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

E-ISSN: 2278-4136
P-ISSN: 2349-8234
JPP 2018; 7(6): 658-662
Received: 24-09-2018
Accepted: 25-10-2018

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Soil fertility status of some villages in Phiringia block of Kandhamal district under North-Eastern Ghat agro climatic zone of Odisha, India

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Abstract
A soil fertility status inventory work was carried out in few villages of Phiringia block in Kandhamal district located in the North-Eastern Ghat Agroclimatic Zone of Odisha, India. Results show that soil texture of villages under investigation varied from loamy sand to clay loam. Clay content varied from 9.2 to 28.4 percent. Soil pH ranged between 4.33 to 6.6 and electrical conductivity of the entire study area remained below 1 dSm^{-1}. Soil Organic Carbon (SOC) content ranged between 2.3 to 9.7 g kg^{-1}. Available nitrogen content in these soils was found to be varying between 88.0 and 263.0 kg ha^{-1}. Available Bray's phosphorus content varied from 5.0 to 56.0 kg ha^{-1}. Available soil potassium content varied widely from 130.0 to 997 kg ha^{-1}. $CaCl_2$ extractable soil sulphur varied from 1.2 to 11.3 mg kg^{-1}. Hot water soluble boron content ranged from 0.60 to 0.97 mg kg^{-1}. All the figures in lower range were found in upland soils while the higher values for all the parameters were found in low land soils.

Keywords: Soil fertility, agro climatic zone, Kandhamal, SOC

1. Introduction
Four villages of Phiringia block of Kandhamal district namely Pabingia, Jargipadara, Dangerpada and Dangidikia were selected in the present investigation for studying the soil fertility status in order to identify the major soil fertility related crop production constraints. Phiringia block belongs to Kandhamal district which comes under North Eastern Ghat Agro Climatic Zone of Odisha (Nanda *et al.*, 2008) [16]. As per modern system of soil classification "Soil Taxonomy" the soils of Kandhamal district are classified under the *Alfisols, Inceptisols and Entisols* (Sahu & Mishra, 2005) [22]. Determination of soil available nutrient status of an area using Global Positioning System (GPS) helps in formulating site specific balanced fertilizer recommendations along with making critical decisions on nutrient management (Patil *et al.*, 2017) [19]. GPS based soil fertility evaluation not only gives ideas about fertility status of the soil but also helps in monitoring the soil health from time to time (Mishra *et al.*,2016) [10]. Although soil fertility status and maps have been prepared for different areas of Odisha, but no such intensive work had been done for Phiringia block of Kandhamal district. Therefore an attempt has been made in the present investigation to prepare soil fertility status of four selected villages of Phiringia Block of Kandhamal district. As nitrogen, phosphorus and potassium are the three major primary macro nutrients; that of sulphur is one of the most important secondary macronutrients and boron is one of the most important micronutrients, soil fertility status is evaluated focusing on these nutrients. Along with these parameters some of the basic soil physical and chemical properties are also determined which includes mechanical analysis (soil texture), soil pH, EC and SOC. This study will help in finding out soil fertility related crop production constraints along with suggesting remedial measures for higher crop production.

2. Materials and methods
2.1 Experimental site
All the four villages are situated in Phiringia Block on the state highway running from Phulbani (District Headquarter of Kandhamal) to Baliguda sub division of Kandhamal. The small town Phiringia is located at middle in between Phulbani and Baliguda. Pabingia is situated at 5 kms away from Phiringia, Jargipadara is 3 kms from Pabingia, Dangerpada is situated at 5 kms away from Jargipadara and fourth village Dangidikia is situated at 2 kms away from Dangerpada. The most important river of Kandhamal District is Salki (the odia name is Salunki) intersects the 25 km state highway which is 25 km away from Phiringia. The river Salki is considered as the lifeline of the district.

The mean annual rainfall of the study area is 1597 mm. The mean maximum summer temperature is 37 ^{0}C and the mean minimum winter temperature is 10.4 ^{0}C. The climate is hot, moist and sub-humid. The soils of this Agro Climatic zone are mostly red loam, brown forest soils (*Haplustalfs, Rhodustalfs, Ustochrepts, Ustorthents)*.

2.2 Soil sampling and analysis

The landform of the study area was determined through traversing the area and elevations above MSL of different points were recorded using GPS instrument (Garmin make; model: 76MAPCSx). Total 40 numbers of composite surface (0–15 cm) soil samples were collected from the study area which includes 10 samples from each village from different land types such as upland, medium land and low land. Composite soil samples were collected along with latitude and longitude of the plots with the help of GPS instrument. Soils were analysed for its colour (by using Munsell colour chart), textural class by Bouyoucos Hydrometer method (Bouyoucos GJ,1962) [3], pH(1:2) (Jackson, 1973)[8], EC(1:2) (Jackson, 1973)[8], organic carbon (Walkley and Black, 1934) [25] as described by Page *et al.*(1982) [18], available nitrogen (Subbiah and Asija, 1956) [24], phosphorus (Bray and Kurtz, 1945) [4], potassium (Hanway and Heidel, 1952) [7], sulphur (Chesnin and Yien, 1950) [5], and hot water extractable boron (John *et al.*, 1975) [9].

3. Results and discussion

3.1 Soil Colour

The colour of the soil is one of the most important indications of the pedogenic processes (soil forming processes) as well as moisture status of the soil. The soil colour of Pabingia village varied from yellowish (10YR5/6) to dark brown (10YR3/3); that of Jargipadara village ranged from dark yellowish brown (10YR4/4) to brownish yellow (10YR6/6); that of Dangerpada village ranged from brownish yellow (10YR6/6) to dark red (2.5YR3/6). Similarly soil colour of Dangidikia village ranged from yellowish brown (10YR5/8) to very dark grayish brown (2.5YR3/2). Such variation in soil colour could be attributed to the varying water table in different land types.

3.2 Soil Texture

The sand, silt and clay content in the soils of Pabingia village were found to vary in between 66.9 to 77.8, 6.6 to 15.6 and 14.0 to 20.4 percent respectively; that of Jargipadara village varied between 62.4 to 75.9, 9.6 to 17.4 and 13.0 to 20.2 percent respectively; that of Dangerpada varied between 70.2 to 80.2, 3.3 to 15.6 and 11.0 to 21.2 percent respectively; that of Dangidikia village varied between 62.1 to 80.6, 8.1 to 17.5 and 9.2 to 28.4 percent respectively (Table 1). From the Table 1 it is clear that the average clay content increased from upland to low land in all the four villages, which could be attributed to washing away of clay particles from upland and medium land (along with runoff water during heavy rain fall) and their subsequent deposition in the low land. Similar findings have also been observed by Nayak (2014) [17], Mishra *et al*. (2014) [12] and Dash *et al*. (2018) [6].

3.3 Soil reaction

Soil pH (1:2) of surface soil samples of Pabingia village were found to vary in between 4.9 to 6.1 with a mean value of 5.53; that of soils of Jargipadara village varied between 5.1 to 5.8 with a mean value of 5.42; that of Dangerpada varied between 4.3 to 6.0 with a mean value of 4.98; that of soils of Dangidikia village varied between 4.7 to 6.6 with a mean value of 5.30 (Table 2). The data showed a gradual increase in soil pH value from upland towards low land, which could be attributed to the removal of basic cations with runoff water from upland and medium land during intensive rainfall and their subsequent deposition in the low land. Hence, the soil acidity appears to be a major crop production constraint in the study area. Similar findings have also been reported earlier by Priyadarshini *et al* (2017) [21] and Satpathy (2015) [23].

3.4 Electrical conductivity

Electrical Conductivity (1:2) of surface soil samples of the entire study area was found to be less than 2 dS m^{-1} (Table 2). Hence, all the soils under the study area are safe for all types of crop production with respect to the soluble salt content.

3.5 Organic carbon

Soil Organic Carbon (SOC) of surface soil samples of Pabingia village were found to vary in between 4.6 to 9.7 g kg^{-1} with a mean value of 6.09 g kg^{-1}; that of Jargipadara village varied between 6.0 to 8.0 g kg^{-1} with a mean value of 5.73 g kg^{-1}; that of Dangerpada varied between 3.4 to 6.1 g kg^{-1} with a mean value of 5.32 g kg^{-1}; that of Dangidikia village varied between 2.3 to 7.6 g kg^{-1} with a mean value of 5.11 g kg^{-1} (Table 2). The results clearly showed a gradual increase in average SOC from upland towards low land surface soil samples which could be attributed to higher cropping intensity followed by crop residue incorporation in the low land. Again, due to higher water table in case of low land, the oxidation of organic matter is slower than that of upland. In the entire study area organic carbon status was found to be medium to high which enables the soil for higher crop production. Medium to higher organic carbon in the study area could be attributed to its presence in the bottom of dense forest. Similar findings have also been reported by Mishra (1981) [13] and Mishra (2013) [14].

Table 1: Mechanical Composition of soils of the study are

Name of Village	Land Type	% Sand		%Silt		%Clay	
		Range	Mean	Range	Mean	Range	Mean
Pabingia	Upland	70.4-77.8	73.1	6.6-15.6	12.2	14-15.6	14.7
	Medium Land	67.4-72.6	70.6	11.6-15.6	13.2	15.7-17	16.1
	Low Land	66.9-73.1	69.5	9.3-14.6	12.0	17.3-20.4	18.3
Jargipadara	Upland	72.2-75.9	74.3	10.6-14.2	12.3	13-13.6	13.3
	Medium Land	73.0-75.2	73.8	9.6-11.6	10.6	15.2-16.2	15.6
	Low Land	62.4-73.0	67.8	9.8-17.4	14.2	17.0-20.2	17.9
Dangerpada	Upland	71-80.2	77.0	6.1-15.6	10.3	11-13.6	12.5
	Medium Land	70.2-75.2	73.2	9.1-10.1	9.8	15.6-16.6	15.9
	Low Land	74.9-78.2	75.9	3.3-7.1	5.5	16.6-21.2	18.6
Dangidikia	Upland	74.1-80.6	76.8	10.1-11.5	10.7	9.2-14.3	12.4
	Medium Land	72.2-74.1	73.0	11.1-11.5	11.3	14.3-16.6	15.6
	Low Land	62.1-70.2	66.0	8.1-17.5	11.7	19.0-28.4	22.2

Table 2: Chemical properties of soils of the study area

Name of Village	Land Type	pH (1:2)		EC (1:2) (dS m^{-1})		OC (g kg^{-1})	
		Range	Mean	Range	Mean	Range	Mean
Pabingia	Upland	4.9-5.3	5.1	0.03-0.29	0.01	4.6-5.3	4.8
	Medium Land	5.6-5.7	5.6	0.06-0.09	0.08	5.6-6.1	5.8
	Low Land	5.7-6.1	5.8	0.10-0.12	0.11	6.3-9.7	7.2
Jargipadara	Upland	5.1-5.2	5.1	0.04-0.08	0.05	4.6-4.9	4.7
	Medium Land	5.3-5.5	5.3	0.09-0.10	0.55	5.3-5.6	5.5
	Low Land	5.5-5.8	5.6	0.10-0.12	0.11	6.0-8.0	6.6
Dangerpada	Upland	4.3-4.6	4.4	0.01-0.09	0.06	3.4-5.1	4.3
	Medium Land	4.8-5.0	4.9	0.11-0.16	0.12	5.4-5.6	5.4
	Low Land	5.0-6.0	5.5	0.27-0.93	0.56	5.8-6.1	5.9
Dangidikia	Upland	4.7-5.0	4.8	0.04-0.08	0.03	2.3-4.4	3.7
	Medium Land	5.0-5.4	5.2	0.05-0.08	0.06	4.9-5.1	4.9
	Low Land	5.4-6.6	5.8	0.10-0.30	0.19	5.6-7.6	6.3

Table 3: Soil fertility status of the study area

		Available Nutrient Status									
Name of Village	Land Type	N		P		K		S		B	
		(kg ha^{-1})						(mg kg^{-1})			
		Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean
Pabingia	Upland	88-113	104	9-13	10.3	184-235	209	7.3-7.7	7.4	0.63-0.66	0.6
	Medium Land	125-138	133	13-17	15.4	241-249	245	8.1-9.0	8.5	0.68-0.7	0.7
	Low Land	150-213	178	19-40	29.4	281-429	333	9.1-11.2	9.9	0.73-0.96	0.8
Jargipadara	Upland	112-125	116	5-7	6.0	130-160	145	8.2-8.5	8.3	0.61-0.65	0.6
	Medium Land	125-138	133	8-10	8.5	208-216	212	8.6-9.0	8.8	0.68-0.70	0.7
	Low Land	138-163	143	19-46	27.2	239-278	255	9.2-11.3	9.8	0.71-0.90	0.8
Dangerpada	Upland	88-125	108	18-21	19.8	230-390	258	1.2-8.6	5.9	0.64-0.67	0.7
	Medium Land	126-150	137	22-25	23.9	304-410	362	8.7-8.8	8.7	0.60-0.70	0.7
	Low Land	163-263	206	32-56	41.2	425-997	755	9.0-9.1	9.02	0.70-0.97	0.8
Dangidikia	Upland	113-125	116	15-18	16.5	140-198	165	7.6-7.8	7.7	0.60-0.67	0.6
	Medium Land	124-126	125	21-26	23.2	227-289	252	8.2-8.5	8.3	0.68-0.70	0.7
	Low Land	138-175	146	28-42	34.8	384-877	573	9.1-9.5	9.2	0.70-0.74	0.7

Table 4: Correlation between different soil properties

	%Sand	%Silt	% Clay	pH	EC	OC	Av N	Av P	Av K	Av S	Av B
%Sand	1										
%Silt	-0.66*	1									
% Clay	-0.65*	-0.11	1								
pH	-0.60*	0.02	0.82**	1							
EC	0.03	-0.55*	0.53*	0.39	1						
OC	-0.59*	0.01	0.79*	0.77**	0.31	1					
Av N	-0.19	-0.38	0.65*	0.65*	0.82**	0.65*	1				
Av P	-0.32	-0.29	0.73*	0.47	0.72*	0.59*	0.80**	1			
Av K	-0.12	-0.54*	0.73*	0.47	0.90**	0.43	0.79**	0.82**	1		
Av S	-0.52*	0.10	0.59*	0.63*	0.26	0.71*	0.56*	0.42	0.27	1	
Av B	-0.38	-0.14	0.66*	0.67*	0.62	0.79**	0.88**	0.80**	0.61	0.57*	1

(*=5% level of significance, **=1% level of significance)

3.6 Available nitrogen
Available soil nitrogen content of surface soil samples of Pabingia village were found to vary in between 88 to 213 kg ha^{-1} with a mean value of 142.5 kg ha^{-1}; that of soils of Jargipadara village varied between 112 to 163 kg ha^{-1} with a mean value of 132.4 kg ha^{-1}; that of soils of Dangerpada varied between 88 to 263 kg ha^{-1} with a mean value of 156.2 kg ha^{-1}; that of soils of Dangidikia village varied between 113 to 175 kg ha^{-1} with a mean value of 131.3 kg ha^{-1} (Table 3). The results clearly showed a gradual increase in average N content from upland to low land which could be attributed to the increased SOC in the low land than that of upland and medium land (as N is released from the soil organic matter by the activity of micro-organisms). Available N was found to be positively correlated with organic carbon (r=0.65*) (Table 4). In the entire study area available soil nitrogen content varied between low to medium. Similar results were reported by Behera *et al.* (2016) [2].

3.7 Available phosphorus
Available soil phosphorus content of Pabingia village were found to vary in between 9 to 40 kg ha^{-1} with a mean value of 19.5 kg ha^{-1}; that of Jargipadara village varied between 5 to 46 kg ha^{-1} with a mean value of 15.3 kg ha^{-1}; that of Dangerpada varied between 18 to 56 kg ha^{-1} with a mean value of 29.6 kg ha^{-1}; that of Dangidikia village varied between 15 to 42 kg ha^{-1} with a mean value of 25.8 kg ha^{-1} (Table 3). The results clearly showed a gradual increase in average P content from upland to low land which could be attributed to the increased SOC in the low land than that of upland and medium land (as organic fractions of available phosphorus is mobilized to plant available form by the activity of micro-organisms). Available P was found to be

positively correlated with organic carbon (r=0.59*) (Table 4).In the entire study area available phosphorus was found within the range of low to high. Similar trends of available P were also observed by Barik *et al.* (2017) [1].

3.8 Available potassium

Available soil potassium content of Pabingia village were found to vary in between 184 to 429 kg ha^{-1} with a mean value of 270.0 kg ha^{-1}; that of Jargipadara village varied between 130 to 278 kg ha^{-1} with a mean value of 209.8 kg ha^{-1}; that of Dangerpada varied widely between 230 to 997 kg ha^{-1} with a mean value of 488.6 kg ha^{-1}; that of Dangidikia village varied between 140 to 877 kg ha^{-1} with a mean value of 354.8 kg ha^{-1} (Table 3). The results clearly showed a gradual increase in average K content from upland to low land which could be attributed to the increased clay content in the low land than that of upland and medium land (potassium ion being a cation present in the exchange site of negatively charged clay particles). Available K was found to be positively correlated with amount of clay content (r=0.73*) (Table 4). In the entire study area available potassium was found within the range of medium to high. Similar results were also observed by Mishra *et al.* (2017) [11] and Dash *et al.* (2018) [6].

3.9 Available Sulphur

Available soil sulphur content of Pabingia village were found to vary in between 7.3 to 11.2 mg kg^{-1} with a mean value of 8.74 mg kg^{-1}; that of Jargipadara village varied between 8.2 to 11.3 mg kg^{-1} with a mean value of 9.04 mg kg^{-1}; that of Dangerpada varied widely between 1.2 to 9.1 mg kg^{-1} with a mean value of 8.02 mg kg^{-1}; that of Dangidikia village varied between 7.6 to 9.5 mg kg^{-1} with a mean value of 8.50 mg kg^{-1} (Table 3). The results clearly showed a gradual increase in average S content from upland to low land which could be attributed to the increased SOC content in the low land than that of upland and medium land (as S is released from the soil organic matter by the activity of micro-organisms). Available S was found to be positively correlated with organic carbon (r=0.71*) (Table 4).In the entire study area available sulphur was found to be in the range of low to medium. Similar results were also observed by Nahak *et al.* (2016) [15] and Mishra (2016) [10].

3.10 Available Boron

Hot water extractable boron content of the surface soil samples of Pabingia village were found to vary in between 0.63 to 0.96 mg kg^{-1} with a mean value of 0.73 mg kg^{-1}; that of Jargipadara village varied between 0.61 to 0.90 mg kg^{-1} with a mean value of 0.70 mg kg^{-1}; that of Dangerpada varied widely between 0.64 to 0.97 mg kg^{-1} with a mean value of 0.72 mg kg^{-1}; that of Dangidikia village varied between 0.60 to 0.74 mg kg^{-1} with a mean value of 0.68 mg kg^{-1} (Table 3). The results clearly showed a gradual increase in average B content from upland to low land which could be attributed to the increased SOC content in the low land than that of upland and medium land. Available B was found to be positively correlated with organic carbon (r=0.59*) (Table 4.).In the entire study area available boron was found to be in sufficient range. This type of result is in close conformity with results obtained by Pattanayak (2016) [20].

4. Summary

From the above study it was found that the soils were very-slightly acidic (5%), slightly acidic (28%), moderately acidic (37%), strongly acidic (22%), and extremely acidic (8%). SOC content of the study area was found to be high (8%), medium (57%) and low range (35%). While 97% of soils were found to be in lower range of available nitrogen content, only 3% soils were in medium range. The soil available phosphorus was found to be high (3%), medium (62%) and low range (25%). Available potassium was found to be in both medium (57%) and high range (43%). While 95 percent of soils were found to be in low range of available sulphur; only 5% soils were found to be in medium range. Hence, 25 per cent more nitrogenous and phosphatic fertilizers than that of the recommended dose should be applied in the plots having lower range of the same; that of rest other plots with the recommended dose of fertilizers. Since maximum plots of the farm were found to be higher in potassium status, 25 per cent less potassic fertilizers than that of the recommended dose should be applied and recommended dose should be applied in the rest of the plots having medium range of potassium. Since all most all the plots of the farm were found to lower in available sulphur status, 25 per cent more sulphur containing fertilizers than that of the recommended dose should be applied. In the soils of the study area, micronutrient B was found to be in sufficient range.

5. Conclusion

Soil acidity was found to be the major crop production constraint in the study area. Most of the soils were found to be deficient in available nitrogen, phosphorus and sulphur content. Soil erosion and water logging were found to be the major constraints in upland and low land respectively. So, application of liming materials along with application of soil test based nitrogenous, phosphatic and sulphur containing fertilizers and manures will help to obtain higher crop production as well as sustaining soil health.

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