

# Phosphorous Transformation and Fixation of Some Main Soils in Vietnam

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**Abstract** – Phosphorus is a very important nutrient for plant growth, and phosphorus deficiency is often observed in tropical soils because of high concentration of iron (Fe), aluminum (Al), and fixation capacity of soils. So that farmers usually apply with high rates of phosphate to improve crop yields. However, the effects and dynamic of phosphorus in soils are not understood. To investigation these effects, the research is carried out on some main soils of Vietnam.

The results showed that most of the studied soils have high phosphorus fixation capacity. The fixation capacity of soil decreases from Ferralic Acrisols to Xanthic Ferrasols, Gleyic Fluvisols, Eutric Fluvisols and Haplic Arenosols. In term of fractions, the fraction of Fe-P is predominant in most of the studied soils, except Xanthic Ferrasols. The fraction of Al-P is higher than Ca-P in soil with highly ferralitic intensity of Rhodic Ferrasols, but lower in soils with weakly ferralitic intensity of Eutric Fluvisols and Haplic Arenosols.

Water logged has high effects on phosphorous fractions in soils. The contents of Org-P, Ca-P and Al-P decrease but the contents of Fe-P increases due to logged soils. Phosphorous applies also have significant effects on the sorption capacity as well as the fractions of phosphorous in soils. At high rates of phosphate applied, all the fraction of phosphorus increases significantly, especially Fe-P and Ca-P.

**Keywords** – Fixation, Phosphorus, Transformation, Vietnam Soils.

## I. INTRODUCTION

Phosphorus is one the most important macronutrients for crop production. However, the content of available phosphorus in the soil, especially in tropical regions are quite poor to meet the nutritional needs of the crops. Therefore, phosphorus is often the limiting factor in most productive land [1]-[2]. Moreover, phosphorus leaching also causes serious problems for water environment [3]. Nutritional deficiency of phosphorus in soils is considered as big problem in the tropical regions due to soils with high capacity of phosphorous fixation capacity. So farmers usually use of phosphate fertilizers with in high doses to meet the requirement of the crop nutrition.

According to Tate (1984), organic forms of soil phosphorus are an important source of available P for plants following mineralization. The rates and pathways of P through soil organic matter are, however, poorly understood when compared to physic-chemical aspects of the P cycle. The essential role of soil microorganisms as a labile reservoir of P, confirmed experimentally and in modelling studies, has recently led to the development of methods for measuring their P content [4].

In Vietnam, phosphorus is considered as one of the leading element to crop yields. Therefore, the rate of

phosphorus fertilizer applied to soils is increased. For example, in the Red River Delta, phosphorus fertilizer for rice has increased from 21 kg in 1980 to 36 in 1990, 75 kg in 2000 and 90 P<sub>2</sub>O<sub>5</sub>/ ha now. This has contributed to increase rice yield from 3.9 tons / ha in 1980 to 4.6 ton / ha in 1990, 6.2 tons / ha in 2000 and 6.5 ton/ha now [5]-[6]-[7]. The long-term application of phosphate fertilizers causing accumulation of phosphorus in the soil as fixed fractions. To investigate this problem, the paper is conducted to study the contents and transformation of phosphorous fractions in different soil types; determine phosphorus sorption capacity of soils and the effect of submergence and added phosphorus to phosphate fractions of soils.

## II. MATERIALS AND METHODS

The study is carry out in 75 topsoil samples (0-30 cm) of 6 different soil types, i.e., Eutric Fluvisols (FLe), Gleyic Fluvisols (FLg), Haplic Arenosols (ARh), Ferralitic Acrisols (ACf), Xanthic Ferrasols (FRx) and Rhodic Ferrasols (FRr) taken from different regions in the Northern Vietnam under tropical monsoonal climate, with hot wet summers and cool dry winter. Mean annual temperatures is about 15-25 °C and mean annual precipitation of 2000 mm. The soil samples were air dried at air temperature (28-30 °C), crushed and sieved (<2 mm) for chemical analysis.

The soil chemical properties analyzed by the following methods: pH(KCl) determined in 1N KCl (w/v ratio 1/2.5), the total C by Walkley-Black, the total N by Kjeldahl, total K determined by flame photometer. The fractions of phosphorus is extracted and determination according to Chang-Jackson method.

The available P-NH<sub>4</sub>Cl (P-ht) was extracted by 1N NH<sub>4</sub>Cl; calcium phosphate (Ca-P) by 0.5 N H<sub>2</sub>SO<sub>4</sub>; iron phosphate (Fe-P) by 0.1 N sodiumhydroxide, aluminum phosphate (Al-P) by 0.5 N NH<sub>4</sub>F. The residual phosphorus in soil or insoluble phosphorus (Occ-P) is calculated on the basis of total phosphorus and all phosphorus fractions extracted by the above solutions. Organic phosphorus (Org-P) was determined in the extracted solution of soil with hydrochloric acid / Sodium hydroxide (Mehta et al., 1954). Phosphorus fractions was extracted by shaking 5g of soil with 100 mL of a solution for 1 h at laboratory temperature (about 28 °C).

The phosphorous adsorption capacity of soil (PSC) is defined as increasing phosphorus added to soil from 0 to 600 mg P/kg, shaking 2 hours and determine the amount of phosphorus remaining in solution equilibrium. The

amount of phosphorus absorption is calculated by the difference between the amount of added phosphorus and the remaining phosphorus in the solution.

### III. RESULTS AND DISCUSSION

#### 1. Some basic chemical properties of soils

The data presented in Table 1 shows the difference of chemical properties of the studied soils. The soil reaction (pH.KCl) of FRr is very acid; ACf, ARh and FRx are slightly acidic, whereas FLe land FLg have a neutral to near neutral. In general, all soils are poor in the contents of organic matter.

Table 2: The contents of phosphorous fractions in soils

Soil	Inor-P						Org-P
	NH <sub>4</sub> C I-P	Fe-P	Al-P	Ca-P	Occ- P	Total	
FLe*	14	149	52	107	417	739	291
	1.35	14.5	5.1	10.4	40.5	71.7	28.3
ARh*	10	101	35	41	327	514	86
	1.7	16.8	5.9	6.8	54.5	85.7	14.3
FRx*	12	151	131	221	227	742	328
	1.1	14.1	12.2	20.6	21.3	69.4	30.6
FRr*	13	538	82	62	750	1445	285
	0.8	31.1	4.7	3.6	43.4	83.5	16.5

\*First row=mg/kg, second row=%

In general, the content of total phosphorus is high (870-1730 mg P/kg), except ARh have low total phosphorus at 600 mg/kg. These is descending from FRr to FRx, FLe, FLg, ACf, and lowest in ARh. The results also show that soils with higher weathering intensity also have greater total phosphorus. It can be said that the content of total phosphorus in soils partly reflects the weathering velocity of soil. This view was also mentions by Sanchez (1976) that the phosphorus content of the soil can be used as an index for weathering processes.

#### 2. Contents and transformation of phosphorus fractions in soil

The soils have relatively low in organic phosphorus (Org-P) compared to inorganic phosphorous fractions and only contributes 14-31% of total phosphorus in soils (Table 2). In general, the fraction of Occ-P have highest content to other fractions. This results is reported in other soil, e.g. in Sweden soils. For example, research on phosphorus in soils in the Northern Sweden also reported the total P content is about 927-1433 mg/kg; the fraction strongly bound P 283-734 (27-64%); dissolved NaOH-EDTA P 334-769 (69-73%); organic P 175-651 (19-62%); inorganic P 113-271 (10-21%) [8]. The values in parenthesis are proportion (%) of total soil phosphorus.

In the forms of inorganic phosphorus, Fe-P fraction prevails in most studied soils, except Xanthic Ferrasols (FRx). But the content of Al-P is greater than Ca-P in the soils with higher ferralitic degree of Rhodic Ferrasols (FRr). These results are also consistent with studies of Dubus and Becquer (2001) suggested that Fe and Al are highly positively correlated with P in soils [2]. In general, the amount of phosphorus in soils is descending in the order:

Fe-P>Ca-P> Al-P in Fluvisols (FLe) and Haplic Arenosols (ARh)

Fe-P>Al-P>Ca-P in Rhodic Ferrasols (FRr), and Ca-P>Fe-P>Al-P in Xanthic Ferrasols (FRx)

The results also show the proportions of Ca-P decrease whereas Fe-P increase with weathering degrees. Figure 1 shows clearly the difference in the amount of phosphorus in the different weathering level of soils.

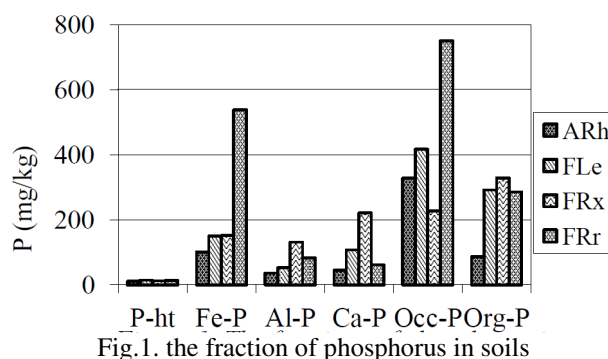


Fig.1. the fraction of phosphorus in soils

The transformation among phosphorous fractions also depends greatly on the nature of soil acidity and weathering intensity. The soils have higher weathering process and acidity, the calcium phosphate become more soluble and easier to transform into the less soluble iron and aluminum phosphates. Because of high contents of iron in soils, the Fe-P fractions are usually dominant in almost studied soils, especially soils with high weathering intensity of Rhodic Ferrasols (FRr). Meanwhile the contents of Ca-P fractions is highest in Xanthic Ferrasols (FRx) formed on limestone.

The strong correlations between soil organic P, climate, and soil properties suggested that equilibrium levels of organic P in western U.S soils reflect a balance between the physical protection offered by the soil matrix, and the suitability of the environment for biological productivity. In contrast, the presence of often large concentrations of CaCO<sub>3</sub> appeared to have little influence on soil organic P concentration [9].

The water submergence also affects the fractions of phosphorus in soils. These results were obtained in the experiments with submerged FLe at the water depth of 5 cm. Soil Org-P, Ca-P and Al-P decreased corresponding to 15%, 13% and 7% compared to before submergence whereas Fe-P increased by 14% after 60 days of submergence (Figure 2). The increase of Fe-P after water submergence is due to process of reduction of Fe (III) phosphate to Fe (II) phosphate with higher soluble ability. Moreover in wetland conditions, a part of Ca-P would also gradually shift to Fe-P [6]-[7]-[10].

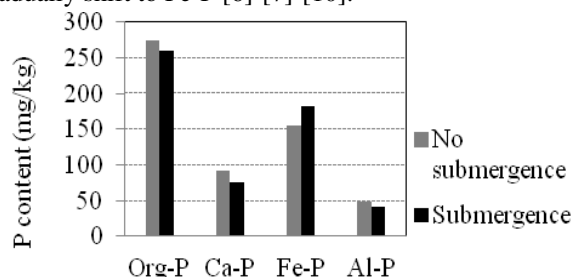


Fig.2. Effect of submergence to P fractions in soil

### 3. Phosphorous sorption capacity of soils

The results in Table 3 show the phosphorus sorption capacity of soils (PSC) are quite high. For example, at high added P level of 600 ppm P, the ACf has the highest level of phosphorus sorption capacity at 295 ppm, and ARh has the lowest level of phosphorous sorption capacity at 145 ppm. However, at the low level of added P at 50 ppm, there is not much different in phosphorus sorption capacities among the study soils. The proportions of P sorption range between 62-95% of total added phosphorus at the added P level at 50 ppm P, however, at the level of 200 ppm of added P, it decreases to about 46-80% and at the level of 600 ppm added P, only 24-49% of added P is adsorbed. Desorption of phosphate anion in CaCl<sub>2</sub> solution were also detected in most of the studied samples with values ranging from 0.7 to 2.7 ppm.

Table 3: Phosphorous sorption capacity of soils in different added P levels

Soils	The amount of added P (ppm)							
	0	50	100	150	200	300	400	600
ARh	0	31	54	69	92	118	134	145
FLe	-2.4	36	64	89	107	133	145	179
FLg	-2.7	28	63	99	128	178	206	225
FRx	-0.7	37	69	91	127	152	201	234
ACf	-1.6	48	94	135	161	209	251	295

The relationship between the adsorbed P and the remaining in the equilibrium solution is described in Figure 3. The P adsorption capacity of ACf is at the highest whereas ARh with phosphorus sorption capacity is at the lowest level. Based on the results of this study, the soils can be divided into 4 groups with different PSC. These decrease in the order from ACf to FRx and FLg, FLe, and ARh. From this result, it can be said that soils with higher ferralitic process and/or greater acidity. i.e., ACf and FRx, also have higher PSC compared to the lower acidity and/or low intensity of ferralitic process, i.e., FLe and ARh. It is also reminded that the high PSC of FLg causing by high iron content due gleyic process in flooding soils.

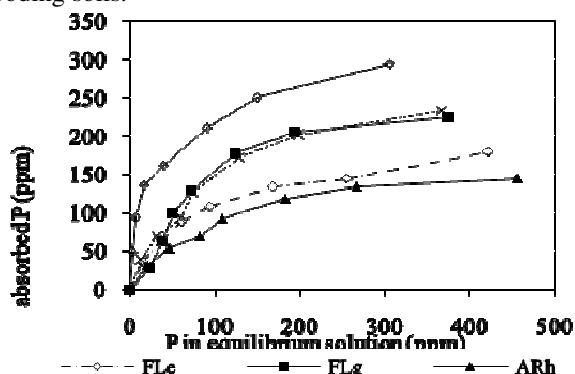


Fig.3. Relationship between P adsorbed and P in the solution equilibrium

### 4. Effect of phosphorus fertilizer on the fractions and the phosphorous sorption capacity of soils

The results of phosphorous fertilizers affect the fractions and phosphorus sorption capacity of FLe obtained from

pot experiment with paddy rice cultivation in 6 months. In this experiment the amount of phosphorus fertilizer increased from 0 to 700 ppm (Table 4). The data in Table 4 also show as many as 47-56% of added P is adsorbed in soils. Phosphorus sorption capacity (PSC) decreases rapidly when the rate of P fertilizers increases.

Table 4: Effect of phosphorous fertilizer on phosphorus fractions and sorption of soils

P fer. (ppm P)	PSC at P added 500 ppm		P fractions in soil (ppm)			
	mg/kg	% P added	NH <sub>4</sub> Cl-P	Al-P	Fe-P	Ca-P
0	283	56.6	18.0	21.0	158.9	87.2
50	279	55.8	18.5	21.0	167.0	118.4
100	275	55.0	20.0	24.5	172.3	145.0
200	256	51.2	25.1	29.8	203.7	168.3
400	248	49.6	43.4	37.1	341.0	202.1
700	237	47.4	74.5	45.2	450.1	215.0

These results also shows that phosphorus fertilizer also affects significantly the fractions of phosphorus in soils. At low level 50 ppm of P applied, the Ca-P concentrations increased faster than other phosphorus fractions. However, at higher levels of 100 ppm of phosphorus fertilizer, the Fe-P and Al-P concentrations increased faster. Meanwhile dissolved phosphorus increased only when the amount of fertilizer exceeded 400 ppm P. At very high level of 700 ppm P applied, all the concentrations of P-NH<sub>4</sub>Cl, Fe-P, Ca-P and Al-P increase corresponding to 297%, 183%, 147% and 115% compared to the control.

## IV. CONCLUSION

The results of this study show that soils have high ability to absorb phosphorus, and the phosphorus sorption capacity decreased from Ferralitic Acrisols (ACf) to Xanthic Ferrasols (FRx), Gleyic Fluvisols (FLg), Eutric Fluvisols (FLe), Haplic Arenosols (ARh),

In term of phosphorus fractions, the Fe-P fraction dominates in all studied soils, but Xanthic Ferrasols (FRx). The soil with higher ferralitic intensity (Rhodic Ferrasols FRr) have higher levels of Al-P than Ca-P. Conversely, soils with lower ferralitic intensity and higher levels of Ca<sup>2+</sup> (Eutric Fluvisols (FLe) and Haplic Arenosols ARh) have Ca-P concentrations greater than Al-P.

The water submerged process greatly affects the fractions of phosphorus in soils. The contents of Org-P, Ca-P and Al-P decreased 15%; 13% and 7%, respectively; while Fe-P concentrations increased approximately 14% after flooding. The amounts of phosphorus fertilizer also significantly affect the phosphorous sorption capacity as well as the phosphorus fractions in soils. At the level of 700 ppm P applied, the amount of NH<sub>4</sub>Cl-P, Fe-P, Ca

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