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Vertical Distribution of Available Plant Nutrients in Soils of Mid Central Valley at Odisha Zone, India

Antaryami Mishra[1], Trupti Mayee Pattnaik[2], D. Das[1*] and Mira Das[2]

[1]Department of Soil Science and Agricultural Chemistry, College of Agriculture, Orissa University of Agriculture and Technology (OUAT), Bhubaneswar-751003, India.
[2]Departments of Chemistry, ITER, SOA University, Bhubaneswar, India.

Authors' contributions

This work was carried out in collaboration between all authors. Author AM designed the study, wrote the protocol and wrote the first draft of the manuscript. Author DD reviewed the experimental design, all drafts of the manuscript and performed the statistical analysis. Author TMP managed the analyses of the study and help in draft of the manuscript. Author MD helped in draft preparation. All authors read and approved the final manuscript.

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ABSTRACT

Vertical distribution of plant nutrients is most importance for plant production. We always explored nutrients distribution in the top soil. But plants also take nutrients from the sub soil. It is hypothesizing that vertical nutrient distributions are dominated by plant cycling relative to leaching, weathering dissolution and atmospheric deposition. Therefore, four pedons were selected for the study of available plant nutrients with the objective to sustain the better productivity and sustainability. The study area consists of the upper and lower land of Dhenkanal district come under mid central valley at Odisha zone, India which is situated between 20º29' and 21º11' N latitudes and 85^{0}58' and 86^{0}20' E longitudes. Soils were analyzed for the status of pH, organic carbon, available nitrogen, phosphorus, potassium, sulphur and boron content in vertical direction. Soil organic carbon, nitrogen, phosphorus and sulphur content decreased from higher elevation to lower elevation while pH, potassium and boron showed reverse trend. Soils of upland are relatively more

**Corresponding author: E-mail: dib_das101@yahoo.co.in;*

fertile with 1200 to 1400 mm annual precipitation and appropriate proportions of soil separates imparts the opportunity to the farmers to grow high value vegetable 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 are suitable for rice cultivation. Long term crop productions planning may be done on the basis of variability of nutrients status in the vertical distribution of soil profile.

Keywords: Vertical distribution; Dhenkanal district; plant nutrients.

1. INTRODUCTION

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 [1]. 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 nutrient to the plants. Brar and Sekhon [2] and Pal and Mukhopadhyay [3] observed that the vertical distribution of potassium is of considerable importance as many deep rooted crops known to absorb potassium from the sub surface layers. Therefore, the information of vertical distribution of potassium is importance.

To understand the importance of plants in structuring the vertical distributions of plant nutrients, Jobbagy and Jackson [4] explored nutrient distributions in the top meter of soil, hypothesizing that vertical nutrient distributions are dominated by plant cycling relative to leaching, weathering dissolution, and atmospheric deposition, they examined three predictions that: (1) the nutrients that are most limiting for plants would have the shallowest average distributions across ecosystems, (2) the vertical distribution of a limiting nutrient would be shallower as the nutrient became more scarce, and (3) along a gradient of soil types with increasing weathering-leaching intensity, limiting nutrients would be relatively more abundant due to preferential cycling by plants. They also found that most of the nutrients are dominant in surface soil and decreasing with increasing depth.

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, and its extensive observation and synthesis from the basis of pedogenetic and taxonomic study [5-8]. The type, thickness, and position of horizons can yield information about soil forming factors such as climate, topography, and vegetation type [6,9,10]. Likewise, the vertical distribution of plant nutrients should yield similar insights into nutrient inputs, outputs, and cycling processes [11,12]. Most knowledge about the role of plant cycling on the distribution of nutrients comes from studies on horizontal nutrient patterns [13].

According to Patil and Patel [14] in the present strategy of high yielding and intensive cropping system, fertilizer application based on soil test assumed great significance for the purpose of fertilizer recommendation. Generally the soil samples are collected from the surface (0-15 cm) layer. The findings of Department of Agricultural Chemistry, Gujurat Agricultural University, Junagada indicate that the sub surface soil fertility also contributes greatly towards the yield of groundnut whose roots have been observed to proliferate to a depth of 45 cm. They also opined that the sub surface soil fertility had greater contribution than that of surface soil towards the production of groundnut. Hence the above study provides evidence that sub surface fertility status of soil has to be taken into account while making fertilizer recommendation of different crops.

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. In the study of Singh et al. [15] showed the more than 30% of the roots of dry matter to be present in the depth of 25-40 cm even for rice which is normally taken as surface feeder.

With these background, we have conducted a study of vertical distribution of available plant nutrients in the mid central table land agro climatic zone of Odisha with the aim to sustain the better productivity and sustainability.

2. MATERIALS AND METHODS

2. 1 Study Area

Dhenkanal district is located between longitudes 85° 58´ E to 86°20´E and between latitudes 20°29´N to 21°11´N which is come in the mid central table land agro climatic zone of Odisha (Fig. 1). It occupies a central position in the geo-political map of Odisha state in India. The mid central table land agro climatic zone consist of Dhenkanal and Anugul Districts.

2.2 Climate

The climatic condition of the zone is hot and dry in sub humid with a mean rainfall of 1421mm per annum. The climate is hot with high humidity in April and May and cold during December and January. The monsoon generally breaks in the month of June. The mean summer temperature is 38.7°C and mean winter temperature 14°C. The district has 8 numbers of blocks consisting of 1215 numbers of villages covering total area of 4452 km^2 [16]. The main crops of the district are rice, groundnut, sesamum, greengram, horsegram, sugarcane, vegetable and fruits.

2.3 Soils

The district mainly consisting of red and laterite soils through patches of yellow soils are found in some parts of the district. River *Bramhani*, the second biggest river of Odisha flows through this district and alluvial soil are found on the both of the river banks, which are very suitable for vegetable cultivation during summer. So as per older system of classification though red, literate and alluvial soils are present, as per the soil taxonomy these are classified as *Alfisols, Inceptisols and Entisols* [17]. The red colour of the soil is due to the high iron oxides content. The laterite soil have been formed by the process of laterization because of intense leaching of bases due to high rain fall. The alluvial soils are products of the pedogeonic process of illuviation mostly by the river Bramhani and its tributaries. The relief of the district consists of high hills, valleys with dense forest. The pedogenic process of colluvation has also take place in these types of topography. The colluvial deposit are found in the foot slope of most of the hills which are mostly used for cultivation of rice in the Kharif season followed by pulses and vegetables in the Rabi- Summer season. The area has deciduous natural forests and grasses. As the area is irrigated by Brahmani command area rice is grown both in kharif and rabi in different land types.

2.4 Soil sampling

A details soil survey of the area was conducted by using the soil survey manual of USDA [18] and guidelines for soil profile description by Food and Agriculture Organization [19]. Soil profiles of sizes 2m x 1.5m up to a depth of 1.5 to 2 m opened from two different land types (upland and lowland) of 2 blocks in the districts (Figs. 2-3). Nine soil samples from nine different horizons have been collected by spade during summer season. The textural classes analysis to determine the sand, silt, clay was carried out by Boycous Hydrometer method [20]. The pH of 1:2 soil water suspension was determined by means of glass electrode wing digital pH meter.

Organic carbon was determined by Walkley and Black's rapid titration method [21]. Available phosphorous was determined by Olsen's method [22]. Available potassium was determined by neutral normal ammonium acetate method using digital flame photometer [23]. Available boron was done by hot water extraction method and available sulphur was done by 0.15% $CaCl_2$ method.

3. RESULTS AND DISCUSSION

Tables 1-4 described the physic-chemical properties of the four pedons. The soils of the four pedons were sandy clay loam to sandy. Sand was dominating fraction (56.40-90.80%) but sand percent decreased with decreasing height in the soils of all four pedons. An increasing trend of silt and clay fractions down the depth was noted in all four pedons but it is more prominent in the soils of low land due to the process of eluviation and illuviation [24].

Surface soils of the four pedons are acidic in nature (pH<7). pH value increases with decreasing height. Value of pH was relatively higher (pH-8.81) in the soils of low land whereas lower (pH-5.2) in the soils of upland [24].

Organic carbon is comparatively higher (>0.5 g kg^{-1}) in surface horizons of upper land than lower land (Tables 1-4). The higher amount of organic carbon in the surface layers is due to addition of organic matter like farm yard manure and incorporation of stubble left after harvesting of paddy. The irregular amount of organic carbon down the depth in pedon-2 is because of slope wash in the hill bottom lands in different period of times due to the pedogenic process of colluvation.

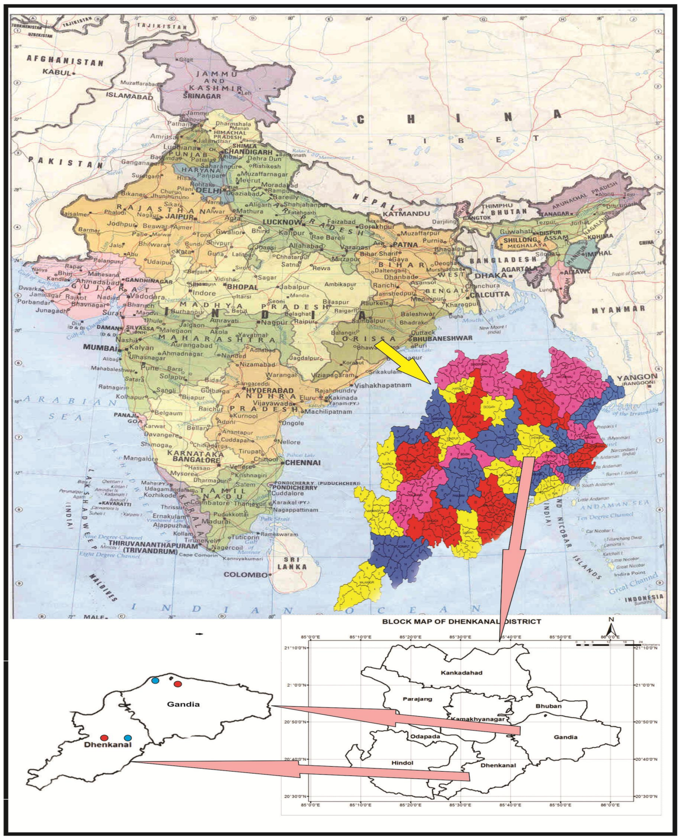

Fig. 1. Study area in the Dhenkanal district, Odisha state, India

Fig. 2. Upper land profile of Tarava village of Dhenkanal Sadar block, Dhenkanal, India

Fig. 3. Upper land profile of Deogaon block of Gondia block, Dhenkanal, India

Table 1. Soil physical and chemicals properties of pedon-1 at upper land (Latitude -20º41.224' Longitude -85º42.355') of Sankhua village, Dhenkanal sadar block in Odisha zone, India

Sl. No.	Sample No.	Depth (Cm)	Horizon	Particle size (%)			Textural class	pH	OC (g Kg^{-1})	Available nutrients				
				Sand	Silt	Clay				N (mg kg^{-1})	P_2O_5 (mg kg^{-1})	K_2O (mg kg^{-1})	S (mg kg^{-1})	B (mg kg^{-1})
1	1	0-13	O	88.00	10.80	1.20	Sandy	5.20	0.521	138.75	5.29	204.29	5.05	2.04
2	2	13-28	Ap	83.00	14.80	2.20	Sandy	5.20	0.212	139.38	4.79	215.71	2.52	1.68
3	3	28-43	A	75.00	18.80	6.20	Loamy sand	5.24	0.308	100.63	4.78	227.14	3.83	1.44
4	4	43-59	AB	74.00	19.80	6.20	Loamy sand	5.43	0.289	100.00	3.66	208.99	1.13	1.44
5	5	59-79	E	69.00	22.80	8.20	Sandy loam	5.79	0.347	109.38	2.53	201.60	3.39	1.38
6	6	79-107	BE	67.60	23.80	8.60	Sandy loam	5.92	0.212	69.38	2.25	214.37	4.70	1.38
7	7	107-132	Bt1	65.60	26.80	7.60	Sandy loam	6.07	0.328	76.88	2.25	230.50	2.26	1.32
8	8	132-162	Bt2	61.60	29.80	8.60	Sandy loam	6.04	0.328	87.50	1.91	303.07	1.74	1.80
9	9	162-180	BC	62.60	28.80	8.60	Sandy loam	6.31	0.193	72.50	1.41	296.35	0.61	2.22

Table 2. Soil physical and chemicals properties of pedon-2 at low land (Latitude -20º41.719' Longitude -85º37.570') of Tarava village, Dhenkanal sadar block in Odisha zone, India.

Sl. No.	Sample No.	Depth (Cm)	Horizon	Particle size (%)			Textural class	pH	OC (g Kg^{-1})	Available nutrients				
				Sand	Silt	Clay				N (mg kg^{-1})	P_2O_5 (mg kg^{-1})	K_2O (mg kg^{-1})	S (mg kg^{-1})	B (mg kg^{-1})
1	1	0-16	Ap	87.80	5.20	7.00	Sandy	6.22	0.328	86.25	5.29	141.79	3.05	0.90
2	2	16-32	A	90.80	4.20	5.00	Sandy	6.24	0.057	84.38	4.22	153.22	3.48	0.72
3	3	32-45	AB	90.80	4.20	5.00	Sandy	6.37	0.057	82.50	2.53	148.51	2.61	0.96
4	4	45-63	E	86.80	5.20	8.00	Sandy	7.34	0.115	71.25	2.25	173.38	4.18	0.96
5	5	63-73	BE	88.80	4.20	7.00	Sandy	7.50	0.057	68.75	1.97	154.56	4.35	1.08
6	6	73-89	Bt1	85.80	5.20	9.00	Sandy	7.63	0.077	71.25	1.97	141.12	3.83	1.14
7	7	89-113	Bt2	78.80	10.00	11.00	Loamy sand	7.72	0.173	65.63	1.69	153.22	5.22	1.26
8	8	113-131	Bt3	75.00	8.20	16.80	Loamy sand	7.73	0.270	73.75	1.06	175.39	4.26	1.32
9	9	131-181	BC	73.00	9.20	17.80	Loamy sand	7.81	0.270	68.75	1.06	181.44	2.96	2.04

Table 3. Soil physical and chemicals properties of pedon-3 at upper land (Latitude -20º42.087' Longitude -85º44.942') of Deogaon village, Gondia block in Odisha zone, India

Sl. No.	Sample No.	Depth (M)	Horizon	Particle size (%)			Textural Class	pH	OC (g Kg^{-1})	Available nutrients				
				Sand	Silt	Clay				N (mg kg^{-1})	P_2O_5 (mg kg^{-1})	K_2O (mg kg^{-1})	S (mg kg^{-1})	B (mg kg^{-1})
1	1	0-15	O	81.40	6.60	12.00	Loamy sand	5.31	0.901	193.13	9.86	34.94	2.87	2.52
2	2	15-30	Ap	80.40	6.60	13.00	Loamy sand	5.39	0.518	167.50	15.21	49.06	3.13	1.50
3	3	30-50	A	73.40	18.60	16.00	Sandy loam	5.72	0.595	169.38	10.14	62.50	4.09	1.68
4	4	50-70	AB	68.40	10.60	21.00	Sandy clay loam	6.10	0.518	171.88	4.51	61.82	3.22	1.62
5	5	70-85	E	64.40	15.60	20.00	Sandy loam	6.43	0.461	163.75	4.79	73.25	3.74	0.60
6	6	85-110	BE	56.40	18.60	25.00	Sandy clay loam	6.79	0.307	173.75	6.76	163.97	4.00	0.18
7	7	110-140	Bt1	60.00	14.60	25.40	Sandy clay loam	6.68	0.326	181.88	4.51	116.93	6.53	0.42
8	8	140-190	Bt2	61.00	13.60	25.40	Sandy clay loam	6.64	0.230	128.75	5.36	96.10	2.52	0.30
9	9	190-220	BC	66.00	6.60	21.40	Sandy clay loam	6.47	0.211	133.75	3.67	100.80	2.18	0.66

Table 4. Soil physical and chemicals properties of pedon-4 at low land (Latitude -20º45.126' Longitude -85º47.350') of Deogaon village, Gondia block in Odisha zone, India

Sl. No.	Sample No.	Depth (M)	Horizon	Particle size (%)			Textural Class	pH	OC (g Kg^{-1})	Available nutrients				
				Sand	Silt	Clay				N (mg kg^{-1})	P_2O_5 (mg kg^{-1})	K_2O (mg kg^{-1})	S (mg kg^{-1})	B (mg kg^{-1})
1	1	0-15	Ap	72.00	10.60	17.40	Sandy loam	6.81	0.345	175.00	12.68	137.76	4.35	0.36
2	2	15-28	A	69.00	11.60	19.40	Sandy loam	7.30	0.369	77.50	9.02	168.00	2.87	1.56
3	3	28-50	AB	74.00	10.60	15.40	Loamy sand	7.90	0.332	58.75	8.73	33.60	3.05	0.48
4	4	50-75	E	68.00	12.60	19.40	Sandy loam	7.87	0.351	56.25	7.33	36.96	2.87	0.36
5	5	75-110	BE	69.00	10.40	20.60	Sandy loam	8.03	0.351	41.25	5.92	40.99	3.13	0.42
6	6	110-125	Bt1	71.00	8.40	20.60	Sandy loam	8.03	0.295	35.63	4.23	32.255	3.48	0.36
7	7	125-165	Bt2	69.00	9.40	21.60	Sandy loam	8.15	0.295	48.63	3.94	26.21	4.79	0.24
8	8	165-180	Bt3	68.00	10.40	21.60	Sandy loam	8.14	0.277	26.88	3.10	16.80	3.74	0.96
9	1	180-215	BC	70.00	10.60	19.40	Sandy loam	8.81	0.271	25.00	2.68	16.20	3.35	0.86

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 [24]. The available nitrogen is comparatively higher in the surface horizons of all the soil profiles, which is because of the higher amount of organic carbon in those horizons [4] (Tables 1-4). A gradual decrease of nitrogen was noted down the depth in all four pedons [24,25]. It is also observed low nitrogen in lowland as compared to upland [26].

Phosphorus (P) is also an essential part of the process of photosynthesis, involved in the formation of all oils, sugars, starches, etc. [24]. The available phosphorus content is higher in the surface horizon and decreases down the depth in the soil profiles [4] (Tables 1-4). It is because of the addition of large quantities of phosphorus for paddy cultivation. The surface horizon of all pedons are ranged from medium to low (7-20 mg kg^{-1}) whereas sub surface horizons are low (<7 mg kg^{-1}) in available phosphorus. A gradual decrease of phosphorus was recorded down the depth in all four pedons [24,25].

Potassium is absorbed by plants in larger amount than any other mineral element except nitrogen and in some cases, calcium [24]. The comparatively higher amount of potassium in the sub surface horizon of all the profiles except pedon 4 is because of the development of the soil from the residual parents material which mostly consist of feldspars and micas which are mostly potash bearing minerals [27] (Tables 1-4). Potassium content of surface horizon of pedon 1 and 2 are high (>140 mg kg^{-1}); rest two are varied between medium and low. It was observed that content of potassium decreased down the depth in upland [24]. It is indicated that silt size particles were the major contributor of potash while clay contributed to a very little extent to crops and it is mainly due to weathering of biotite mica up to the stage of silt fractions [24].

The soluble sulphur content in all the horizons are below the critical limit (<5 mg kg^{-1}) which could be attributed to lower content of organic carbon in these horizons (Tables 1-4). The soluble boron content of the surface horizon of all the soil profile is above the critical limit (>0.5 mg kg^{-1}) except the pedon 2 which is below the critical limit (Tables 1-4). Sulphur is deficient (<5 mg kg^{-1}) in all the sub horizons of all the soil profiles, while boron is deficient (<5 mg kg^{-1}) only in pedon 4.

4. CONCLUSION

It can be concluded that judicious application of phosphorus and sulphur is necessary for higher crop productivity in two blocks of the Dhenkanal district whereas liberal amount of boron should be applied in low lands of Gandia block. Similarly liberal amount of potassium application is necessary in upland of Gandia block. To maintain the soil quality, liberal application of organic matter is required in upland of Central land agro climatic zone of Odisha. The variability in nutrient status in the vertical distribution of soil profile has a long term bearing on the production and productivity of field crops, vegetables, orchard plantation and agro forestry in different blocks of Dhenkanal district. Land use planning can be done on the basis of physico-chemical properties and nutrient status of different horizons of upland and lowland soil of the district.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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