



## Predicting Phosphorus Desorption from Acid Piedmont Rice Soils of Bangladesh

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### Abstract

A laboratory experiment was conducted at the Bangladesh Rice Research Institute, Gazipur during 2003 to determine phosphorus (P) desorption characteristics for 10 acid piedmont rice soils of Bangladesh. Soil samples were analyzed for sand, silt and clay, pH, organic carbon, available P, Mehlich-3 (M3) extractable P and dithionite extractable Fe ( $Fe_D$ ). Desorption of phosphorus (release pattern) from different soils varied from 1.34 to 19.17 ppm. Phosphorus desorption was affected by the increased shaking time up to one hour. In almost all the studied soils, the highest desorbed P was extracted at one hour shaking time, beyond which there was again re-adsorption in most of the soils. Soil properties, particularly,  $pH_{KCl}$ ,  $\Delta pH$ , organic carbon and clay content were found to be important soil variables in determining phosphorus desorption in piedmont soils. The increase in  $\Delta pH$  and organic carbon increased P desorption, while an increase in clay and Fe tended to decrease in P desorption. Equations were proposed for predicting  $\alpha$ ,  $\beta$  and  $K$  of famous Sharpley's equation and were tested for better prediction of P desorption in Piedmont soils of Bangladesh. Sharpley's equations for Piedmont soils resulted in a strong relationship ( $R^2 = 0.86$ ) between measured and predicted P desorption. The equations recommended by Sharpley to predict values for  $\alpha$ ,  $\beta$  and  $K$  has provided a good prediction of P desorption for our Piedmont rice soils.

**Keywords:** Phosphorus desorption, piedmont soil, prediction of P desorption, sharpley's equation

### 1. Introduction

The role of phosphorus in plant nutrition is well recognized. It is also well known that the phosphorus content of most of the soils of Bangladesh is not adequate for obtaining high crop yields. In improving the understanding of phosphorus availability from soils, P concentration in soil solution at equilibrium in relation to adsorption and desorption characteristics of soil matrix are equally important. Adsorbed P cannot be utilized by

plants until it passes into solution by the desorption step (Nagarajah *et al.*, 1968). Desorption of ions is studied usually from respective ion-equilibrated soil by their sequential extraction from some extracting reagents. Barrow (1979) utilized 0.01 M  $CaCl_2$  solution for desorption study. In many studies of P desorption, it is commonly observed that desorption reactions occur rapidly at first and decrease as equilibrium is approached. It is also observed that the quantity of P desorbed is

largely a function of the time allowed for desorption and the water/soil ratio during desorption (Barrow, 1979). Sharpley *et al.* (1981) proposed a simplified P desorption equation:

$$P_d = KP_o t^\alpha W^\beta \quad (1)$$

Where,  $P_d$  is the amount of P desorbed ( $\text{mg kg}^{-1}$ ) in time,  $t$  (min). at a water/soil ratio  $W$  ( $\text{mL g}^{-1}$ ),  $P_o$  is the initial amount of desorbable P present in the soil ( $\text{mg kg}^{-1}$ ), and  $K$ ,  $\alpha$  and  $\beta$  are empirical constants for a given soil and related to clay and organic carbon content.

$$\alpha = a (\text{clay} / \text{organic carbon})^{-b}$$

$$\beta = a (\text{clay} / \text{organic carbon})^b$$

$$K = a (\text{clay} / \text{organic carbon})^{-b}$$

For any given runoff event, either simulated or observed, the time, water/soil ratio, and desorbable P parameters are either known, can be easily measured or calculated. Sharpley (1983) pointed out that the application of Eq (1) is limited if the values of the constants  $K$ ,  $\alpha$  and  $\beta$  must be experimentally determined for a given soil before P desorption can be predicted. Application of Eq (1) is much broader if the values for the constants can be predicted from known or easily estimated soil physical and chemical properties. Therefore, Sharpley (1983) related  $K$ ,  $\alpha$  and  $\beta$  to soil properties and found statistically significant relationships with the ratio of soil Fe/OC and clay to OC for 43 soils collected from throughout the USA. Because the clay and Fe contents of soils have a strong influence on P desorption phenomena, the relationships provided by Sharpley to predict  $K$ ,  $\alpha$  and  $\beta$ , and to subsequently predict P desorption may not accurately represent piedmont soils. Given these considerations, the objectives of this experiment were to determine P desorption characteristics and release pattern of the piedmont rice soils of Bangladesh and if Sharpley's relationship for predicting  $K$ ,  $\alpha$  and  $\beta$  are applicable to piedmont soils and if not, to develop relationships for predicting  $K$ ,  $\alpha$  and  $\beta$  from known or easily measured properties of piedmont soils. Although the research presented here was conducted for only piedmont soils, it

should be applicable to other soils with similar physical and chemical characteristics.

## 2. Materials and Methods

### 2.1. Study of soils

A laboratory experiment was conducted at the Bangladesh Rice Research Institute during 2003 in which 10 soils from piedmont, 3 phosphorus amendments and 9 desorption times were compared in a factorial randomized complete block design with two replications. Ten soil samples used for this study were collected from cultivated rice fields after the harvest of wet season rice (Transplanted Aman) from Hobigonj and Moulvibazar districts of Bangladesh. In the FAO-UNESCO legend, these soils have been classified as Chromi-Dystric and Eutric, Gleysols. According to USDA Soil Taxonomy, these soils have been classified as Typic Haplaquepts and Aeric Haplaquepts. Specific locations and descriptions of the studied piedmont soil samples have been presented in Table 1.

These samples were collected from the surface horizon (A horizon or plow layer) of selected farmers' fields. Soil sand, silt and clay content,  $\text{pH}(\text{H}_2\text{O})$  and  $\text{pH}_{\text{KCl}}$ , organic carbon, dithionite extractable Fe ( $\text{Fe}_\text{D}$ ) and available P were determined by the standard methods. Initial soil properties are presented in Table 2.

### 2.2. Soil amendments

Each of the ten composite soil samples was amended with 100 and 200  $\text{mg P kg}^{-1}$  soil, another treatment was maintained as control. To prepare phosphorus treated samples, a portion of 50 g of each soil samples was taken in polythene bags. To the respective bags,  $\text{KH}_2\text{PO}_4$  @ 100  $\text{mg P kg}^{-1}$  and 200  $\text{mg P kg}^{-1}$  soil with 10 ml distilled water was added. In the control treatment, only 10 ml distilled water was added. After 24 hours, water formed a semi moist belt in the bag. The soil sample in the semi moist belt was mixed thoroughly with the remaining soils of the bag. To allow complete P adsorption, 72 hours were allowed for equilibration.

**Table 1.** Location and description of the studied piedmont soil samples.

Design -ation	Farmer and Village	Upazilla and District	FAO Soil Unit	USDA Soil Family	Soil series
Soil 1	Ajit Paul, Nischintapur	Sreemongal, Moulvibazar	Haplic Alisols	Plinthic Haplustult	Sreemongal loam
Soil 2	Abinash Deb, Nischintapur	Sreemongal, Moulvibazar	Haplic Alisols	Plinthic Haplustult	Sreemongal loam
Soil 3	Hemendra Datta, Nischintapur	Sreemongal, Moulvibazar	Haplic Alisols	Plinthic Haplustult	Sreemongal sandy loam
Soil 4	Ranadhir Datta, Nischintapur	Sreemongal, Moulvibazar	Haplic Alisols	Plinthic Haplustult	Sreemongal sandy loam
Soil 5	Rabindra Deb, Nischintapur	Sreemongal, Moulvibazar	Haplic Alisols	Plinthic Haplustult	Sreemongal sandy loam
Soil 6	Abu Taher, Sirajnagar	Sreemongal, Moulvibazar	Chromi-Eutric Gleysols	Typic Haplaquept	Pritimpasa loam
Soil 7	Afroz Khan, Isobpur	Sreemongal, Moulvibazar	Chromi-Eutric Gleysols	Typic Haplaquept	Pritimpasa loamy sand
Soil 8	Mahram Ali, Haturakandi	Chunarughat, Hobiganj.	Chromi-Eutric Gleysols	Typic Haplaquept	Bijipur silt loam
Soil 9	Poritosh Boidha, Debipur	Kamalgonj, Moulvibazar	Chromi-Eutric Gleysols	Typic Haplaquept	Bijipur silt loam
Soil 10	Monjulal Dhar, Madhabpur	Kamalgonj, Moulvibazar	Chromi-Eutric Gleysols	Typic Haplaquept	Bijipur loam

**Table 2.** Some selected properties of the experimental soil.

Soil no.	Sand (%)	Silt (%)	Clay (%)	pH <sub>KCl</sub>	pH <sub>w</sub>	ΔpH	Org. C (%)	Fe <sub>D</sub> (ppm)	Available P (ppm)
1	28	49	23	4.81	4.69	0.12	3.3	814	14
2	49	38	13	4.85	4.66	0.19	3.12	370	15
3	54	30	15	4.90	4.75	0.15	2.74	574	12
4	54	33	13	4.85	4.74	0.11	2.06	389	11
5	65	28	8	5.01	5.00	0.01	2.42	259	4
6	51	36	13	4.69	5.84	-1.15	3.38	407	4
7	80	15	5	5.10	5.12	-0.02	1.96	333	18
8	26	56	18	4.79	5.25	-0.46	0.96	1018	3
9	29	51	20	5.00	5.41	-0.41	1.62	315	2
10	48	44	8	4.90	6.05	-1.15	1.9	592	9

### 2.3. Desorption study

One g air-dried soil was taken into 25 ml test tube from both the P-treated and untreated soil sample and 20 ml 0.01M CaCl<sub>2</sub> solution was added to it. All the test tubes in a box were shaken for 0.5, 1, 3, 6, 12, 24, 48, 72 and 96 hours and the supernatants were passed through Whatman # 1 filter paper. Inorganic P in the filtrates of each soil extract was determined colorimetrically following the method of Murphy and Riley (1962). Absorbance was determined at a wavelength of 710 nm. The measurement was performed in duplicate on each composited sample from each of the three treatments. The amount of P released was calculated from the difference in P measured between P treated and untreated test tube for each period of shaking. The desorbed P was plotted against shaking time to calculate the rate of release, under room temperature. The desorption data were fitted to the Sharpley's equations as mentioned earlier. Given that Eq (1) is valid and is a power equation, at any given combination of  $W$  and  $P_o$ , the logarithm of  $P_d$  should be linearly related to the logarithm of  $t$  for each soil. The slope of this line is the value of  $\alpha$  for that soil at that combination of  $W$  and  $P_o$ . Similarly, at a given combination of  $t$  and  $P_o$ , the logarithm of  $P_d$  should be linearly related to the logarithm of  $W$  for each soil. The slope of this line is the value of  $\beta$  for that soil at that combination of  $t$  and  $P_o$ . In the final case, at any given combination of  $t$  and  $W$ ,  $P_d$  should be linearly related to  $P_o$ . The slope of this line is the value of  $K$  for that soil at that combination of  $t$  and  $W$ .

### 2.4. Statistical analysis

All measurements of P were done in duplicate, and the data were analyzed by ANOVA using the statistical software IRRISTAT 4.1 (Windows version). Backward-stepwise regression analysis was utilized to evaluate the effect of soil properties on P-desorption.

## 3. Results and Discussion

### 3.1. Phosphorus desorption

The mean values of the desorption of phosphorus from different soils treated with 100 and 200 mg P kg<sup>-1</sup> soil at various period of equilibration are presented in Table 3. The effect of P application (P) and time of desorption (t) on the P desorption was significant. The highest mean P desorption was found (19.17 ppm) in soil 7 and the lowest (1.34 ppm) in soil 8. The variation in extractability in different soils followed the descending order of soil 7 (19.17 ppm), 5 (8.20 ppm), 2 (8.16 ppm), 3 (7.00 ppm), 4 (6.12 ppm), 6 (5.25 ppm), 10 (3.84 ppm), 9 (3.57 ppm), 1 (2.49 ppm) and 8 (1.34 ppm), respectively. The mean value of P-desorption was 2.95 ppm when soil was amended at the rate of 100 ppm P which increased to 10.07 ppm with the application of 200 ppm P. Application of 200 ppm P desorbed more than three-fold higher P than the application of 100 ppm P.

Mean phosphorus desorption was affected with the increase in shaking time although no consistent impact was observed after one hour shaking time. In almost all the studied soils, the highest desorbed P was extracted at one hour shaking time, beyond which there was again re-adsorption in most of the soils although in some soils maximum P-desorption was observed at 24, 48 and 96 hours shaking time. The variable P desorption with time and soils need to be studied in detail. Nonetheless, it can be speculated that the desorption at various shaking time in certain soils may be attributed to the precipitation of desorbed-P with Fe compounds, which eventually came into solution after 24, 48 or 96 hours of shaking.

Barrow (1983) showed that P desorption from soils was influenced by desorption time and the liquid/solid ratio. He also found that the effects of these factors on P desorption from soils incubated with phosphate for different periods were not the same.

**Table 3.** Variation in phosphorus desorption in ten soils as affected by phosphorus amendments and time of shaking.

Soil	n	Desorption (ppm)	Treatment	n	Desorption (ppm)
Soil 1	36	2.49	100 ppm P	180	2.95
Soil 2	36	8.16	200 ppm P	180	10.07
Soil 3	36	7.00	SE		0.06
Soil 4	36	6.12	LSD <sub>0.05</sub>		0.16
Soil 5	36	8.20			
Soil 6	36	5.25	<i>Time(hrs)</i>		
Soil 7	36	19.17	0.5	40	5.90
Soil 8	36	1.34	1	40	7.66
Soil 9	36	3.57	3	40	6.71
Soil 10	36	3.84	6	40	7.16
SE		0.13	12	40	6.44
LSD <sub>0.05</sub>		0.37	24	40	6.57
			48	40	6.56
			72	40	5.26
			96	40	6.38
			SE		0.12
			LSD <sub>0.05</sub>		0.35

**Table 4.** Correlation of desorbed P (ppm) with soil properties at different desorption period and rate of P application.

Soil properties	Desorption time (hour)								
	0.5 hour	1 hour	3 hour	6 hour	12 hour	24 hour	48 hour	72 hour	96 hour
	Desorbed P (ppm) in 100 mg P kg <sup>-1</sup>								
pH (H <sub>2</sub> O)	0.03	-0.36	-0.07	-0.11	-0.18	-0.16	-0.26	-0.32	-0.37
pH (KCl)	0.46	0.46	0.63*	0.63*	0.60	0.60	0.60	0.41	0.44
Δ pH	0.07	0.45	0.21	0.25	0.31	0.29	0.39	0.40	0.45
Org C	0.19	0.25	0.01	0.01	0.08	0.05	0.19	0.32	0.21
Fe	-0.58	-0.56	-0.47	-0.45	-0.44	-0.48	-0.43	-0.63*	-0.24
Clay	-0.68*	-0.63*	-0.71*	-0.67*	-0.66*	-0.70*	-0.53	-0.57	-0.44
	Desorbed P (ppm) in 200 mg P kg <sup>-1</sup>								
pH (H <sub>2</sub> O)	-0.08	-0.44	-0.08	-0.09	-0.19	-0.18	-0.17	-0.29	-0.17
pH (KCl)	0.68*	0.54	0.71*	0.70*	0.68*	0.70*	0.67*	0.59	0.64*
Δ pH	0.23	0.54	0.24	0.25	0.34	0.34	0.31	0.41	0.31
Org C	0.03	0.09	-0.07	-0.04	0.03	0.07	0.05	0.21	0.00
Fe	-0.64*	-0.61	-0.54	-0.53	-0.53	-0.62	-0.51	-0.66*	-0.46
Clay	-0.78**	-0.60	-0.72*	-0.75*	-0.71*	-0.74*	-0.68*	-0.72*	-0.65*

\* = Significant at 5 % level, \*\* = Significant at 1 % level

Desorption of P in a soil is inversely related to the duration of P sorption, content and form of Fe and Al oxides in the soil, soil P sorption capacity, and the portion of soil sorbing capacity that is unoccupied (Frossard *et al.*, 1995). Sui and Thompson (2000) showed that whether or not the soil had been amended with biosolids, for a given extraction period the amount of P desorbed increased as the liquid/solid ratio increased.

The experimental results have indicated that bulk of the phosphorus desorption occur during a slow reaction after the initial rapid reaction. The initial fast reaction occurring within 0.5 to 1.0 hour may correspond to the dissolution of phosphorus from surface phosphate and poorly crystalline or amorphous phosphate reactions products formed in soils. The subsequent slower desorption may be attributed to slow dissolution of the phosphate compounds of soils and relatively less labile phosphorus on the crystalline surface (Evans and Jurinak, 1976). The results on desorption of phosphorus from different soils showed that a single extraction for a definite period of equilibration may not adequately reflect the P supply characteristics of soils. The cumulative desorption of P from soils followed a curve that increased very rapidly from the time zero and then gradually leveled off. The initial steep rise may be attributed to a very fast reaction accounted for desorption of bulk of so-called labile phosphorus.

### 3.2. Correlation of desorbed P with soil properties

Correlation of desorbed P with soil properties at different desorption periods and rate of P application are presented in Table 4. A significant and positive correlation of desorbed P was observed with  $pH_{KCl}$  at different desorption period and rate of P application, especially at 200 ppm P application. On the other hand, a significant and negative correlation of Fe and clay content was observed at both the P application rate. With 100 ppm P application, desorbed P was positively and significantly ( $r = 0.63^*$ ) correlated with  $pH_{KCl}$  at 3 and 6 hours desorption period. At the same application rate

of P, Fe was negatively ( $-0.63^*$ ) correlated with P-desorption only at 72 hours desorption period. A significant and negative correlation of clay content with P-desorption was observed up to 24 hours desorption period for the 100 ppm P application. For example, desorbed P was negatively and significantly correlated ( $r = -0.70^*$ ) with clay content at 24 hours desorption period. More clear and similar trend of correlation of desorbed-P with  $pH_{KCl}$ , Fe and clay content was observed at different desorption period when P was applied at 200 ppm P. For example, with the application of 200 ppm P, a significant and negative correlation ( $-0.78^{**}$ ) of desorbed P with clay content was observed at 0.5 hour desorption period. Other desorption periods also showed the significant negative relationship with clay.

### 3.3. Multiple relationship of P-desorption with different soil properties

Multiple relationships of P-desorption with different soil properties are presented in Table 5. This relationship was made at one hour shaking time with 200 ppm P application. A relationship was found between phosphorus desorption and  $pH_{KCl}$  which focused that phosphorus desorption in piedmont soils was positively affected by  $pH_{KCl}$ . The  $R^2$  value of this equation was 0.21 which indicated that  $pH_{KCl}$  predicts 21% variation of phosphorus desorption in soil. Multiple regression equation of P-desorption with  $pH_{KCl}$  and  $\Delta pH$  is shown in Table 5. This equation also focused that the phosphorus desorption was positively correlated with  $pH_{KCl}$  and  $\Delta pH$ . The  $R^2$  and P value of this regression equation was 0.55 and 0.28, respectively. The  $R^2$  value (0.55) indicated that  $pH_{KCl}$  and  $\Delta pH$  explained about 55 % variability of phosphorus desorption in that soil. With the inclusion of  $\Delta pH$ , the predicted value increased from 21 to 55 %. This indicates that  $\Delta pH$  alone accounted for 34 % variation in phosphorus desorption. The remaining 45 % variation may be accounted for by other soil variables. Inclusion of other variable like organic carbon raised it to 67 % and this along with Fe raised it further to 71 %. Further inclusion of clay content, the prediction

value increased from 71 to 87 %, which means clay content alone could increase the predictability of phosphorus desorption by 16 %. Again, remaining 13 % variation in phosphorus desorption may be due to other soil variables. These results suggest that the  $pH_{KCl}$ ,  $\Delta pH$ , organic carbon and clay content were important soil variables in determining phosphorus desorption in piedmont soils.  $pH_{KCl}$ ,  $\Delta pH$  and organic carbon exercised a positive influence on P-desorption whereas clay content exerted a negative effect.

### 3.4. Relation of phosphorus desorption to soil properties

Sharpley (1983) found that  $K$ ,  $\alpha$  and  $\beta$  were highly correlated with the ratio of extractable Fe/OC and clay/OC. He used these two ratios to represent the interactive specific surface area involved in soil P adsorption and desorption as well as to predict  $K$ ,  $\alpha$  and  $\beta$ . The constant  $\alpha$  represents a P desorption rate term. Mathematically, an increase in  $\alpha$  results in an increase in the rate of desorption. Therefore,  $\alpha$  should be related to those soil properties that affect how quickly P desorbs from soil. In this study,  $\alpha$  values were best correlated to Fe/Clay (Table 6), which is although not similar to what Sharpley observed. This ratio could be used to predict  $\alpha$  values. For the sake of consistency and to minimize the soil analysis required to use Eq (1), we proposed Fe/Clay regression equation (Fig. 1a) to predict  $\alpha$  in piedmont plain and soils with same physical and chemical characteristics.

Vadas and Sims (2002) found that the  $\alpha$  value for P desorption in Delaware soils (USA) was better correlated to the ratio of Fe/OC than Al/OC. They also found that including the OC parameters in the regression equations generally improved the ability to predict  $\alpha$ , although not always significantly. This suggests that the association of OC with Fe or Al hydroxides in soil can increase the rate at which P is desorbed

from soil. This could be because of the ability of OC to maintain Fe and Al hydroxides in poorly crystalline forms that are more susceptible to P desorption (Toor and Bahl, 1999), the replacement of P on soil surfaces with organic anions, or the formation of soluble complexes between Al and organic anions that can prevent reprecipitation of desorbed P (Bhatti et al., 1998).

A soil that has a relatively large capacity to supply P to the soil solution can be considered well buffered against changes in solution P concentrations (Vadas and Sims, 2002). This soil may therefore, exhibit fairly uniform P desorption under various water/soil ratios. Phosphorus desorption in a poorly buffered soil is more influenced by changing water/soil ratios. The value of  $\beta$  for a given soil reflects this buffering phenomenon because it is the exponent for the variable  $W$  in Eq (1). As  $\beta$  increases, dilution of the interacting soil and water has a greater influence on P desorption. Therefore,  $\beta$  should be related to those soil properties that determine a soil's P buffering capacity. Unlike Sharpley (1983), we found that  $\beta$  values in our piedmont soils were not well correlated to the ratios of Fe/OC or clay/OC. In our experiment, Clay/Fe ratio was found as the best relationship between  $\beta$  and soil properties (Table 6). An increase in Clay/Fe ratio represents a decrease in P buffering capacity, and thus a decrease in  $\beta$ . This is consistent with the data in Fig.1b, which shows how  $\beta$  decreases with increasing the ratio of Clay/Fe.

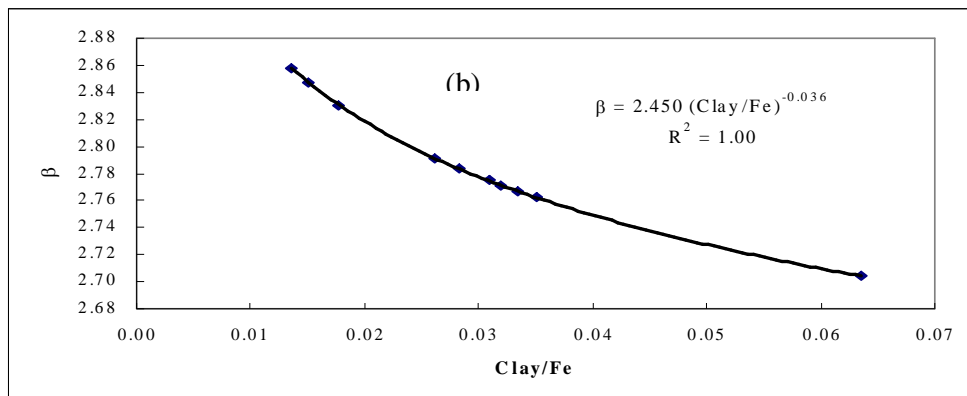
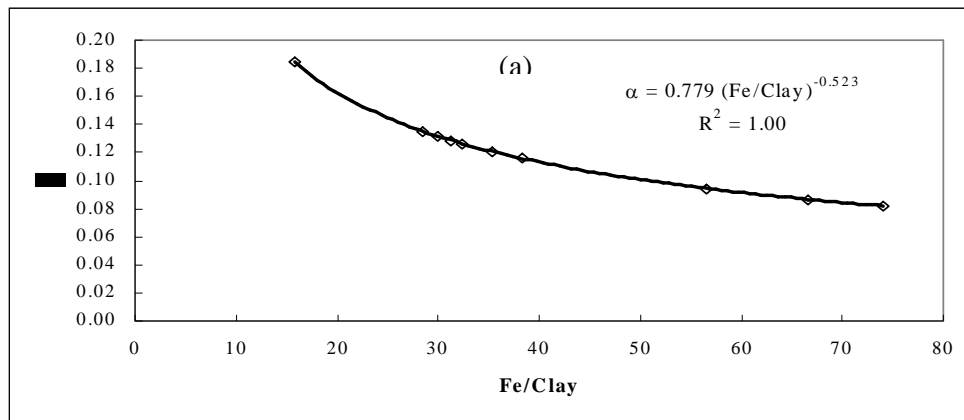
In our experiment,  $K$  values seemed to be best related to soil (Fe + Clay + OC) (Table 6). The constant  $K$  represents a P desorbability or capacity term. It expresses the proportion of available soil P that can be desorbed from a soil for a given time and water/soil ratio. An increase in  $K$  means that the proportion of P desorbed from a soil will also increase.

**Table 5.** Stepwise regression analysis for prediction of P-desorption by different soil properties.

Sl.	Desorption Equation	R <sup>2</sup>	P
1	Desorption = -45.31 + 12.72 pH <sub>KCl</sub>	0.21	0.18
2	Desorption = -32.38 + 9.54 pH <sub>KCl</sub> + 2.11 ΔpH	0.55	0.28
3	Desorption = -58.92 + 15.22 pH <sub>KCl</sub> + 1.24 ΔpH + 1.80 org. C	0.67	0.28
4	Desorption = -27.69 + 8.25 pH <sub>KCl</sub> + 1.75 ΔpH + 1.04 org.C - 0.004 Fe	0.71	0.40
5	Desorption = 6.62 + 0.54 pH <sub>KCl</sub> + 3.17ΔpH + 0.92 org.C - 0.0012 Fe - 0.39 clay	0.87	0.21

**Table 6.** Relationship between the constants of Sharpley’s equation and selected soil properties for piedmont plain soils.

Regression Equations			
α	=	$0.779 (\text{Fe}/\text{Clay})^{-0.523}$	R <sup>2</sup> = 1.00
β	=	$2.450 (\text{Clay}/\text{Fe})^{-0.036}$	R <sup>2</sup> = 1.00
K	=	$0.453 (\text{Fe} + \text{Clay} + \text{OC})^{-0.535}$	R <sup>2</sup> = 1.00





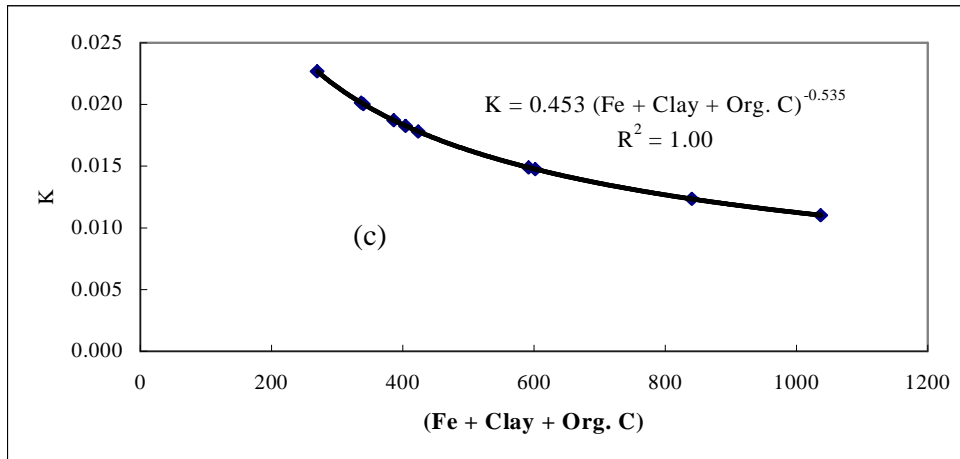


Fig. 1. Relationship between soil properties and the constants (a) a, (b) b, and (c) K for 10 piedmont soils.

This may be attributed to low soil sorption capacity, which in piedmont soils is represented by a low content of (Fe + Clay + OC). This is consistent with data in Fig.1c, which shows that as (Fe + Clay + OC) increases, the P sorption capacity of the soil increases, and the K value subsequently decreases.

In summary, the following equations are proposed for predicting  $\alpha$ ,  $\beta$ , and K values for piedmont soils and similar soil types at any place:

$$\alpha = 0.779 (\text{Fe/Clay})^{-0.523} \dots\dots\dots(2)$$

$$\beta = 2.450 (\text{Clay/Fe})^{-0.036} \dots\dots\dots(3)$$

$$K = 0.453 (\text{Fe} + \text{Clay} + \text{OC})^{-0.535} \dots\dots\dots(4)$$

The relationship between soil properties and the values of  $\alpha$ ,  $\beta$  and K as described by Eq (2) through (4) were all statistically significant and all coefficients in Eq (2) through (4) were also statistically significant. Even though Eq (2) through (4) were determined using data from only piedmont soils, they may be applicable to similar soil types in any place of Bangladesh. It is important to emphasize that those relationship developed by Sharpley (1983) to predict  $\alpha$ ,  $\beta$  and K should still be used for soils that are chemically and physically similar to the ones he used. For soils that are similar to our piedmont soils, Eq (2) through (4) may provide a better prediction of  $\alpha$ ,  $\beta$  and K and thus of P desorption.

### 3.5. Predicting phosphorus desorption

To determine the accuracy of the relationships of  $\alpha$ ,  $\beta$  and K for piedmont soils, Eq (1) was tested for its ability to predict P desorption. First,  $\alpha$ ,  $\beta$ , and K were calculated for the 10 piedmont soils. Values for  $t$  and  $W$  in Eq (1) were taken from the specific methods of our desorption experiments, and values for  $P_o$  in Eq (1) were taken from the quantities of desorbable P as measured in all soils before the desorption experiments. Then Eq (1) was used to predict P desorption for all soils and the combinations of specific  $t$ ,  $W$  and  $P_o$ . The predicted amounts of P desorbed were then compared with the amounts of P desorbed as measured during the desorption experiments. Fig. 2 shows that using Sharpley's equations for Piedmont soils resulted in a strong relationship ( $R^2 = 0.86$ ) between measured and predicted P desorption. These results suggest that the equations recommended by Sharpley to predict values for  $\alpha$ ,  $\beta$  and K provide a good prediction of P desorption for our piedmont soils or soils that are similar to our Piedmont soils. Therefore, Eq (2) through (4) will likely provide a better prediction of P desorption for Piedmont soils or similar soil types in Bangladesh condition.

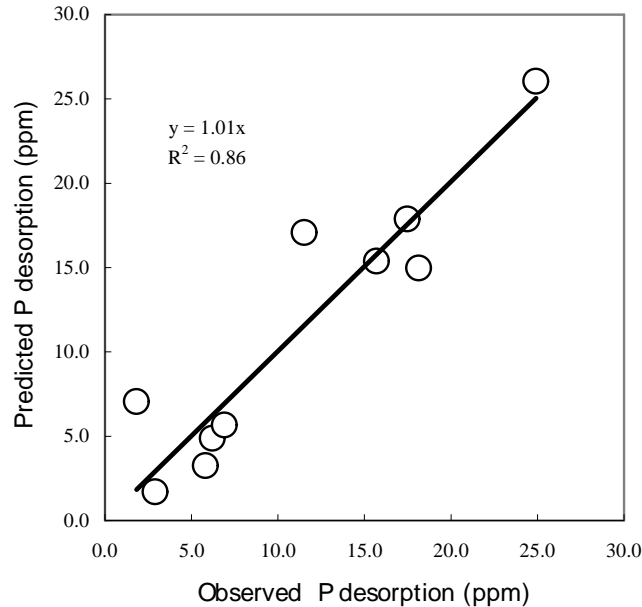


Fig. 2. Relationship between P desorbed estimated from the values a, b and K calculated from organic carbon, clay, iron and desorbable P and P desorbed as measured under experimental conditions for ten piedmont soils.

#### 4. Conclusions

The desorption of P by Bray's extractant was observed to vary significantly ( $P = 0.000$ ) in different studied soils. The highest P desorption was found in soil 7 and the lowest in soil 8. Soil properties, particularly,  $\Delta\text{pH}$ , organic carbon and clay content were important soil variables in determining phosphorus desorption in piedmont soils. The increase in  $\Delta\text{pH}$  and organic carbon increased P desorption, while an increase in clay and Fe tended to decrease in P desorption. New power functions for the parameters of famous Sharpley's equation have been proposed and were tested for better prediction of P desorption in Piedmont soils of Bangladesh

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