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Release Behaviour of Phosphorus and Its Fractions in Different Phosphorus Status Soils

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Phosphorus is essential to all forms of life and its contribution towards aiding the native soil fertility and sustaining it, is well known. With passage of time, P added to soil undergoes transformation into various unavailable forms. Native P compounds, some being highly insoluble are mostly unavailable for plant uptake. The availability of phosphorus to the plants depends on soil properties, soil pH, soluble iron, aluminum and manganese, calcium minerals, organic matter, activities of microorganisms thus availability of P may vary according to soil types. Knowing the changes in P fractions especially in low and in high P status soils is much more important for P availability to plant. Therefore, the release behaviour of phosphorus and its fraction in different P status soils was assessed over 5 weeks under laboratory incubation periods using a sequential fractionation procedure. The results of the experiment revealed that the content of available P and different P fractions were higher in high P status soil as compared to low P status soil. Among the various P fractions, Ca-P was the dominant fraction in both soils. The release of available P was

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first increased up to 21 and 28 days in low and high P status soil, respectively and the release of different forms of P fractions in both soils increased up to 28 days after incubation and then decreased with further increase in incubation period.

Keywords: Phosphorus; fraction; incubation; status; release behaviour.

1. INTRODUCTION

Phosphorus is one of the most important nutrient element after nitrogen in crop production as it is vital for several functions such as photosynthesis, protein information, nucleic acid production, nitrogen fixation, oil formation and transformation of sugar to starch [1]. It's availability to plants is a major issue as soil phosphorus is least mobile in contrary to the other macronutrients and it is considered as a less available nutrient. Its low availability in soil is due to fixation of P as oxides or hydroxides to Fe and Al or other amorphous minerals [2] and its release behaviour in soil has been ascribed to different adsorption, desorption reactions and precipitation or dissolution processes [3]. Phosphorus in soil is present in inorganic and organic forms and its different forms exist in different amounts and proportions, depending on soil type and management. Phosphorus fractionation provides an effective approach for investigating soil P availability and P transformation in soil [4]. The phosphorus adsorption capacity depends upon number of factors like pH, clay content and organic matter [5]. Devau et al., [6] stated that clay content has major effect on P retention in soil. In addition to these properties, adsorption also depends on temperature and contact time between soil and P. After the initial adsorption, P can become less labile with time, perhaps by diffusive penetration of adsorbed phosphate ions into the internal structure of components [3]. Adsorption from added P was found at initially low levels but, slowly increased with increasing incubation period. This might be due to desorption of greater number of P ions [7]. The P absorbed by plants directly comes from the soil solution, and there is a dynamic equilibrium between P in the soil solution and on the surface of clay particles. Such equilibrium is governed by P sorption and release from the solid phase and plant P uptake [8]. Hence the release rate of absorbed phosphorus directly affects the P supply to plants. Therefore, the objective of this study was to study the release behaviour of two different phosphorus status soils for available P and different P fractions at different periods of incubation.

2. MATERIALS AND METHODS

2.1 Soils

The soils of different P status (on the basis of 0.5 M $NaHCO_3$ extractable-P) used in the present investigation were collected from the farmer's fields from two different locations of Haryana *viz.* Sadalpur village of Hisar district and Saniyana village of Fatehabad district. Soil collected from village Saniyana was sandy loam in texture and high in available P (25 kg ha^{-1}) whereas, soil collected from Sadalpur village was found low in available P content (8 kg ha^{-1}). The application of phosphorus fertilizer was being practiced by the farmers in both soils. These soil samples were brought to the laboratory. The soil samples of two soils were air dried, crushed and sieved (2 mm) and analyzed for various physico-chemical properties *i.e*. texture, pH, electrical conductivity, organic carbon, cation exchange capacity and available N, P and K by using standard methodology.

2.2 Phosphorus Release Behaviour Study

To study the release behaviour of available P and its fractions in different P status soils, 100 g processed soils were taken into wide mouth plastic bottles (in triplicates) from low and high P status soils. After maintaining the moisture content at field capacity these bottles were placed in an incubator. Both the soils were incubated at room temperature (25°C ± 2 °C) for 1, 7, 14, 21, 28 and 35 days. A subsample of soil from each bottles and at each date was taken out and subjected for the analysis of available P and different P fractions (Saloid-P, aluminium-P, iron-P, reductant soluble-P, calcium-P and organic-P). A sequential fractionation for soil inorganic phosphorus was performed by following method outlined and modified by Peterson and Corey (1966). Different fractions of soil P were extracted by using different extractants.

3. RESULTS

The initial physico-chemical properties of both soils presented in Table 1 revealed that both the

soils were non-saline and neutral in reaction. The texture of the low available P status soil (Sadalpur) was sand (92% sand, 4% silt and 4% clay) with 0.12 dS m^{-1} of electrical conductivity (EC) and 0.15% of organic carbon (OC). The available N, P and K content of the soil was 28, 8 and 112 kg ha^{-1}, respectively. The content of DTPA-extractable Zn, Fe, Cu and Mn were 0.3, 2.11, 1.94 and 2.48 mg kg^{-1}, respectively. In contrast, the Saniyana soil was found rich in available macro and micronutrients. The soil had sandy loam texture (60% sand, 24% silt and 16% clay) and 1.0 dS m^{-1} of EC and 0.62% of OC. Saniyana soil was medium in available N (182 kg ha^{-1}), high in available P (25 kg ha^{-1}) and K (430 g ha^{-1}). The availability of DTPA-extractable Zn, Fe, Cu and Mn were 0.72, 18.74, 3.08 and 10.26 mg kg^{-1}, respectively. In general, high P status soil had higher CEC than low P status soil. The high P status soil was found medium in organic carbon content and low availability status of organic carbon was recorded from low P status Sadalpur soil.

3.1 Release Behaviour of Available P

During the course of the incubation period, changes in the release behaviour of available P (Fig. 1) revealed that the content and the release behaviour of available P in both the two soils varied with time. Available P was found to be larger in magnitude in high P status soil as compared to the soil with low P status and also appeared at peak on 21 days after incubation (DAI) in low P status soil and 28 DAI in high P status soil. In low P status soil, available P content increased with 120.2% *i.e.* 7.91 to 17.4 kg ha^{-1} with increase in incubation period from 1 to 21 days, thereafter, it decreased to 9.10 kg ha^{-1} at 35 days of incubation. In contrast, the available P content in high P status soil increased was up to 28 days after incubation (DAI) and after which it was decreased. The content of available P in high P status soil increased from 24.87 to 98.01 kg ha^{-1} with increase in incubation period from 1 to 28 days, thereafter, it decreased to 87.93 kg ha^{-1} at 35 days of incubation.

3.2 Phosphorus Fractions

In both the soils, the P content under different fractions varied with incubation intervals. Except organic-P (Org-P) fraction, all other P fractions *i.e.* Saloid-P, Aluminium-P (Al-P), Iron-P (Fe-P), Reductant soluble-P (Red-P), Calcium-P (Ca-P) and Total-P increased up to 28 DAI and thereafter showed declining trend in the content in both soils (Figs. 2 and 3).

3.2.1 Saloid phosphorus (Saloid-P)

This form of P fraction was released early in the incubation period but in minimal amount compared to other P fractions in both the soils. The content of Saloid P in both the soils ranged from 2.98 to 3.60 mg kg^{-1} in low P status soil and 4.20 to 6.55 mg kg^{-1} in high P status soil during 1 to 35 days of incubation. The magnitude of this fraction was continued to increase during the incubation and reached maximum value at 28 DAI in both low P (4.65 mg kg^{-1}) and high P (7.11 mg kg^{-1}) status soils and declined thereafter by the end of the incubation period (35 DAI) in both the soils. The content of this P fraction was higher in high P status soil than the low P status soil.

Table 1. Initial physico-chemical properties of low and high phosphorus status soils

Initial soil parameters	Low P status soil	High P status soil
pH	7.4	7.1
EC (dS m^{-1})	0.12	1.0
Sand (%)	92	60
Silt (%)	4	24
Clay (%)	4	16
Texture	Sand	Sandy loam
CEC [(cmol (p^+) kg^{-1})]	4.46	9.28
Organic carbon (%)	0.15	0.62
Available Nitrogen (kg ha^{-1})	28	182
Available Phosphorus (kg ha^{-1})	8	25
Available Potassium (kg ha^{-1})	112	430
DTPA-extractable Zinc (mg kg^{-1})	0.30	0.72
DTPA-extractable Copper (mg kg^{-1})	1.94	3.08
DTPA-extractable Iron (mg kg^{-1})	2.11	18.74
DTPA-extractable Manganese (mg kg^{-1})	2.48	10.26

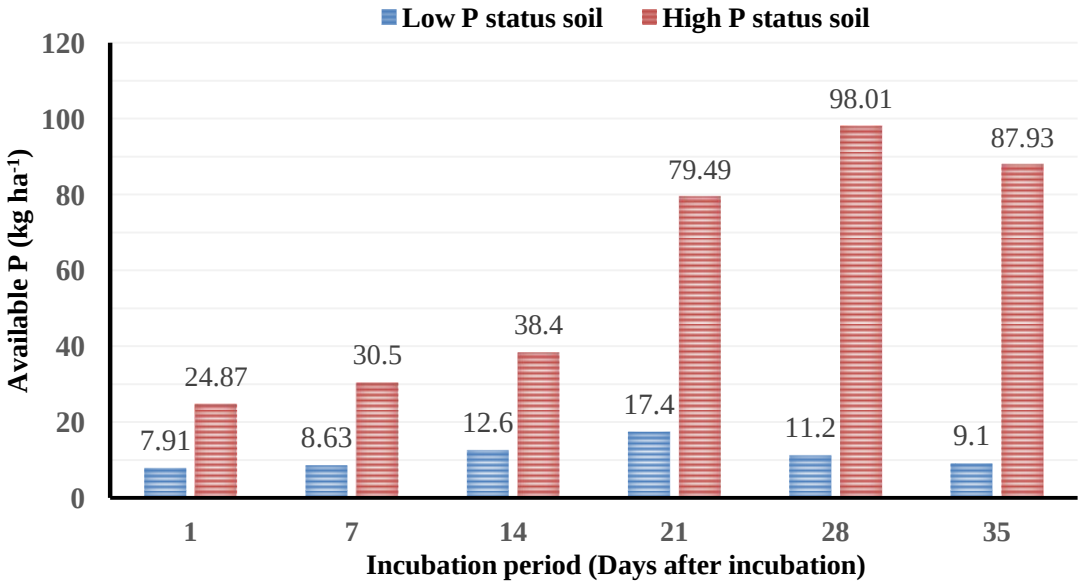

Fig. 1. Release behaviour of available P in low P and high P status soils at different days of incubation

3.2.2 Aluminium phosphorus (Al-P)

The content of Al-P in high P status soil ranged from 70.60 to 75.80 mg kg^{-1} and in low P status it ranged from 25.83 to 27.84 mg kg^{-1} with increasing DAI from 1 to 35 days. In low as well as high P status soils, the Al-P content increased from 25.83 to 29.26 mg kg^{-1} and 70.60 to 76.20 mg kg^{-1}, respectively with increasing DAI from 1 to 28 days and thereafter the content decreased to 27.84 and 75.80 mg kg^{-1} in low and high P status soil, respectively.

3.2.3 Iron phosphorus (Fe-P)

The release of this fraction consistently increased upto 28 DAI in both the soils and its concentration in low P status soil fell in the range of 24.1 to 28.40 mg kg^{-1} and on later period of incubation *i.e.* upto 35 DAI, it declined to 27.25 mg kg^{-1}. Similar trend was also observed in high P status soil where the range of Fe-P was found from 42.15 to 49.64 mg kg^{-1} upto 28 DAI and then declined to 47.10 mg kg^{-1} at 35DAI. However, in comparison to the low P status soil, high P status soil had larger concentration of this kind of fraction.

3.2.4 Reductant phosphorus (Red-P)

This form of P, like the other forms of P mentioned above, also displayed similar patterns of increase and decrease throughout the incubation and maximum content of red-P was reached at 28 DAI and then declining in both soils by the end of incubation. Its concentration from 1 to 28 DAI fell in the range of 23.69 to 27.21 and 37.59 to 46.31 mg kg^{-1} in low P and high P status soils respectively and thereafter on further increase of incubation time upto 35 DAI the content of Red-P get decreased from 27.21 to 26.88 mg kg^{-1} in low P status soil. As well as, its content was also get decreased in high P status soil from 46.31 to 45.60 mg kg^{-1} with the increase of incubation period upto 35 DAI. However, the content of red-P in all the days of incubation was found higher in high P status soil as compared to the low P status soil.

3.2.5 Calcium phosphorus (Ca-P)

The concentration of Ca-P differed in the two soils but followed the same trend in the release behaviour. This form of P fraction accounted for the majority of the released P in both the type of soils. The concentration of this form of P in low P and high P status soil ranged from 100.73 - 104.70 mg kg^{-1} and 158.75-163.85 mg kg^{-1} respectively. The release of Ca-P continued to increase during the incubation period but appeared to reached maximum at 28 DAI in both low P (106.59 mg kg^{-1}) and high P status soil (163.98 mg kg^{-1}) and slightly declined thereafter. It was observed from this study that among all the P fraction, Ca-P was the dominant fraction in both the soil and its content was found larger in high P status soil as compared to low P status soil at all the days of incubation.

3.2.6 Organic phosphorus (Org-P)

This form of P fraction gradually decreased from 43.36 to 27.64 mg kg^{-1} in low P and from 69.11 to 43.97 mg kg^{-1} in high P status soils, respectively with increasing incubation period up to 28 days and appeared maximum at 1 day of incubation in both the soils. Its decline, with the progress of incubation period corresponded with increase in quantity of other P fractions but with further increase of incubation time up to 35 days, it showed elevated values in both the soils and its concentration was increased in both low P (27.64- 31.97 mg kg^{-1}) and high P (43.97-47.86 mg kg^{-1}) status soils. However, like the other fractions, a similar pattern was appeared while comparing the amounts of org-P in the two soils and the content of this kind of P fraction was found to be more abundant in the high P status soil in contrast to the low P status soil.

3.2.7 Total phosphorus (Total-P)

The total P concentration in both the soils continued to increase with the incubation period and reached maximum at 28 DAI ranging from 220.69-224.45 mg kg^{-1} and 382.40-387.21 mg kg^{-1} in low and high P status soils, respectively. But its concentration in both the soils declined thereafter by the end of the incubation and its concentration was decreased from 224.45 to 222.24 mg kg^{-1} in low P status soil and 387.21 to 386.76 mg kg^{-1} high P status soil. The magnitude of the total P in high P status soil was higher in contrast to the other soil and this was due to the higher magnitude of other P fractions in high P status soil as compared to the low P status soil and also, this might be due to the differences in clay, organic carbon content and Fe and Al oxides which were higher in high P status soil, therefore, contributing to the higher concentration of total-P in high P status soil in comparison to the low P status soil.

4. DISCUSSION

The release amount of available P was higher in high P status soil than low P status soil. This might be due to the higher initial P and OC content available in high P status soil. The results of the study are in agreement with the findings of Kaloi et al. [9] and Rajput et al. [7]. Similar results regarding P release behaviour increased through incubation period was also reported by McDowell and Sharpley, [10], Moharana et al. [11] and Dey et al. [12]. The decrement (at 28 and 35 DAI) in P release with time was also reported by Shariatmadari et al. [13] and this might be due to the decreased surface charge and interaction between the adsorbed P ions.

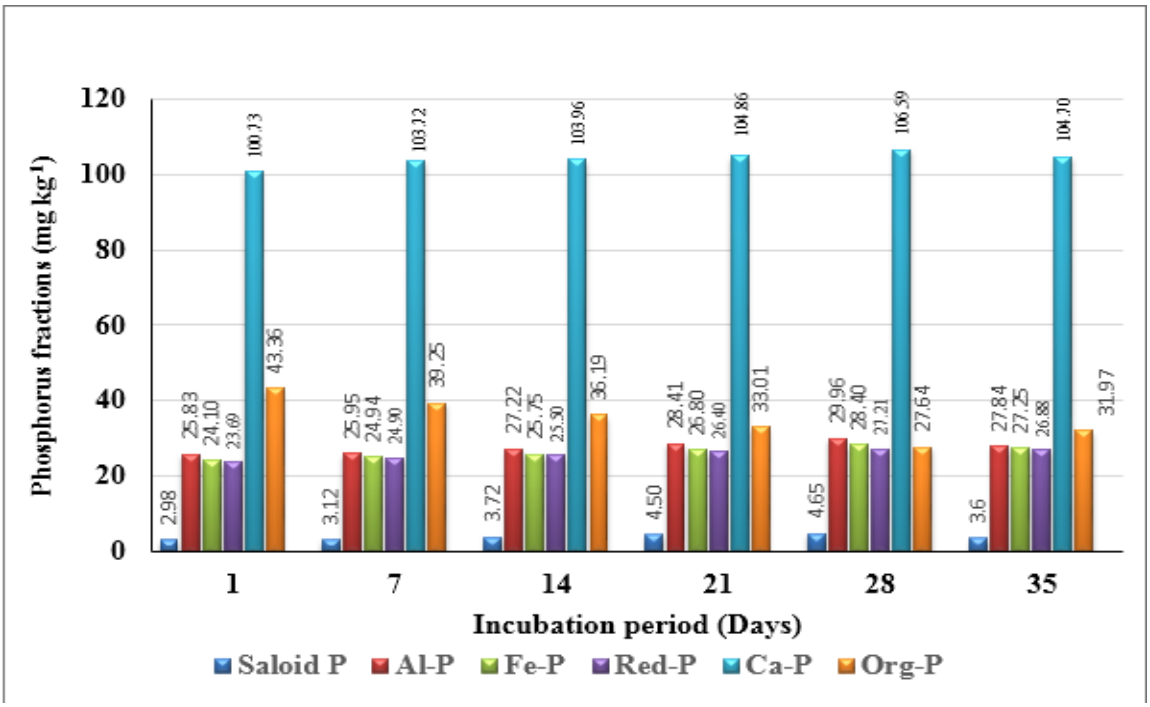

Fig. 2. Distribution of P fractions in low P status soil at different days of incubation

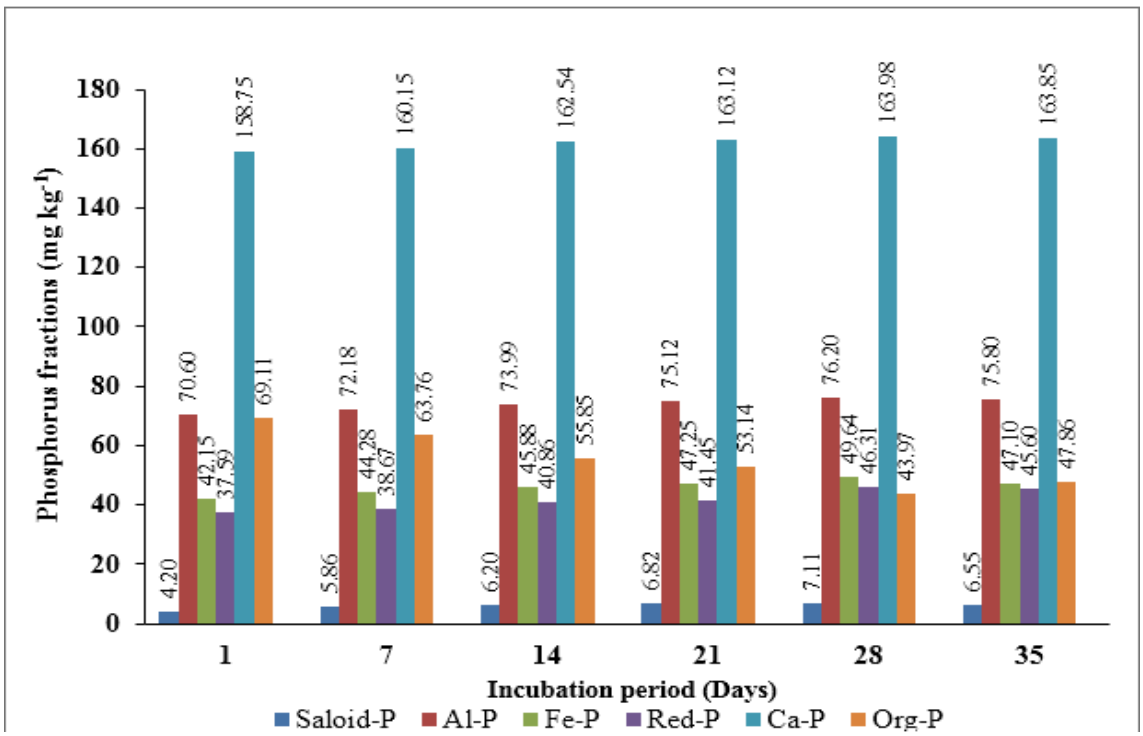

Fig. 3. Distribution of P fractions in high P status soil at different days of incubation

Relatively higher content of different forms of P fractions and total phosphorus was reported in high P status Saniyana soil. This might be due to higher clay content, organic matter and comparatively higher amount of available macro and micronutrients in high available P staus soil, thus higher values of different P fractions were reported from this soil. These results were found in accordance with the findings of Daroub et al. [14], Ochwoh [15], Lair et al. [3], Gichangi [2], Xavier et al. [16], Kumar et al. [17] and Pant et al. [18,19].

5. CONCLUSION

The days of intervals proved as a significant factor in the release of available P and different P fractions. It was observed that the release of available P was increased up to 21 and 28 days of incubation in low and high P status soil, respectively and decreased at later stages of incubation. In both the soils, the release of different forms of inorganic P showed similar trend as they increased up to 28 DAI and declined thereafter, with further increase in incubation period. The content of organic fraction in both the soil was more during initial days of incubation and consistently reduced with the progress of incubation time up to 28 days and increased by the end of incubation period. It was also noticed that among the P fractions in both the soils, saloid-P was released early and least available P fraction in the incubation and Ca-P was the most dominant fraction. The distribution of various P fractions was found in following sequence Ca-P > Org-P > Al-P > Fe-P > Red-P >Saloid-P in both soils.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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