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Research Paper

Correlations of available phosphorus and potassium with pH and organic matter content in the different forested soils of Chittagong Hill Tracts, Bangladesh

Imam Hossain*, K.T. Osman, Abul Kashem & Ashoka Sarker

Department of Soil Science, University of Chittagong, Chittagong -4331, Baangladesh
*Corresponding author. Email: mihossain@cu.ac.bd

Abstract: Altogether 300 soil samples, from surface and subsurface, were collected from Chittagong Hill Tracts, Bangladesh under different land use system like forest, orchard & shifting cultivation etc. Among those samples, 60 surface soil (0 to 15 cm.) samples under 4 different forest tree species like Teak (*Tectona grandis*), Jarul (*Lagerstroemia speciosa*), Gamar (*Gmelina arborea*) & Mahogany (*Swietenia mahagony*) were selected to analyze the soil pH, organic matter content, available phosphorus and available potassium for each land use system. The mean values of available phosphorus, available potassium, organic matter content and pH were calculated along with the soil texture determination. In addition, the simple linear correlations between available phosphorus-organic matters, available potassium-organic matter, available phosphorus-pH, available potassium-pH and organic matter-pH were calculated for all the land use system. The significance of the simple linear correlation was tested under 0.05 and 0.01 level of significance. The study revealed that there is a strong negative correlation between the available phosphorus and organic matter content in the soils of Jarul (*Lagerstroemia speciosa*) forest. The correlations of available phosphorus and potassium with pH and organic matter content remain non-significant in all other test cases. However there was a non-significant but positive trend of correlation between organic matter content and potassium in the soils under Gamar forests. There is no any significant correlation of soil pH with available phosphorus, available potassium or soil organic matter content.

Key words: Forest soil, phosphorus, potassium, organic matter, Chittagong, Hill Tracts

INTRODUCTION

Soil pH and organic matter content strongly affect soil functions and plant nutrient availability. Specifically, pH influences chemical solubility and availability of plant essential nutrients, soil management performance and organic matter decomposition. To understand plant nutrient availability and optimal growing conditions for specific plant, it is important to understand soil chemistry and interacting factors that affect soil pH (McCauley *et. al.*, 2009). Therefore the soil pH is one of the determining factors in the plant nutrient availability in the soil. The pH of forest soils varies from 4.0 to 8.5 under different plant species (P.R. Hesse, 1994). The essential range of soil pH is 5.5 to 7.0 for the appropriate growth and development of most of the plants (S.S.Singh, 1995). Most of the plant nutrients are available at slightly acidic to slightly alkaline soil (pH 6.5 to 7.5). A number of plant nutrients are unavailable at extremely acidic or extremely alkaline soils due to the different reactions in the soil which fix the nutrients and transform them to the state that is unavailable for the plants (N.C.Brady, 1984).

Soil organic matter (SOM) is defined as the summation of plant and animal residues at various stages of decomposition, cells and tissues of soil organisms, and well-decomposed substances (Brady and Weil, 1999). Soil organic matter serves multiple functions in the soil, including nutrient storage and soil aggregation. Soil organic matter levels have declined over the last century in some soils as a result of intense agricultural practices, over-grazing on grasslands, deforestation and conversion of forest to tilled farmland. This reduction has lead to decreased soil fertility, increased fertilization needs, and increased soil erosion in some areas including the Chittagong Hill Tracts, Bangladesh. Furthermore, soil organic matter has been recognized as the key indicator of soil quality due to its role to maintain soil fertility and productivity.

The consequence of the organic matter in soil may be either direct or indirect. Organic matter acts directly as a source of plant nutrients and indirectly influences the other soil physical and chemical properties. Increasing the organic matter content in the soil enhances the plant nutrients availability and helps to improve the overall physical and chemical properties. Soil organic matter content is up to 5 percent in normal forest soils or agricultural soils while it could be up to 30 percent in the organic soils (Brady and Weil, 2002).

The aim of this research is to study the correlations of available phosphorus (P) and potassium (K) with pH and organic matter content in the different forested soils of Chittagong Hill Tracts, Bangladesh.

MATERIAL AND METHODS

Location

Chittagong Hill Tracts is about 13,184 sq km, which is more than one-tenth of the total land area of Bangladesh. Chittagong Hill Tracts (CHT) is the only wide-ranging hilly area in Bangladesh in the southeastern part of the country between 21° 25' N to 23° 45' N latitude and 91° 54' E to 92° 50' E longitude. It borders with Myanmar on the southeast, the Indian state of Tripura on the north, Mizoram on the east and Chittagong district on the west. The hills range in height from several meters to 1,000 meters from the sea levels above the mean sea level and are steep to very steep sloped having a rather youthful soil mantle ranging from a few centimeters to several meters thickness over bedrocks.

The weather of this region is characterized by tropical monsoon climate with mean annual rainfall about 2540 mm in the north and east and 2540 mm to 3810 mm in the south and west. The dry and cool season is from November to March; pre-monsoon season is April-May which is very hot and sunny and the monsoon season is from June to October, which is warm, cloudy and wet. More than 80% of rainfall is received in 4 months from June to September of peak monsoon. The region is characterized by a huge network of drainage channels (locally known as "Jhiri") consisting of some major rivers draining into the Bay of Bengal. The major rivers are the Karnafuli, the Sangu, the Matamuhuri and the Feni River.

Soil Sampling

Soil Sampling was carried out between the April-2009 and June-2009 from the all three districts of Chittagong Hill Tract, Bangladesh. There were 17 sites and each site was an individual hill with variable slopes, distinctive forest type and a considerable elevation. Totally 300 soil samples were collected under various land use system of that hilly regions like forest, orchard & shifting cultivation etc. From which only 60 surface (0-15cm) soil samples under 4 forest tree species (Table-1) like Teak *(Tectona grandis),* Jarul (*Lagerstroemia speciosa*)*,* Gamar *(Gmelina arborea) &* Mahogany (*Swietenia mahagony*) were considered for this study to analyze the available phosphorus, potassium, organic matter content and soil pH.

Table 1. Categories of soil samples under different forest

SL.	Categories of soils under different forest	Number of samples taken
1	Teak *(Tectona grandis)*	24
2	Jarul (*Lagerstroemia speciosa*)	09
3	Gamar *(Gmelina arborea)*	15
4	Mahogany (*Swietenia mahagony*)	12
	Total no. of soil samples analyzed	60

Soil analysis

Collected soil samples were air dried ground and sieved through a 2 mm sieve. Particle size analysis was done by hydrometer method (Bouyocos 1962 and Piper 2005). Soil pH was recorded by corning (Model-7) glass electrode pH meter from soil water suspension at the ratio of 1:2.5. Soil organic matter (OM) content was determined by the wet oxidation method of Walkley and Black (Walkley and Black 1934). Available soil phosphorus (P) was determined by Modified Olsen's bicarbonate method using $NaHCO_3$ (Olsen *et. al.*, 1954). Available soil potassium (K) was estimated by the using of a flame photometer after the nutrient extracted from the soil using 1N ammonium acetate (NH_4OAc) (Jackson 1967).

Statistical analysis

The correlation of the analyzed soil nutrients with evaluated soil chemical properties were calculated and compared using MINITAB statistical software (Version 13.2) and Microsoft Excel-2007.

RESULTS AND DISCUSSIONS

Soil physical properties

Soil texture: Four soil textural classes were determined from the soil samples of studied land use system such as sandy loam, loam, sandy clay loam and clay loam. The highest mean value for sand, silt & clay were found under Teak (56.40 ±1.89%), Jarul (31.43 ±1.46%) & Mahogany (27.40 ±1.99%) respectively. On the other hand, the lowest mean value for sand, silt & clay were found under Jarul (42.65 ±2.54%), Teak (20.10 ±1.34%), & Teak (23.51 ±1.15%) respectively (Table-2).

Table 2. Mean values for the percentage of soil particles under each type of land use.

Tree species	%Sand	%Silt	%Clay
Teak (n=24)	56.40 ±1.89	20.10 ±1.34	23.51 ±1.15
Jarul (n=9)	42.65 ±2.54	31.43 ±1.46	25.93 ±2.06
Gamar (n=15)	45.96 ±1.38	28.30 ±1.48	25.93 ±1.12
Mahogany (n=12)	44.82 ±2.35	27.78 ±2.11	27.40 ±1.99

Note: ± indicates the standard error of mean.

Soil chemical & nutritional properties

After the soil analysis, the soil pH status under different forested soils were classified into four descriptive ranges such very strongly acidic, strongly acidic, moderately acidic and slight acidic according to the "Soil survey manual, 1993". The percentage of soil samples under these descriptive ranges are given in Table 3. The minimum and maximum values of all evaluated soil chemical and nutritional properties are also shown in Table-4.

Soil pH: The highest (6.50) and lowest (4.60) soil pH value was estimated under the soils of Teak forest. Another lowest pH value (4.60) was found in the soils of Mahogany forest (Table-4). The mean pH calculation was within the strongly acidic range (5.1 to 5.50) with a lowest mean value of 5.2889 ±0.0857 in Jarul forest while the highest mean pH value was 5.4625 ±0.0980 in soils under Teak forest (Table- 5). Total four soils acidic range was measured in the studied soil samples such as very strongly acidic, strongly acidic, moderately acidic and slight acidic (Table- 3).

Table 3. Soil pH status under different forest

Tree Species	Percentages of soil samples under four pH range			
	Very strongly acidic (4.5-5.0)	Strongly acidic (5.1-5.5)	Moderately acidic (5.6-6.0)	Slight acidic (6.1-6.5)
Teak	21	42	25	13
Jarul	22	67	11	0
Gamar	7	53	40	0
Mahogany	17	50	33	0

(Soil survey manual, 1993)

Table 4. Max and min values of soil properties under different land use

Soil parameters	Teak	Jarul	Gamar	Mahogany
pH	4.60-6.50	5.00-5.70	5.00-5.80	4.60-6.00
OM (%)	0.980-3.270	1.030 -2.920	1.69-3.320	1.8000-3.0100
P-Olsen (ppm)	0.720-7.150	3.910-9.810	1.48-8.63	4.250-11.580
K (ppm)	31.00- 273.00	77.00-168.00	80.00-375.00	82.00-293.00

Table 5. Means of different soil parameters under different land use

Soil parameters	Teak (n=24)	Jarul (n=9)	Gamar (n=15)	Mahogany (n=12)
pH	5.4625 ±0.0980	5.2889 ±0.0857	5.4400 ±0.0608	5.354 ±0.104
OM (%)	1.963 ±0.12	1.624 ±0.213	2.436 ±0.131	2.3383 ±0.0940
P-Olsen (ppm)	4.523 ±0.337	7.227 ±0.744	4.497 ±0.599	7.337 ±0.565
K (ppm)	114.79 ±9.86	121.40 ±13.50	163.70 ±21.20	158.60 ±18.00

Soil organic matter content: The range of organic matter content is medium to high in soils under Gamar species but it is low to high in soils under rest of the species (Table- 4). The mean organic matter content is also highest (2.436 ± 0.131%) in soils under Gamar species and it is lowest (1.624 ± 0.213%) in soils under Jarul forest (Table-5). Soil organic matter content in studied soils is medium under all tree species except some lowest values (0.980%) found in Teak forest. The highest soil organic matter content (3.320%) was determined in the soils of Gamar forest.

Available phosphorus content in the soil: The range of the available phosphorus is low to very low in all the studied soils under different tree species. The mean available phosphorus is highest (7.337 ±0.565 ppm.) in the soils under Mahogany forest while it is lowest (4.497± 0.559 ppm.) in the soils under Gamar forest (Table-5). The highest value (11.580 ppm) for available soil phosphorus was recorded in the soils of Mahogany forest and the lowest value (0.720 ppm) found in the soils of Teak forest (Table-4). Study shows that the phosphorus availability is higher in slightly acidic soil than in the very strongly acidic soil. Lower the pH, more available are the metallic ions, especially Mn, Fe and Al. These elements then combine with soluble P and form insoluble compounds (B. Lalljee, 1997). The limited microbiological activities in the very strongly acidic soil also reduce the soil available phosphorus (Havlin *et. al.*, 1999).

Available potassium content in the soil: The range of estimated available potassium (K) is low to high in rating in all the soil under four plant species. The mean value on potassium availability is the highest (163.70 ± 21.20 ppm.) in the Gamar forest soil and is the lowest (114.79 ± 9.86 ppm.) in the Teak forest soil (Table-5). The lowest value (31.00 ppm.) of available potassium measured in the soil of Teak forest while the highest value (375.00 ppm.) found in the soils of Gamar forest (Table-4). The potassium content decreases with the decrease in soil pH from slightly acidic to strongly acidic in reaction and very strongly acidic in reaction.

Correlations between soil pH and organic matter content: The correlation coefficient between soil pH and organic matter content is negative and non-significant at studied forest soils except the positive non-significant value in the soils of Gamar forest (Table-6). It is the highest (r = -0.458) under the soils of Jarul forest while it is the lowest (r = -0.013) in Mahogany forest soil.

Correlations of soil pH with available phosphorus and potassium: The correlation of soil pH with available phosphorus is non-significant in all the studied soils of different forest (Table -6). It is positive in all the studied soils except the Gamar forest soil. The value is the highest (r = 0.416) in Mahogany forest while it is the lowest (r = 0.076) in the soils of Teak forest.

The correlation between soil pH and available potassium is also non-significant at all the studied forest soils (Table-6). It is positive in all the soil samples. The value is the highest (r = 0.211) in the soils of Mahogany forest and the lowest (r = 0.086) in Teak forest.

Correlations of soil organic matter content with available phosphorus and potassium: The correlation coefficient between organic matter content and available phosphorus is negatively significant (r = -0.753**) for the soils under Jarul forest. It is non-significant for the rest soil samples with another negative value for teak forest. It is also highest (r = -0.753**) in Jarul forest while the lowest (r = 0.155) correlation coefficient measured under the soils of Gamar forest (Table-6).

The correlation coefficient for organic matter content and potassium is positive and non-significant for all the soil samples. The correlation coefficient is highest (r = 0.558) in the soils of Jarul forest and it is lowest (r = 0.071) in the Teak forest soil (Table-6).

Table 6. Simple linear correlations among the different parameters of four forested soil.

Soil parameters	Teak	Jarul	Gamar	Mahogany
pH - OM	-0.328	-0.458	0.215	-0.013
pH - P (Olsen)	0.076	0.399	-0.365	0.416
pH - K	0.086	0.135	0.166	0.211
OM - P (Olsen)	-0.209	-0.753**	0.155	0.212
OM - K	0.071	0.558	0.446	0.410
P (Olsen) - K	0.201	-0.028	0.053	0.499

Note: **Significant at < 0.001 percent level

Correlations between available phosphorus and potassium: The correlation coefficient between two nutritional properties like phosphorus and potassium of studied soils from four forests became non-significant. The correlation is positive for all the soils except the soils under Jarul forest. It is highest (r = 0.499) in the Mahogany forest while it is lowest (r = -0.028) in the soils of Jarul forest (Table-6).

CONCLUSIONS

The present study revealed that available Phosphorus, available potassium & organic matter content of the studied soils are lowest in the Teak forest due to the lack of forest under growth and nutrients depletion through erosion and run off. Some dramatically peak values of available soil potassium found due to the burning ash in the Teak forest for Jhum (shifting) cultivation. Soil under Mahogany and Gamar forests are comparatively rich in Phosphorus and potassium. The soil pH range is more widely variable in the soils of Teak and Mahogany forests than that of Jarul and Gamar.

The correlations of available phosphorus and potassium with pH and organic matter content remain non-significant in all the test cases except a negatively significant correlation (p = 0.019) between organic matter content and phosphorus in the soils of Jarul forest. Another positive trend of correlation found between organic matter content and potassium in the soils of Gamar forest.

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