Journal of Pharmacognosy and Phytochemistry
Available online at www.phytojournal.com

E-ISSN: 2278-4136
P-ISSN: 2349-8234
www.phytojournal.com
JPP 2020; Sp9(3): 01-04
Received: 16-01-2020
Accepted: 20-02-2020

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Characterization of soil profile in Sal forest of Nayagarh district in Odisha

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Abstract
The important physical and chemical properties of soil profile were studied under natural Sal forest near Krishi Vigyan Kendra, Nayagarh of Odisha. Soil samples were collected from 0-15, 15-30, 30-45,45-60, and 60-75cm depths of exposed soil profile in Sal forest. Soil samples were air-dried, ground, passed through 2mm sieves and preserved for necessary physical and chemical analysis. Soil texture at different layers of the profile varied from sand to sandy loam. Sand, silt and clay content varied from 8.8 to 11.4% respectively in the profile. Bulk density of the soils varied from 1.42 to 1.48 g/cm3 at different layers of the profile. Particle density remained constant (2.66g/cm3) across the profile. Pore space varied between 44.4-46.7% and water holding capacity from 29.8 to 34.2% in different layers of the profile. Soils at different layers of the profile were moderately to slightly acidic (5.64-5.89). Electrical conductivity of the soil ranged from 0.417-0.419 dS/m in all the layers. Percent organic carbon was low in the profile varying from 0.134 to 0.345%. Mineralizable N, available P and available K in different layers of the profile under natural Sal forest varied from 43.8 to 62.5mg/kg, 0.57 to 1.41mg/kg and 51.7 to 77.5 mg/kg respectively. All those nutrients changed inconsistently with soil depth. These light texture soils with low fertility status need application of nutrient management regime for improving soil fertility for intercropping with medicinal, horticultural and other plant species for best utilization of these forest lands.

Keywords: Physico-chemical property, soil profile, correlation, Shorea robusta

Introduction

Forest covers 1/3 rd of the total geographical area of the world. Forest provides important products like timber, fuel, rubber, paper, medicinal plant, Ntfps etc. and services eg. mitigating climate change, storing carbon, providing oxygen, renewable energy and soil and water conservation. Forest is the one of the important biologically diverse ecosystem provides livelihood for 60 million indigenous people and 1.6 billion people depend on forests for their livelihood. The forests of Odisha are endowed with many useful plants like timber species, orchids, medicinal & aromatic plants and Ntfp plants. The forest of the state is rich in large number of timber yielding species of which Sal (*shorea robusta*) dominates with about 43% of the total forest cover and is a common forest species of Odisha. The Forest Cover in the State is 51,618.51 sq km, which is 33.15% of the State's geographical area. Nayagarh district has a forest coverage of 44.49% with 1,713.75 km2 of forest area (India State Forest Report, 2019).

Accumulation of leaf litters, removal of nutrients by the tree species up to a greater soil depth and mobilization of nutrients in the profile have specific effects on the physical, chemical properties and nutrient contents in the forest soil profile. The rate of decomposition of the leaf litters depends on the type of forest species, soil type and prevailing climatic conditions. Organic matter content in the soil reduces the bulk density making the soil more porous and loose, improves the soil aeration and increases the rate of infiltration and percolation of water into the soil. It increases the water holding capacity of the soil and leads to favourable aggregate formation which improves the physical condition. During decomposition of organic matter, several organic acids are released making the soil reaction acidic. Due to loss of electrolytes, organic colloids disperse and move to lower part of the soil profile and get precipitated. Accumulation of organic colloids down the profile also influences the physical and chemical properties of the soil. Formation of clay humus complex in soil significantly influences the soil properties. It increases the organic matter content by protecting from microbial decomposition. Soil properties also change with depth of the profile, type of forest species, stand age and afforestation. Zhang *et al.* (2012) [6] observed that afforestation with *Eucalyptus grandis* increased the soil organic matter, CEC, C: N ratio and microbial biomass with time in the upper soil layer. Total exchangeable base and base saturation in soil decreased significantly with depth and increasing age of the stand. The present investigation was undertaken to study the physical and chemical properties of soil profile under natural Sal forest which would be helpful for soil and nutrient management in the forest area for plantation and intercropping of medicinal, horticultural or forest plants.

Materials and Methods

Soil profiles were selected in the naturally regenerated Sal forest areas near KVK Nayagarh. The naturally regenerated Sal forests are of more than 30 years. The profiles were exposed and soil samples were collected from 0-15, 15-30, 30-45, 45-60, 60-75cm depths. Soil samples were air dried, ground and passed through a 2mm sieve. The sieved samples were preserved in polythene bottles for necessary laboratory analysis. Mechanical composition of soil was determined by Bouyoucos hydrometer method (Piper, 1950) [4]. Bulk density, particle density and percentage pore space in soil was determined by cylinder method. Water holding capacity of soil was determined by Ken Raczkowski box measurement. Soil pH was determined in 1:2 soil water ratio by a glass electrode Elico pH meter. Electrical conductivity (EC) was measured in 1:2 soil water ratio. The contents were stirred several times during a period of 2hrs and was allowed to stand till soil particles completely settle down. The supernatant was filtered and conductivity of the filtrate was measured by Elico pH Conductivity Bridge. Organic carbon (OC) was determined by Walkley and Black method of rapid titration (Piper, 1950) [4]. Mineralizable nitrogen in soil was determined by alkaline KMnO4 method (Subbiah and Asija 1956) [5]. Available phosphorus in the extract was determined by Chlorostannous reduced molybdophosphoric blue colour method in hydrochloric acid system (Jackson 1973) [3]. Intensity of blue colour was measured at 660 nm wave length by an UV-VIS spectrophotometer. Available Potassium in the soils was determined in the neutral NNH4OAc extract of soil by a Flame Photometer (Jackson, 1973) [3].

Results

It was observed that soil texture was loamy sand in the surface layer and changed to sandy loam in the subsequent layers. Sand content was maximum (83.4%) in the 1st layer and minimum (82.0%) in 5th layer (Table-1). Silt content in the 1st layer was highest (7.8%) and lowest (5.9%) in the third layer. Clay content in the surface layer was 8.8% and it gradually increased to 11.4% in the 5th layer. Bulk density (BD) of the soil in the 1st to 4th layer of profile was 1.42g/cm3 and is slightly increased to 1.48 gm/cm3 in the 5th layer. Particle density of the layers of the soil profile under Sal forests remained constant at 2.66gm/cc. Percent pore space in the 1st to 4th layer of profile was 46.7% which slightly decreased to 44.4% in the 5th layer. Water holding capacity of the soils at different layers of the soil profile varied from 29.8 to 34.2%. It was 33.2% in the surface layer and changed irregularly with depth to 29.8% in the 5th layer.

Table 1: Physical properties of the soils in different layers of the soil profile in the Sal forest area

Layers	Depth(cm)	Sand (%)	Silt (%)	Clay (%)	Texture	BD (gm/cc)	PD (gm/cc)	PS (%)	WHC (w/w) (%)
1st	0-15	83.4±.14	7.8±.16	8.8±.37	Loamy sand	1.42±.57	2.66±.01	46.7±.14	33.2±.09
2nd	15-30	83.3±.37	6.9±.15	9.8±.66	Sandy loam	1.42±.16	2.66±.05	46.7±.61	34.2±.18
3rd	30-45	83.3±.71	5.9±.47	10.8±.47	Sandy loam	1.42±.41	2.66±.13	46.7±.85	30.6±.18
4th	45-60	82.0±.94	6.6±.57	11.4±.28	Sandy loam	1.42±.14	2.66±.06	46.7±.42	34.0±.33
5th	60-75	82.0±.85	6.6±.18	11.4±.57	Sandy loam	1.48±.34	2.66±.11	44.4±.72	29.8±.23

Soil pH varied from 5.64 to 5.89 in layer-5 and 4 respectively (Table-2). It was 5.74 in the 1st layer and 5.64 in the 5th layer. Electrical conductivity of the soils varied from 0.417 to 0.419 ds/m. Organic carbon content at different layers varied from 0.134 to 0.345%. It was 0.249% in the surface layer and changed irregularly with depth in the profile.

Table 2: Chemical properties of the soils in different layers of the soil profile in the Sal forest area

Sl. No.	Depth (Cm)	pH (1:2)	EC (ds/m)	% OC
1	0-15	5.74±94	.417±.02	.249±.09
2	15-30	5.72±.47	.417±.09	.345±.04
3	30-45	5.80±.52	.417±.08	.134±.01
4	45-60	5.89±.23	.418±.05	.172±.02
5	60-75	5.64±.47	.419±.14	.153±04

Mineralizable N content varied from 43.8 to 62.5 mg/kg (Table-3).It was 43.8 mg/kg at the 1st layer and changed inconsistently with soil depth to 62.5 mg/kg in the 5th layer. It was 62.5 mg/kg in the surface layer and changed irregularly with soil depth to 81.3 mg/kg in the 5thlayer. Available P content determined in Bray's extract varied from 0.57 to 1.41 mg/kg at different layers in the profile. It was 0.85 mg/kg in the 1st and 2nd layer, 0.57mg/kg in the 3rdand 4thlayer and 1.41 mg/kg in the 5thlayer. Available K content at different layers in profile varied from 51.7 to 77.5mg/kg. It was 71.2 mg/kg in the surface layer and changed inconsistently with soil depth to 53.1 mg/kg in the 5th layer.

Table 3: Mineralizable N, available P and available K content in different layers of the soil profile in the natural Sal forest area

Layers	Depth (cm)	Mineralizable N (mg/Kg)	Available P (mg/kg)	Available K (mg/kg)
1st	10-15	43.8±.47	0.85±.02	71.2±.57
2nd	15-30	50±.33	0.85±.01	77.5±.24
3rd	30-45	50±.38	0.57±.15	75.3±.57
4th	45-60	43.8±.47	0.57±.08	51.7±.71
5th	60-75	62.5±.24	1.41±.19	53.1±.66

Interrelationship among different soil characteristics were studied (Table-4). % Sand was negatively correlated with % clay (r = -0.927**). Bulk density of the soil was positively correlated to % sand (r =0.567*) and negatively correlated to % clay (r = -0.558*), percent organic carbon (r = -0.699**) and % pore space (r = -0.940**). Percent pore space in soil was positively correlated with % clay (r = 0.603*), % organic carbon (r = 0.644**) and negatively related to %sand (r = -0.606*). Water holding capacity of the soil was positively correlated with % clay (r = 0.562*), % organic carbon (r =0.655**) and % pore space (r= 0.319*) but was negatively correlated with % sand (r = -0.573*). Percent organic carbon the soil was positively correlated with % clay (r = 0.882**). A negative correlation existed between % organic carbon and mineralizable N in soil (r = -0.617*) indicating that organic carbon is not an index of mineralizable N content in the soil. Available phosphorus was negatively correlated with % clay (-0.539*).

Table 4: Correlationship coefficient (r) values among different soil characteristics

%Sand	vs	%Clay	-0.927**
BD	vs	% Sand	0.567*
BD	vs	% Clay	-0.558*
BD	vs	% Organic carbon	-0.699**
BD	vs	% PS	-0.940*
%PS	vs	% Sand	-0.606*
%PS	vs	% Clay	0.603*
%PS	vs	% Organic carbon	0.644**
WHC	vs	%Sand	-0.573*
WHC	vs	%Clay	0.562*
WHC	vs	% Organic carbon	0.655**
WHC	vs	%PS	0.319*
OC	vs	%Clay	0.882*
Mineralizable N	vs	% Organic carbon	-0.617*
Available P	vs	% Clay	-0.539*

Discussion

Clay content in the profiles increased slightly with depth indicating that the profiles are yet to be matured. Increase in clay content with depth was due to migration of the dispersed clay particles from surface down the profile. There was little variation in the bulk density of the soils at different layers in the profile. This was due to small variations in sand and clay content in the profile. Particle density of the soils was 2.66 g/cm3 in the profile indicating the dominance of quartz, feldspar, mica and the silicate clays in the mineral fraction of soil. There was small variation in percent pore space in soil in the profile which might be due to small variation in sand and clay contents in the profile. The small variation in water holding capacity of the soils in the profile might be due to low organic carbon content and a narrow difference in sand and clay contents at different layers of the profile. Soil pH in profile showed that the soils at different layers were moderately acidic. Electrical conductivity in different layers was very low in the profile indicating that the soils were almost free of soluble salts. Organic matter content was low in different layers of the profile in spite of continuous accumulation of leaves. This might be due to rapid decomposition of organic matter because of intense microbial activities due to light texture soils with improved soil aeration. Mineralizable N content in the soils were low which might be due to low protein fraction in the soil organic matter. Nitrogen being a mobile element is also less returned to soil through leaf fall. Available P content in the soils was very low. Phosphorous being a mobile element, is less returned to soil through leaf fall than absorbed by the tree from soil. Available K content in the soils was very low which might be due to greater absorption of K by the trees and less return to the soil through leaf fall since K is a mobile element. Besides the leaching loss of K is high since the soils were sand to sandy loam in texture.

The negative relationship between sand and clay is due to decrease in sand and increase in clay content with depth in the profiles. Bulk density of the soil was positively correlated with % sand and negatively correlated with % clay, since % pore space in soil decreases with increase in sand content but increases with increase in clay content. Negative correlation between bulk density and % organic carbon was due to increase in pore space with increase in organic carbon content. A highly significant negative correlation between BD and % pore space has also been obtained in this experiment. Per cent pore space in soil was negatively correlated with % sand but positively correlated with % clay. The heavier sand particles lie close to each other reducing the total pore space in the soil. On the other hand the lighter clay particles do not come so close to each other. Besides the clay particles lead to aggregate formation and much of the pore space exist within the aggregates and among the aggregates. With increase in organic carbon content in the soil, % pore space increases. A positive correlation has, therefore, been obtained between % pore space and % organic carbon in the soil.

Water holding capacity of the soils was negatively correlated with % sand but positively correlated with % clay and % organic carbon. This was due to decrease in pore space with increase in sand content and increase in pore space with increase in clay and organic matter contents. Water holding capacity also increased with increase in %pore space as was established in the finding. A highly significant positive correlation was obtained between % organic carbon and % clay. This was due to increase in the formation of clay humus complex with increase in clay content. The formation of this complex protects humus from further decomposition. Negative correlation between mineralizable N and % organic carbon indicated that organic carbon is not an index of mineralizable N in soil. Negative correlation between available P and % clay obtained might be due to increase in phosphate fixation with increase in clay content in soil. Das (1992) [1] reported strong positive correlation between clay and phosphate fixing capacity of the soil. These light textured soils with low fertility status need specific management for reviving the growth of existing forest, for intercropping with medicinal, horticultural or forest plant species for best utilization of these forest lands.

Conclusion

Some of the important physical and chemical properties of Sal forest soil profiles near Nayagarh Krishi Vigyan Kendra (KVK, Nayagarh) of Nayagarh district were studied. The naturally regenerated Sal forest in Nayagarh was more than 30 years old. There are irregular spacing among the Sal trees. Soil profiles were exposed in the month of May and samples were collected from 0-15, 15-30, 30-45, 45-60, 60-75 cm depths. The collected soil samples were air-dried, ground and passed through 2mm sieve. The sieved soil samples were preserved in polythene bottles for necessary laboratory analysis. The profile was sand to sandy loam in texture at different layers. Clay content in the surface layer of profile was 8.8% which slowly increased to 11.4% in the 5th layer. Bulk density in profile varied from 1.42 to 1.48 g/cc at different layers. Particle density of the soil was 2.66g/cc in all the layers of the profile indicating the dominance of quartz, feldspar, mica and silicate clays in the mineral fractions of the soil. Percent pore space varied from 44.4 to 46.7 in different layers. Water holding capacity of the soils varied from 29.8 to 34.2% in different layers of profile. The small variations in % pore space and water holding capacity of soils in different layers of the profile was due to small variations in the sand and clay contents in the profiles. Soil pHw (1:2) in different layers of profile varied from 5.74 to 5.89 indicating that the soils were acidic in reaction. Electrical conductivity of the soil in different layers of the profile varied from 0 .417 to 0 .419 dS/m indicating that the soils were free of soluble salt. Organic carbon content varied from 0 .134 to 0 .345% in different layers of profile under Sal forest. The change in organic carbon content with depth of the profiles was inconsistent. Mineralizable N content in different layers of profile varied from 43.8 to 62.5mg/kg. The change in mineralizable N content with depth was inconsistent in the profile. Available P (Bray's extract) was very low varying from 0.57 to 1.41 mg/kg in different layers of profile. Such a low phosphorous content might be due to more absorption of phosphorous than that returned to soil through leaf fall, since phosphorous is a mobile element. Available K in different layers of profile varied from 51.7 to 77.5mg/kg. All the three plant major nutrients in their available forms were low in rating. Since these elements are mobile in plant, therefore very less is returned to soil through leaf fall. Besides the low clay and high sand contents in the profile might be the reason of low available P and K contents in the soils.

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