 m above mean sea level. Breeder Seed Production of Field Crops (BSP-FC) in which dominant soils were Vertisol, classified as Typic Haplusterts, Family-Very fine montmorillonite hyperthermic (Tripathi1998) and Inceptisol, Vertic Ustochrept, fine mixed hyperthermic (Kulkarni, 1986). The soils of BSP-FC Farm are clayey in texture (Fig. 1).

Krishi Nagar Research Farm in which soil order was Alfisol and classified as Typic and Vertic Haplustalf, Fine loamy and mixed, hyperthermic, locally knew as sehra soils. The texture was found to be sandy clay loam and sandy loam (Dhakad, 2017)

Breeder Seed Production of Groundnut (BSP-Groundnut) in which soil type was Inceptisol and classified as Typic Ustochrept, Fine loamy and mixed, hyperthermic (Tripathi, 1998).

Physico-chemical properties of soils

The soil pH was measured in a soil: water ratio of 1: 2.5 using the pH meter and supernatant of same was used for electrical conductivity determination with the help of conductivity–meter (Jackson, 1973). Organic carbon in soil was determined using method as described by (Walkley and Black, 1934). The calcium carbonate in soil was carried out using rapid back titration method as described by (Jackson, 1973). The CEC of soil was determined using method as described by (Jackson, 1973). The particle size analysis (clay percent) of soil was determined by Bouyoucous hydrometer method (Bouyoucous, 1962).
Available nitrogen was determined as per method given by Subbiah and Asija (1956). Available phosphorus was determined by 0.5 M sodium bicarbonate by Olsen et al., (1954) and then read on Spectrophotometer. Available potassium (K) was extracted with 1 N NH₄OAc and then measured by Flame Photometer (Jackson, 1973).

**Determinations of phosphorus fractions**

The procedure of Chang and Jackson (1957) as modified by Peterson and Corey (1966) was followed for fractionation of soil phosphorus. The sequence of Saloid-P, Al-P, Fe-P, Occluded-P and Ca-P from each sample was passed through a 60 mesh sieve. The soil extractant for various fractions in sequence were as follow:-

- Saloid-P extracted by 1 N NH₄Cl
- Al-P extracted by 0.5 N NH₄F buffered at pH 8.2
- Fe-P extracted by 0.1 M NaOH
- Occluded-P extracted by 0.1 M NaOH
- Ca-P extracted by 0.5 N H₂SO₄

In each fraction take 5 ml extract in 25 ml of volumetric flask for determination after dilution shake the content and add 4 ml reagent mixture (Ascorbic acid) the contents of flasks were shaken well and diluted to the mark. Colour intensity was measured in spectrophotometer within 10 minutes after setting the instrument to 100 reading of transmittance with blank prepared. The amount of phosphorus was calculated as P in kg ha⁻¹.

**Flow chart of phosphorus fractions**

1 g of soil samples taken in a 50 ml centrifuge tube

Add 25 ml 1 N NH₄Cl, solution

Shake it for ½ hour and centrifuge it for 5 min

Extract → Saloid-P

25 ml of 0.5 N NH₄F was added in the same tube after filtering

Shake it for ½ hour and centrifuge it for 5 min

Extract → Al-P

The residue of tube is washed by adding 25 ml of NaCl

25 ml of 0.1 M NaOH, was added in the same tube after filtering

Shake it for 17 hours and then centrifuging of 5 min

Extract → Fe-P

The residue of tube is washed by adding 25 ml of NaCl

25 ml of 0.1 M NaOH, was added in the same tube after filtering
Shake it for 1 hours and than centrifuging of 5 min

Extract Occluded-P

The residue of tube is washed by adding 25 ml of NaCl

25 ml of 0.5 N H₂SO₄ was added in the same tube after filtering

Shake it for 1 hours and then centrifuging of 5 min

Extract Ca-P

Results and Discussion

Status of physico-chemical properties of soil

The soil pH of different soil order of JNKVV farm Jabalpur, found to be 7.57, 7.59 and 7.68, 6.37, 6.95 and 7.18, 6.72, 6.27 and 6.35 in V₁, V₂ and V₃ (Vertisols), A₁, A₂ and A₃ (Alfisols) and I₁, I₂ and I₃ (Inceptisols) soil orders, respectively. The EC ranged from 0.07 to 0.35 dS m⁻¹. It was safe in limit the three soil order < 1 dSm⁻¹ at 25°C. The organic carbon content in soil ranged from 4.60 to 6.60 g kg⁻¹ in different orders of soil. The highest content of OC is recorded in Vertisol, which were 6.60, 5.92 and 5.87 g kg⁻¹ in V₂, V₁ and V₃, respectively. In Alfisols, the OC content found to be 5.33, 5.25, and 4.80 g kg⁻¹ in A₁, A₃ and A₂, respectively. However, organic carbon content in Inceptisols was observed to be low in I₁, I₂ and I₃which having value of 5.64, 5.55 and 4.60 g kg⁻³ respectively. The CaCO₃ content was found to be 40, 60, 45 g kg⁻¹ and 60, 70, 40 g kg⁻¹ and 65, 70, 45 g kg⁻¹ in V₁, V₂ and V₃ (Vertisols), A₁, A₂ and A₃ (Alfisols) and I₁, I₂ and I₃ (Inceptisols) soil orders, respectively. Raghuwanshi et al., (1992) analyzed Brown soils were slightly acidic (pH 5.6 to 6.6) while the black soil of Jabalpur was neutral to alkaline (pH 7.2). Organic carbon was found to be low in Inceptisols and the high in Vertisols (Fig. 2). The OC high might be due to incorporation of organic matter on the upper layer of the soil, through roots and other plant residues and manures. The crop species and cropping systems that may also play an important role in maintaining SOC stock because both quantity and quality of their residues that are returned to the soils vary greatly affecting their turnover or residence time in soil and thus its quality. Similar ranges in pH values were also reported by Tripathi et al., (1994). Similar results for various black soils were also reported by Tomar (1968) and Singh et al., (2014). It is concluded that the soils are non calcareous in nature. Similar results were reported by Singh et al., (2014). The highest CEC content was found to be 58.24, 62.78, 55.23 cmol(p+) kg⁻¹ in V₁, V₂ and V₃ (Vertisols) followed by 44.95, 48.21, 47.53 cmol (p+) kg⁻¹ and 45.75, 48.94, 46.72 cmol (p+) kg⁻¹ in, A₁, A₂ and A₃ (Alfisols) and I₁, I₂ and I₃ (Inceptisols) soil orders. The minimum CEC was existed in Alfisols and Inceptisols. However it was the highest in Vertisols, Existence of higher CEC in soils of Vertisols might be due to presence of higher clay content. Pathak (1983) reported that CEC of clay soils derived from basaltic rocks increased with clay content. Similar results were also reported by Matike et al., (2011) and Singh (2014) (Table 1–3).
### Table 1: Details of soil used

| Farm                        | Soil orders      | Site          | Latitude       | Longitude       | Cropping system | Sample No. |
|-----------------------------|------------------|---------------|----------------|-----------------|-----------------|------------|
| BSP-Field Crops             | Vertisols        | (V1)          | N-23°13'02.4“ | E-79°56’40.7”  | Soybean-Wheat   | 3          |
|                             |                  | (V2)          | N-23°12’50.1” | E-79°56’47.0”  | Soybean-Wheat   |            |
|                             |                  | (V3)          | N-23°13’44.6” | E-79°56’36.7”  | Soybean-Wheat   |            |
| Krishi Nagar Research Farm  | Alfisols         | (A1)          | N-23°12’17.6” | E-79°57’17.6”  | Rice-Wheat      | 3          |
|                             |                  | (A2)          | N-23°12’18.2” | E-79°57’32.1”  | Rice-Wheat      |            |
|                             |                  | (A3)          | N-23°12’27.8” | E-79°57’24.3”  | Rice-Wheat      |            |
| BSP-Groundnut               | Inceptisols      | (I1)          | N-23°12’53.1” | E-79°57’59.2”  | Rice-Wheat      | 3          |
|                             |                  | (I2)          | N-23°12’56.7” | E-79°57’47.5”  | Rice-Wheat      |            |
|                             |                  | (I3)          | N-23°13’04.8” | E-79°57’48.1”  | Rice-Wheat      |            |

### Table 2: Soil properties of different soils

| Site  | pH    | EC (dS m⁻¹) | OC (g kg⁻¹) | CaCO₃ (g kg⁻¹) | CEC [cmol(p+) kg⁻¹] | Clay (%) | Available major nutrient (kg ha⁻¹) | N  | P  | K  |
|-------|-------|-------------|-------------|----------------|----------------------|----------|-----------------------------------|----|----|----|
| (V1)  | 7.57  | 0.35        | 5.92        | 40.00          | 58.24                | 50       | 267.79                            | 16.24 | 328.68 |
| (V2)  | 7.59  | 0.26        | 6.60        | 60.00          | 62.78                | 55       | 302.70                            | 11.09 | 308.32 |
| (V3)  | 7.68  | 0.22        | 5.87        | 45.00          | 55.23                | 52       | 250.88                            | 15.15 | 345.60 |
| (A1)  | 6.37  | 0.16        | 5.33        | 60.00          | 44.95                | 25       | 279.97                            | 30.53 | 298.08 |
| (A2)  | 6.95  | 0.12        | 4.80        | 70.00          | 48.21                | 20       | 245.06                            | 30.79 | 276.96 |
| (A3)  | 7.18  | 0.15        | 5.25        | 40.00          | 47.53                | 22       | 276.97                            | 24.91 | 322.80 |
| (I1)  | 6.72  | 0.08        | 4.60        | 65.00          | 45.75                | 25       | 239.14                            | 21.34 | 336.08 |
| (I2)  | 6.27  | 0.09        | 5.55        | 70.00          | 48.94                | 30       | 251.06                            | 17.60 | 323.36 |
| (I3)  | 6.35  | 0.07        | 5.64        | 45.00          | 46.72                | 32       | 272.23                            | 22.00 | 289.76 |

### Table 3: Phosphorus fraction (kg ha⁻¹) in different soils

| Sites  | Saloid-P | Al-P  | Fe-P  | Occl-P | Ca-P  | Res-P | Total-P |
|--------|----------|-------|-------|--------|-------|-------|---------|
| (V1)   | 10.36    | 18.75 | 11.12 | 12     | 47.74 | 32.84 | 132.82  |
| (V2)   | 8.72     | 19.51 | 16.08 | 16.37  | 38.35 | 32.02 | 122.32  |
| (V3)   | 12.46    | 24.48 | 13.71 | 17.62  | 31.99 | 38.35 | 129.62  |
| (A1)   | 11.56    | 18.69 | 26.53 | 13.37  | 34.15 | 17.08 | 140.38  |
| (A2)   | 9.74     | 25.27 | 28.02 | 18.65  | 32.89 | 18.79 | 145.37  |
| (A3)   | 8.51     | 22.7  | 30.93 | 20.21  | 43.41 | 8.7   | 136.46  |
| (I1)   | 7.11     | 19.73 | 12.03 | 16.75  | 28.33 | 26.62 | 134.57  |
| (I2)   | 9.17     | 17.69 | 11.27 | 16.85  | 33.59 | 7.95  | 132.51  |
| (I3)   | 10.55    | 19.54 | 12.04 | 15.82  | 30.12 | 22.11 | 134.17  |
Fig. 1 Location of soil sampling

Fig. 2 Percent contribution of different fraction of P soils
Available major nutrients status in soils

Available N

In Inceptisols, I$_3$, I$_2$ and I$_1$ which had value of 272.23, 251.06 and 239.14 kg ha$^{-1}$, respectively. In Alfisols, it was recorded to be 279.97, 276.83 and 245.06 kg ha$^{-1}$ in A$_1$, A$_3$ and A$_2$, respectively. However, Vertisols, which having value of 302.70, 267.79 and 250.88 kg ha$^{-1}$ in V$_2$, V$_1$ and V$_3$, respectively. The low to medium nitrogen content in the soils is attributed due to high temperature, removal of organic matter leading to nitrogen deficiency. The medium nitrogen status may be due to application of N fertilizer recommended for the crops. Soils with higher levels might be the contribution from the legumes crops and very little tillage. Similar results were reported by Dubliya, (2011) and Singh et al., (2014); Ravikumar and Somashekar (2014).

Available P

The available phosphorus content in Vertisols, Alfisols and Inceptisols i.e., V$_1$, V$_2$ and V$_3$; A$_1$, A$_2$ and A$_3$; I$_1$, I$_2$ and I$_3$ was recorded to be 16.24, 11.09 and 15.15 kg ha$^{-1}$; 30.53 30.79 and 24.91 kg ha$^{-1}$; 22.00, 17.60 and 22.00 kg ha$^{-1}$ respectively. The high accumulation of P in soils is attributed to the regular application of phosphatic fertilizers and the immobile nature of phosphate ions in soils. Results were supported by Ravikumar and Somashekar (2014) similar results were reported by Dubliya, 2011 and Singh et al., (2014).

Available K

The available K content in V$_1$, V$_2$ and V$_3$ (Vertisols) and A$_2$, A$_3$ and A$_1$ (Alfisols) were 328.68, 308.32 and 345.60 kg ha$^{-1}$ and 276.96, 352.80 and 358.08 kg ha$^{-1}$ respectively. The K was recorded in I$_3$, I$_1$ and I$_2$ (Inceptisols) with value of 389.76, 346.08 and 323.36 kg ha$^{-1}$ respectively. The high status of K in these soils may be due to predominance of K rich minerals in parent material. Similar results reported by Ravikumar and Somashekar (2014).

Phosphorus fractions in different soil orders

Vertisols

In Vertisols i.e., V$_1$ and V$_2$, the P fractions were analysed in soil order was in the abundance: Ca-P>Al-P>Occluded-P>Fe-P>Saloid-P which value was 47.74>18.75>12.00>11.12>10.36 and 38.35>19.51>16.37>16.08>8.72 kg ha$^{-1}$ and percent contribution was 35.94>14.12>9.03>8.38>7.80 31.35>15.95>13.38>13.15>7.13 of total-P, respectively. However, in V$_3$ soil order followed Ca-P>Al-P>Occluded-P>Fe-P>Saloid-P, Which value was 31.99>24.48>17.62>13.71>12.46 kg ha$^{-1}$ and percent contribution was 24.68>18.89>13.59>10.58>9.61 of total-P, respectively. Ojo et al., (2015) stated that changes in the values of the P fractions in soils are significantly affected by soil type. Soil orders differ in their total P content because of interactions among soil parent material, weathering, and other pedogenic processes. In general, total P content is low in strongly weathered soil soils orders and high in young soil orders (Yang and Post, 2011). The content of the Ca-P ranks highest which was an indication of the fact that Ca-P form contributed to the major source of P in black soil as reported by Kaushal (1995), Subehia et al., (2005), Samadi (2006) and Garg and Milkha (2010).

Alfisols

The result after analysis that the P fractions was in A$_1$ and A$_2$ of Alfisols soil order was in the abundance: Ca-P>Fe-P>Al-P>Occluded-
P>Saloid-P, which value was 34.15>26.53>18.69>13.37>11.56 and 32.89>28.02>25.27>18.65>9.74 kg ha⁻¹ percent contribution was 24.33>18.90>13.31>9.52>8.23 and 22.63>17.38>12.83>11.56 of total-P, respectively. In A₃ of Alfisols were shown in this order of abundance: Ca-P>Fe-P>Al-P>Occluded-P>Saloid-P, Which value was 43.41>30.93>22.70>20.21>8.51 kg ha⁻¹ and percent contribution was 31.81>22.67>16.63>16.75>7.11; 33.59>17.69>16.85>11.27>9.17 and 30.12>19.54>15.82>12.04>10.55 kg ha⁻¹ of total-P, respectively. Among the different P fractions, Ca-bound P was the dominant fraction in the Vertisols and Alfisols. The next-dominant fraction was non-occluded Al and Fe-bound P, which was highest in the Alfisols and Vertisols. P occluded with in Fe-oxides and hydrous oxides fractions was highest in the Vertisol (Datta and Chandra, 2008). In Alfisols the amount and type of clay mineral especially 1:1 type clay minerals may contribute to more P sorption especially in tropical soil, particularly with low pH and high activity of Al and Fe (Dolui and Dasgupta, 1998).

**Inceptisols**

In Inceptisols, I₁, I₂ and I₃ soil orders the phosphorus fraction were followed this order of abundance: Ca-P>Al-P>Occluded-P>Fe-P>Saloid-P, which value was 28.33>19.73>16.75>16.75>7.11; 33.59>17.69>16.85>11.27>9.17 and 30.12>19.54>15.82>12.04>10.55 kg ha⁻¹ and percent contribution was 21.05>14.66>12.45>8.94>5.28; 25.35>13.35>12.72>8.51>6.92 and 22.45>14.56>11.79>8.97>7.86 of total P, respectively. The low content of Fe-P compared to Al-P and Ca-P might be due to the high activity of Al³⁺ and Ca²⁺ ions than Fe³⁺ ions in these soils. The results are in agreement with the findings of Patgundi et al., (1996). High P was reported in inceptisols which had little or no weathering or with very low decomposition (Yang and Post, 2011). Organic amendments are known to increase P availability in P fixing soils by governing the P fractions in soils (Reddy et al., 1999).

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How to cite this article:
Jayshive Patidar, Y.M. Sharma and Tagore, G.S. 2019. Phosphorus Fractions in Contrasting Soil Orders in Central India. Int.J.Curr.Microbiol.App.Sci. 8(01): 3050-3059.
doi: https://doi.org/10.20546/ijemas.2019.801.325