

Vertical distribution of available plant nutrients in soils of Central Research Station, Orissa University of Agriculture and Technology, Bhubaneswar, Odisha

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ABSTRACT

Vertical distribution of plant nutrients is most important for crop production. Vertical nutrient distributions are dominated by plant cycling relative to leaching, weathering dissolution and atmospheric deposition. Therefore three pedons were selected for the study of available plant nutrients. The study area consisted of the upper, medium and lower land of Central Research Station, OUAT, Bhubaneswar, Odisha which is situated between 19° 40' and 20° 25' N latitudes and 84° 55' and 86° 05' E longitudes. Soils were analyzed for the status of pH, organic carbon, available nitrogen, phosphorus, potassium, sulphur and micronutrients in vertical direction. Soil organic carbon, nitrogen, phosphorus and sulphur content decreased from higher elevation to lower elevation while pH showed reverse trend. Soils of upland were relatively more fertile with 1200 to 1400 mm annual precipitation and appropriate proportions of soil separates imparted the opportunity to the farmers to grow high value crops like maize, bottle gourd, okra, ridge gourd or cowpea in Kharif whereas tomato, groundnut, sesamum, green gram, horse gram, potato, cabbage, cauliflower, brinjal, French bean or pea in Rabi season. Soils of lowland area were suitable for rice cultivation. Long term crop production planning on the basis of variability of nutrients status in the vertical distribution of soil profile is needed.

Keywords: Vertical distribution; pedons; plant nutrients; profile; upland

INTRODUCTION

In view of the present global crises on food, rising food prices in the international market, progressive conversion of good lands to grow bio-fuel crops and/or other non-agricultural uses, SEZ challenge, demand for urbanization and industrialization etc, technologies for efficient management

of our finite soil resources in agro-ecological regions are of utmost importance towards ensuring productivity, profitability and national food security (Sarkar 2011). Knowledge of vertical distribution of plant nutrients in soil is useful as roots of most of the crop plants go beyond the surface layer and draw part of their nutrient requirements from the sub-surface layers of the soil

(Sangwan and Singh 1993). Several workers have studied the horizon-wise levels of plant nutrients in soil profiles of different series. However most of the workers have limited their studies on fertility status of surface layer only. Very few have studied layer-wise fertility status of sub-surface layer which is very important for effective nutrient application. It is also helpful in understanding the inherent capacity of the soil to supply essential nutrients to the plants. Brar and Sekhon (1987) and Pal and Mukhopadhyay (1992) observed that the vertical distribution of potassium is of considerable importance as many deep rooted crops are known to absorb potassium from the sub-surface layers. Therefore the information of vertical distribution of potassium is important.

As the interface between the atmosphere, biosphere and lithosphere, soil undergoes an intense vertical exchange of materials resulting in steep chemical and physical gradients from surface to bedrock. Soil stratification is the most visible result of this exchange Hilgard (1906). The type, thickness and position of horizons can yield information about soil forming factors such as climate, topography and vegetation type (Marion and Schlesinger 1985). Likewise the vertical distribution of plant nutrients should yield similar insights into nutrient inputs, outputs and cycling processes (Smeck 1973). Most knowledge about the role of plant cycling on the distribution of

nutrients comes from studies on horizontal nutrient patterns.

Rice and groundnut are the most important crops of Odisha though several deep rooted crops of pulses and other oil seeds, sugarcane besides fruits and vegetables are also grown. Singh et al (1997) reported that more than 30 per cent of the roots of dry matter are present in the depth of 25-40 cm even for rice which is normally taken as surface feeder.

Central Research Station, OUAT at the head quarter of the University ie Bhubaneswar is located under east and southeastern Coastal Plain Agro-climatic Zone of Odisha. It is located between 84° 55' and 86° 05' E longitudes and between 19° 40' and 20° 25' N latitudes .

The climatic condition of the zone is hot and dry with a mean rainfall of 1421 mm per annum. The climate is hot with high humidity in April and May and cold during December and January. The monsoon generally comes in the month of June. The mean summer temperature is 38.7°C and mean winter temperature 14°C. The main crops of the district are rice, groundnut, sesamum, green gram, horse gram, sugarcane, vegetables and fruits.

The district mainly consists of red and laterite soils. Therefore as per older system of classification though red and laterite soils are present, as per the soil

taxonomy these are classified as alfisols, inceptisols and entisols (Sahu et al 2005). The red colour of the soil is due to high iron oxide content. The laterite soils have been formed by the process of laterization because of intense leaching of bases due to high rainfall. The soils of Central Research Station, Bhubaneswar developed on laterite parent material have been classified as arenic, kandic and ultic haplustalfs (uplands), fluventic and vertic ustochrepts (medium lands) and typic fluvaquents and aquic udorthents (low lands) (Nayak 1998).

With this background a study of vertical distribution of available plant nutrients in the east and southeastern Coastal Plain Agro-climatic zone of Odisha was conducted.

MATERIAL and METHODS

Soil sampling

A detailed soil survey of the area was conducted by using the soil survey manual of USDA and guidelines for soil profile description by Food and Agriculture Organization (Anon 1975, Anon 1977). Soil pedons of size 1 x 1 x 1.5 m dimension were dug open from three different land types (upland, medium land and lowland) in central farm of OUAT, Bhubaneswar (Figs 2 and 3). The textural classes analysis to determine the sand, silt and clay was carried out by Boycous Hydrometer

method (Piper 1950). The pH of 1:2 soil water suspension was determined by means of glass electrode with digital pH meter.

Organic carbon was determined by Walkley and Black's rapid titration method (Jackson 1973), available phosphorus by Bray's method (Olsen et al 1954), available potassium by neutral normal ammonium acetate method using digital flame photometer (Page et al 1982) available sulphur by 0.15 per cent CaCl_2 method and micronutrients by DTPA method.

RESULTS and DISCUSSION

Physical properties

The soils of area were sandy loam to loamy sand. Sand was the dominating fraction (77-81%) in the soils of all three plains. Among the plains, sand fraction was relatively higher (77%) while silt (21%) and clay (22.6%) were lower in the soils of upper rolling plains. The soils of lower plains contained higher amount of silt (25%) and clay (13.1%) and lower sand fractions (70%). The soils of middle slopping plain were moderate in sand, silt and clay fractions. An increasing trend of silt and clay fractions down the depth was noted in all three plains but it was more prominent in the soils of lower plains due to the process of eluviation and illuviation of soil materials.

Table 1 represents the physical properties of pedon 1 (Fig 1) of upland

Table 1. Physical properties of soils of Central Research Station, OUAT, Bhubaneswar

Horizon	Depth (m)	Particle size (%)			Textural class	Bulk density (mg/m³)	Particle density (mg/m³)	Porosity (%)	Water holding capacity (%)
		Sand	Silt	Clay					
Upper land profile									
Ap	0.00-0.15	77.2	14	8.8	Loamy sand	1.40	2.5	44.00	45.00
B1	0.15-0.28	58.2	27	14.8	Silty loam	1.45	2.55	43.13	43.60
Bt1	0.28-0.49	61.2	20	18.8	Loam	1.46	2.55	42.74	42.00
Bt2	0.49-0.80	57.2	22	20.8	Loam	1.48	2.52	41.27	40.00
Bt3	0.80-0.91	49.2	25	22.8	Loam	1.50	2.46	39.02	38.10
Medium land profile									
Ap	0.00-0.16	74.2	12	13.8	Loamy sand	1.61	2.3	38.00	43.00
Bw1	0.16-0.35	73.2	13	13.8	Loam	1.59	2.45	40.13	41.60
Bw2	0.35-0.57	46.2	14	39.8	Loam	1.42	2.50	41.74	40.00
Bw3	0.57-1.30	27.2	22	50.8	Loam	1.32	2.52	43.27	40.00
Low land profile									
A11	0-0.14	80.2	12	17.8	Loamy	1.37	2.60	47.00	40.00
A12	0.14-0.35	60.2	17	21.2	Loam	1.35	2.48	45.56	42.60
A13	0.35-0.70	71.2	22	24.5	Loam	1.40	2.65	47.14	40.00
A14	0.70-1.20	70.4	27	28.8	Sandy loam	1.42	2.65	46.27	38.00

profile which shows that from horizon Ap to Bt3 sand percentage decrease ranged from 77.2 to 49.2 per cent and both silt and clay increased. The textural class ranged from loamy sand to loam. The value of bulk density and particle density varied from 1.4 to 1.5 mg/m³ and from 2.50 to 2.46 mg/m³ respectively in different horizons of pedon. The value of pore space varied from 44.0 to 39.02 per cent and that of water holding capacity from 45.00 to 38.10 per cent. The variation in the values might be due to quantity, nature and mineralogical composition of soil separates.

In general the clay content increased from surface to sub-surface horizon reaching a value of as high as 50.8

per cent in Bw3 horizon of pedon 2 (Fig 2) and correspondingly the content of sand decreased from the surface downwards and the value ranged from 74.2 to 27.2 per cent. The bulk density almost increased from the surface downwards from 1.61 to 1.32 mg/m³. As the texture gradually becomes heavier from the surface downwards this trend of increase in bulk density is expected (Govindarajan and Datta Biswas 1968). The value of pore space varied from 38.00 to 43.27 per cent and of water holding capacity from 43.00 to 40.00 per cent.

In general the clay content increased from surface to sub-surface horizon reaching a value of as high as 28.8 per cent in A14 horizon of pedon 3 (Fig

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Fig 1. Upland profile of Central Research Station, Bhubaneswar



Fig 2. Medium land profile of Central Research Station, Bhubaneswar



Fig 3. Lower land profile of Central Research Station, Bhubaneswar

3). Correspondingly the content of sand decreased from the surface downwards and the value ranged from 80.2 to 70.4 per cent. The value of bulk density ranged from 1.37 to 1.42 mg/m³ and it almost increased from the surface downwards. The value of pore space varied from 47.00 to 46.27 per cent and the of water holding capacity from 40.00 to 38.00 per cent.

Chemical properties

Table 2 represents the chemical properties of land profile. In upland profile from Ap to Bt3 horizon pH ranged from 5.2 to 5.7 and EC from 0.2 to 0.25 dS/m. The value of available nitrogen varied from 323 to 120 kg/ha and decreased down the depth of the pedon. Most of the lower horizons showed low nitrogen status whereas all surface layers were of medium status. This might be due to higher content of organic matter and fertilizers applied on the surface. Available phosphorus ranged from 18.4 to 8.0 kg/ha and it decreased with increase in depth of the pedon. The gradual decrease in value in the lower horizons might be due to activity of iron.

The available K content varied from 105 to 50 kg/ha from surface to sub-surface horizons. The low status of K might be due to its light texture which helped leaching away of this nutrient. The available sulphur in different horizons varied from 8.6 to 3.8 ppm and all the horizons were deficient in sulphur. The available iron ranged from 24.8 to 28.9 ppm and showed higher value in all

horizons. The available Zn ranged from 0.88 to 0.28 ppm. In medium land profile from Ap to Bw3 horizon pH ranged from 5.3 to 7.5 and EC from 0.28 to 0.51 dS/m. The value of available nitrogen varied from 145.3 to 32.6 kg/ha and decreased down the depth of the pedon. Most of the lower horizons showed low nitrogen status whereas all surface layers were of medium status. This might be due to higher content of organic matter and applied fertilizers on the surface. Available phosphorus ranged from 22.5 to 5.3 kg/ha and it decreased with increase in depth of the pedon. The gradual decrease in value in the lower horizons might be due to activity of iron. The available K content varied from 115 to 85.5 kg/ha from surface to sub-surface horizons and available sulphur in different horizons varied from 20.0 to 6.0 ppm. The available iron ranged from 52.6 to 9.4 ppm and showed higher value in all horizons. The available Zn ranged from 0.58 to 0.21 ppm.

In low land profile from A11 to A14 horizon pH ranged from 6.1 to 6.7. The value of available nitrogen varied from 313.96 to 150.26 kg/ha and decreased down the depth. Most of the lower horizons showed low nitrogen status whereas all surface layers were of medium status. Available phosphorus ranged from 14.29 to 7.57 kg/ha and it decreased with increase in depth of the pedon. The available K content varied from 70.5 to 50.5 kg/ha from surface to sub-surface horizons. The available

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Table 2. Chemical properties of soils of Central Research Station, OUAT, Bhubaneswar

Horizon	Depth (m)	pH (1:2)	EC (1:2) (dS/m)	Organic carbon (g/kg)	N (kg/ha)	P (kg/ha)	K (kg/ha)	S (ppm)	Fe (ppm)	Zn (ppm)
Upper land profile										
Ap	0.00-0.15	5.2	0.20	6.0	323.5	18.4	105	8.6	24.8	0.88
B1	0.15-0.28	5.4	0.31	5.2	302.6	15.3	80.5	6.8	26.3	0.61
Bt1	0.28-0.49	5.6	0.20	4.1	232.5	14.2	60.4	5.9	26.8	0.25
Bt2	0.49-0.80	5.6	0.20	3.4	160.0	10.1	60.5	4.4	27.5	0.21
Bt3	0.80-0.91	5.7	0.25	3.3	120.3	8.0	50.3	3.8	28.9	0.28
Medium land profile										
Ap	0.00-0.16	5.3	0.28	5.2	145.3	22.5	115	20.0	52.6	0.58
Bw1	0.16-0.35	6.3	0.23	4.2	115.7	14.6	60.5	15.0	45.3	0.37
Bw2	0.35-0.57	6.9	0.20	2.9	65.9	7.8	100.4	9.0	15.3	0.25
Bw3	0.57-1.30	7.5	0.51	1.8	32.6	5.3	85.5	6.0	9.4	0.21
Low land profile										
A11	0-0.14	6.1	0.6	5.7	313.96	14.29	70.5	3.51	18.6	1.08
A12	0.14-0.35	6.5	0.3	2.5	217.08	13.87	60.5	3.10	19.3	1.15
A13	0.35-0.70	6.6	0.4	2.9	175.3	10.71	60.4	2.15	18.3	0.5
A14	0.70-1.20	6.7	0.5	1.3	150.26	7.57	50.5	1.13	20.4	0.96

sulphur in different horizons varied from 3.51 to 1.13 ppm and available iron from 18.6 to 20.4 pm and showed higher value in all horizons. The available Zn ranged from 1.08 to 0.96 ppm.

Surface soils of the three pedons were acidic in nature ($\text{pH} < 7$). The pH value increased from surface to sub-surface. Value of pH was relatively higher (6.7) in the soils of low land whereas lower (5.2) in the soils of upland. Sharma et al (2013) reported that mean pH values were recorded maximum in the soils of middle slopping plains.

Organic carbon was comparatively higher in surface horizons of upper land than

lower land (Table 2). The higher amount of organic carbon in the surface layers could be due to addition of organic matter like farm yard manure and incorporation of stubble left after harvesting of paddy.

Nitrogen is a part of all living cells and is a necessary part of all proteins, enzymes and metabolic processes involved in the synthesis and transfer of energy (Sharma et al 2013). The available nitrogen was comparatively higher in the surface horizons of all the soil profiles which could be because of the higher amount of organic carbon in those horizons (Table 2). A gradual decrease of nitrogen was noted down the depth in all three pedons by Meena et al (2006). Low nitrogen in

lowland as compared to upland was also reported by Datta et al (1990).

Phosphorus is also an essential part of the process of photosynthesis involved in the formation of all oils, sugars, starches etc (Sharma et al 2013). The available phosphorus content was higher in the surface horizon and decreased down the depth in all the soil profiles (Table 2). It could be because of the addition of large quantities of phosphorus for paddy cultivation. The surface horizon of all pedons ranged from medium (14-40 kg/ha) whereas sub-surface horizons were low (<6 kg/ha) in available phosphorus. A gradual decrease of phosphorus was also recorded down the depth in all three pedons by Meena et al (2006).

Potassium is absorbed by plants in larger amount than any other mineral element except nitrogen and in some cases the calcium. In all three pedons the available potassium was low and decreased along the depth. The middle plain had higher available potassium compared to other plains.

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Received: 1.3.2016

Accepted: 22.5.2016