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Potassium forms and characteristics of hilly soils of Chumekedima district, Nagaland

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ABSTRACT

Soil properties assessments of an area provide critical baseline information on crop health and productivity. Therefore, a study for assessment potassium forms and soil characteristics of the hilly soils of Chumukedima district, Nagaland was undertaken during 2021-22. Forty eight surface soil samples (0-15 cm) from cultivated fields were collected from twelve villages and analyzed for various physicochemical properties, fertility status and potassium forms. Results revealed that the soils were very strongly to strongly acidic in reaction and normal in total soluble salts. The CEC, bulk density, particle density and porosity of the soils ranged from 10.00 to 13.60 cmol$_c$ kg^{-1}, 0.99 to 1.36 Mg m^{-3}, 2.26 to 2.67 Mg m^{-3} and 40.10 to 61.28%, respectively. Nutrient index value for OC, N, P, K and S was found 3.00, 1.29, 1.33, 2.00 and 1.00 indicated that soils were high, low, low, medium and low, respectively in these nutrients. The exchangeable calcium and magnesium of the soils varied from 1.24 to 2.10 cmol$_c$ kg^{-1} and 0.48 to 0.96 cmol$_c$ kg^{-1}, respectively. The water-soluble K, exchangeable K, non-exchangeable K and HNO_3 extractable K in the soils ranged from 9.8 to 15.4 mg kg^{-1}, 53.1 to 86.7 mg kg^{-1}, 474 to 598 mg kg^{-1} and 538 to 700 mg kg^{-1}, respectively. Available nutrients had significant positive correlation with OC. Potassium fractions and CEC had significant positive correlation with organic carbon. Highly significant positive relationship amongst different forms of K indicated existence of dynamics equilibrium among various forms of K. Hence, regular monitoring of soil characteristics and balanced nutrient addition through manures and fertilizers is essential for sustainable crop production.

Key words: Potassium forms, physicochemical properties, fertility status

INTRODUCTION

Soil is the most important natural resource on which the sustainability of an agricultural system ultimately depends upon as it's the primary source of nutrients. It is a naturally occurring body developed by a number of complex pedogenic processes, including climate, relief, organism, parent material, and time and the majority of its constituents are minerals, with a small fraction of organic matter. Soil fertility is a dynamic natural property and it can change under the influence of both natural and man-made induced factors. Soil fertility fluctuates throughout the growing season and each year due to alteration in the quantity and availability of mineral nutrients by the addition of fertilizers, manure, compost, mulch and lime in addition to leaching. Therefore, an essential factor in the context of sustainable agriculture is the evaluation of the soil fertility status of an area or region (Singh and Mishra, 2012). The nutrients in soil play an important role in plant growth, development, and yield, and understanding the fertility status of the soil, as well as its interrelationship with physical and chemical properties which can be helpful in understanding the inherent capacity of soil to supply essential nutrients for plants (Poji *et al.,* 2017). Potassium is an essential and a major nutrient for agricultural crop production (Goerge and Micheal, 2002). It is a component of several major soil forming minerals and is one of the distinct effects of pedogenic processes in terms of the morphological and physicochemical characteristics of soil. Soil potassium exists in four forms *viz*., water soluble, exchangeable, non-exchangeable or fixed and mineral or structural K (Sparks, 2000), of which the first two are important for the growth of plants and microbes. The distribution of soil K among water soluble, exchangeable and non-exchangeable is related to many soil properties (Darryl *et al.,* 2004). In particular soils, containing adequate amount of K, the availability to plants is negligible its availability to plants depends not only on its availability but also on its dynamics *viz.* intensity, capacity and renewal rate, and the equilibrium constant is vital for predicting the status and supply of K for plants (Abaslou and

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Abtahi, 2008). Moreover, recent studies showed declining status of K in Indian soils in most of the states from high to medium or medium to low status. It is considered that Indian soils are rich in K and seldom recommended K fertilizers to crops. High crop K removal than K addition by farmers and imbalanced use of NPK fertilizers are contributing to large-scale K mining leading to emergence of K deficiency in soils and crops. In Nagaland, people generally practice terrace and shifting cultivation and the main occupation of the people is agriculture. As the farms are in developing stages, the basic information regarding the land use pattern, soil pattern and soil fertility status are needed for future research and development programs. Hence keeping the above factors in view, a research investigation was carried out to study potassium forms and characteristics of the soils of Chumekedima district of Nagaland, which can help farmers and extension functionaries in making viable and cost effective soil management strategies.

MATERIALS AND METHODS

Description of study area

Medziphema sub-division of Chumekedima district was selected for present study which is situated at 25^{0}43.923' to 25^{0}50.569'N latitude and 93^{0}37.645' to 93^{0}55.202' E longitude. It lies in the hills and has a total area of 345 sq. km. Medziphema sub-division has an average elevation of about 360 meters above sea level. The climate is hot and humid with mean temperature ranges from 21^{o}C to 31^{o}C during summer and rarely goes below 8^{o}C in winter. Average annual rainfall of the area is 2000-2500 mm. Terrace cultivation is generally practiced and dominant crops are rice, maize, pineapple, banana, papaya and vegetables.

Method of sampling and measurement

Present study was conducted during 2021-22 to study various properties of soils under cultivation. Soil samples from 0-15 cm soil depth were collected from twelve different village of the Medziphema, sub-division. Four cultivated fields in each village were selected randomly for sampling purpose and a total of 48 soil samples (12 villages x 4 field in each village) were collected for the present investigation. Sampling was done with the help of an auger. Collected soil samples were air dried and grinded with the help of wooden hammer. Cation exchange capacity was determined by leaching of soil with 1*N* ammonium acetate at pH 7.0 (Chapman, 1965). Bulk density and particle density were determined using standard method of analysis described by Baruah and Borthakur (1997). Total porosity of the soil was calculated from the bulk density and particle density values using the following formula:

$$\text{Porosity (\%)} = 100(1 - \frac{\text{bulk density}}{\text{particle density}})$$

Soil pH, organic carbon, available N and available K were analyzed following standard procedures (Jackson, 1973). For available P, soil samples were extracted with Bray P-1 extractant (Bray and Kurtz, 1945) and phosphorus content in soil extract was determined using the procedure described by Jackson (1973). Available sulphur was estimated by turbidimetric method (Chesnin and Yien, 1951). Exchangeable calcium and magnesium was extracted using neutral ammonium acetate and determined by Versenate method (Gupta, 2007). Water soluble potassium in soil was extracted using distilled water and determined by flame photometer as given by Singh *et al.,* (2019). Exchangeable potassium was determined by subtracting water soluble potassium from NH_4OAc extractable potassium. HNO_3 extractable potassium was determined using boiling *1N* HNO_3 method as given by (Singh *et al.,* 2019). Non-exchangeable potassium was determined by deducting NH_4OAc extractable potassium from HNO_3 extractable potassium.

Nutrient index (NI)

The nutrient index was calculated using the formula suggested by Biswas and Mukherjee (1989) as give below:

$$Nutrient\ index = \frac{Nl + 2Nm + 3Nh}{Nl + Nm + Nh}$$

Where, Nl, Nm and Nh stand for the number of samples in low, medium and high category of available nutrients respectively. The nutrient index classes were categorized into low, medium and high class of soil fertility using the values of nutrient index as:

Low	:	< 1.5
Medium	:	1.5 – 2.5
High	:	>2.5

Statistical analysis

Simple correlation coefficient was worked out to correlate physicochemical characteristics of soils with available nutrients and forms of potassium. Coefficient of variance was used to assess the extent of variation in soil characteristic.

RESULTS AND DISCUSSION

Physicochemical properties

The pH value of the soils of different villages under varied from 3.98 to 4.95 with a mean value of 4.55 indicating that the soils are very strongly to strongly acidic in reaction (Table 1). Coefficient of variance (CV) was recorded 5.3%, which indicated less variation of pH in these soils. Excess leaching of basic cations from soil profile might have facilitated by heavy rainfall which may be cause of acidity in these soils. Mean electrical conductivity (EC) of the soils was reported 0.15 dSm^{-1} with overall range of 0.06 to 0.27 dSm^{-1}. More variation in EC was observed as evidenced by high CV (32.9%). Low EC is attributed to high leaching/flushing of soluble salts due to heavy rainfall/ sloppy landscape (Patton *et al.,* 2005; Sharma *et al.,* 2013). Cation exchange capacity (CEC) of the soils ranged from 10.00 to 13.60 $cmol_c$ kg^{-1} with a mean 11.59 $cmol_c$ kg^{-1} with CV 5.1%. Low CEC of these soils might be due to presence of low CEC clay minerals *viz;* kaolinite and illite, dominantly occurs in the soils of North Eastern states (Dey and Sehgal, 1997). Bulk density of these soils varied from 0.99 to 1.36 Mg m^{-3} with mean value of 1.16 Mg m^{-3}. High organic matter content in these soils might be possible reason of low bulk density. Particle density of the soils ranged from 2.26 to 2.67 Mg m^{-3} with an average value of 2.51 Mg m^{-3}. Porosity of the soils observed in the range of 40.1 to 61.2 per cent with a mean value of 53.7 per cent. Less CV was observed for BD, particle density and porosity (7.5, 3.4 and 7.6%), indicated more stability of these characteristics. These results are in accordance with those of Konyak *et al.,* (2020).

Fertility status

Wide variation in the organic carbon (SOC) content was observed. Nutrient index value for SOC was found 3.00 which showed high nutrient index for SOC (Table 2). The SOC content of the soils ranged from 11.2 to 25.8 g kg^{-1} with an average of 19.92 g kg^{-1} and CV 19.8%. Less tillage activities in hilly soils and low temperature might have reduced decay of organic residues, which may favor organic matter accumulation in these soils. Furthermore, microorganism activities in acid soils retarded which may have reduced SOM decomposition in these soils. These results are in agreement with those of Sangtam *et al.,* (2017); Imtimongla *et al.,* (2024). Available N and P content of soils ranged from 111.4 to 564.4 and 6.7 to 13.8 kg ha^{-1}, with a mean value of 249.1 and 9.6 kg ha^{-1}, respectively. The CV was reported 37.9 and 14.5% for N and P, indicating more variation in nitrogen than phosphorus. Overall soils belong to low category of available nitrogen and phosphorus with a nutrient index value 1.29 and 1.33. Despite high in organic carbon, low N content might be due to low mineralization rate in cold climatic condition and acidic soil environment. Available sulphur content varied from 8.9 to 19.7 kg $ha^{-1}$with mean value of 13.8 kg ha^{-1} and CV 19.8%. Nutrient index value observed 1.00 denoting severe deficiency of sulphur in the area. Lower N, P and S status in these soils may be due to wide gap between addition and removal of nutrients resulting nutrient mining from inherent pool. Exchangeable Ca and Mg in soils varied from 1.24 to 2.10 and 0.48 to 0.96 $cmol_c$ kg^{-1} with mean value of 1.57 and 0.72 $cmol_c$ kg^{-1} respectively, while the CV was observed 8.9 and 12.1%. Possible reason of variation in Ca and Mg content is variation in organic matter content and mining by crops. Similar results have also been reported by Tsanglao *et al.,* (2014); Odyuo *et al.,* (2015).

Potassium fractions

Available K content in the soils varied from 63.6 to 102.1 mg kg^{-1} with mean 73.8 mg kg^{-1} and CV 11.4% (Table 3). Overall soils fell under medium category of available K with nutrient index value 2.00. Water soluble and exchangeable K contributed 15.8 and 84.1% towards available K respectively. Available K contributed 12.1% to *1N* HNO_3-K. These values are fairly comparable to the results reported by Konyak *et al.,* (2020). Water soluble K ranged from 9.8 to 15.4 mg kg^{-1} with an average of 11.6 mg kg^{-1} and CV 11.2%. Water soluble K contributed 1.9% towards HNO_3 extractable K. The soils had exchangeable potassium ranging

Table 1: Physicochemical properties of the soils

Name of the village	pH		EC (dSm^{-1})		CEC ($cmol_c\ kg^{-1}$)		Bulk density ($Mg\ m^{-3}$)		Particle density ($Mg\ m^{-3}$)		Porosity (%)	
	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean
Socunoma	4.52-4.61	4.57	0.12-0.14	0.13	11.60-11.80	11.70	1.07-1.14	1.12	2.47-2.52	2.50	54.2-57.2	55.1
Sirhi Angami	4.65-4.73	4.70	0.11-0.21	0.16	11.10-13.60	12.35	1.03-1.12	1.08	2.45-2.66	2.57	55.9-61.2	57.9
New Piphema	4.73-4.81	4.77	0.13-0.20	0.17	11.60-12.90	12.43	1.06-1.11	1.08	2.62-2.64	2.63	57.6-59.8	59.0
Ruzaphema	4.49-4.55	4.52	0.10-0.14	0.12	10.80-12.10	11.43	1.05-1.16	1.12	2.43-2.55	2.50	53.7-56.8	55.3
Seirhima	3.98-4.15	4.04	0.14-0.18	0.16	10.20-11.00	10.68	1.18-1.36	1.28	2.27-2.48	2.38	40.1-51.2	46.1
Jharnapani	4.39-4.45	4.42	0.08-0.11	0.10	10.90-11.70	11.20	1.14-1.33	1.22	2.49-2.55	2.55	46.5-54.9	51.7
New Medziphema	4.79-4.85	4.82	0.21-0.25	0.23	10.80-13.20	12.28	1.00-1.10	1.05	2.39-2.42	2.41	54.1-58.6	56.4
Bungsang	4.87-4.96	4.91	0.23-0.27	0.25	10.40-13.00	12.13	0.99-1.09	1.04	2.37-2.42	2.40	54.3-58.9	56.7
Molvom	4.44-4.47	4.45	0.09-0.12	0.11	10.70-12.00	11.40	1.12-1.22	1.18	2.49-2.55	2.53	51.8-55.9	53.2
Hekheshe	4.34-4.40	4.37	0.07-0.10	0.09	10.60-11.80	11.18	1.18-1.30	1.24	2.40-2.54	2.46	46.0-53.5	49.6
Moava	4.61-4.68	4.65	0.13-0.18	0.15	10.60-12.20	11.48	1.07-1.35	1.16	2.62-2.67	2.65	48.4-59.6	56.0
Zhuikhu	4.30-4.40	4.35	0.06-0.18	0.12	10.00-11.60	10.83	1.22-1.34	1.29	2.26-2.60	2.48	42.4-52.1	47.7
Overall	3.98-4.96	4.55	0.06-0.27	0.15	10.00-13.60	11.59	0.99-1.36	1.16	2.26-2.67	2.51	40.1-61.2	53.7
CV (%)	5.3		32.9		5.1		7.5		3.4		7.6	

Table 2: Fertility status of the soils

Name of the village	OC ($g\ kg^{-1}$)		Available nutrients ($kg\ ha^{-1}$)						Ex Ca^{2+} ($cmol_c\ kg^{-1}$)		Ex Mg^{2+} ($cmol_c\ kg^{-1}$)	
			Nitrogen		Phosphorus		Sulphur					
	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean
Socunoma	19.8-21.1	20.50	210.7-237.3	224.8	8.9-9.6	9.2	11.0-14.6	12.9	1.41-1.69	1.58	0.65-0.78	0.71
Sirhi Angami	22.3-23.8	23.00	250.8-312.6	283.2	9.7-10.6	10.0	10.8-15.9	13.9	1.26-1.70	1.39	0.69-0.87	0.80
New Piphema	23.5-24.2	23.90	263.4-326.1	302.3	9.9-11.3	10.5	15.8-18.2	17.0	1.24-1.74	1.43	0.58-0.84	0.68
Ruzaphema	19.0-20.8	19.65	198.6-263.3	223.3	8.7-9.3	9.0	12.0-17.0	14.5	1.56-1.84	1.67	0.61-0.96	0.74
Seirhima	11.2-13.2	12.28	111.4-239.4	164.3	6.7-10.1	7.8	8.9-10.3	9.7	1.36-1.92	1.74	0.48-0.95	0.78
Jharnapani	17.9-18.6	18.15	149.4-220.9	185.9	7.9-8.9	8.2	11.2-13.8	12.3	1.36-1.59	1.49	0.55-0.89	0.77
New Medziphema	24.1-25.0	24.48	250.8-376.3	329.2	9.8-12.2	11.2	16.0-18.5	17.3	1.28-1.90	1.71	0.64-0.91	0.83
Bungsang	24.8-25.8	25.15	413.9-564.4	492.2	11.2-13.0	12.1	17.0-19.7	18.1	1.45-2.10	1.75	0.52-0.92	0.72
Molvom	18.1-19.6	18.83	190.9-238.3	206.2	8.5-12.7	9.7	12.0-14.8	13.3	1.31-1.69	1.55	0.56-0.68	0.62
Hekheshe	16.5-17.8	16.95	141.3-350.6	203.7	7.5-12.1	8.8	10.6-12.4	11.2	1.30-1.47	1.40	0.49-0.60	0.55
Moava	20.0-22.4	21.30	193.0-263.4	236.4	9.6-13.8	10.8	13.8-15.9	15.2	1.59-1.78	1.67	0.74-0.96	0.82
Zhuikhu	13.8-15.9	14.88	125.4-146.2	137.9	7.3-8.0	7.6	9.0-11.5	10.3	1.35-1.44	1.40	0.48-0.94	0.63
Overall	11.2-25.8	19.92	111.4-564.4	249.1	6.7-13.8	9.6	8.9-19.7	13.8	1.24-2.10	1.57	0.48-0.96	0.72
CV (%)	19.8		37.9		14.5		19.8		8.9		12.1	
Nutrient index value	3.00		1.29		1.33		1.00		-		-	
Nutrient index	High		Low		Low		Low		-		-	

Table 3: Potassium forms of the soils

S. No	Name of the village	Forms of potassium (mg kg^{-1})									
		Available		Water soluble		Exchangeable		Non- exchangeable		HNO_3 extractable	
		Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean
1	Socunoma	65.5-73.8	69.1	9.8-11.5	10.7	55.7-62.3	58.4	546-556	551	612-629	620
2	Sirhi Angami	67.1-85.6	77.0	10.9-12.9	11.8	56.2-72.7	65.2	559-570	564	626-655	641
3	New Piphema	78.1-87.6	82.2	12.6-14.1	13.1	65.5-73.5	69.0	568-574	570	646-662	652
4	Ruzaphema	65.8-72.8	69.0	10.4-11.4	10.8	55.4-61.4	58.1	530-544	536	596-617	605
5	Seirhima	64.0-70.5	66.7	9.9-11.0	10.6	54.1-59.5	56.0	474-489	481	538-559	548
6	Jharnapani	63.5-70.1	66.6	10.4-10.9	10.6	53.1-59.2	56.0	498-518	507	561-588	574
7	New Medziphema	77.3-96.8	87.2	12.8-14.9	13.8	64.5-81.9	73.4	568-580	573	645-677	660
8	Bungsang	82.7-102.1	90.2	12.9-15.4	14.1	69.8-86.7	76.0	579-598	586	662-700	676
9	Molvom	64.5-70.2	67.3	10.6-11.2	10.9	53.7-59.2	56.4	509-530	517	573-600	585
10	Hekheshe	63.7-70.1	67.0	9.9-10.9	10.5	53.1-59.2	56.5	481-508	481	545-578	558
11	Moava	68.6-80.1	73.9	11.5-12.5	11.9	57.1-68.1	62.0	556-569	564	624-648	638
12	Zhuikhu	63.6-71.9	68.8	10.0-11.6	10.9	53.6-60.3	57.8	478-495	487	541-566	555
Overall		63.5-102.1	73.8	9.8-15.4	11.6	53.1-86.7	62.1	474-598	536	538-700	609
CV (%)		11.4		11.2		11.5		7.2		7.3	
Nutrient index value		2.00		-		-		-		-	
Nutrient index		Medium		-		-		-		-	

Table 4: Correlation coefficient between different soil properties

Parameters	pH	CEC	BD	OC	N	P	AK	S	WK	Ex K	NEK	HNO_3 K	Ex Ca	Ex Mg
pH	1													
CEC	0.260	1												
BD	-0.761**	-0.553**	1											
OC	0.317*	0.646**	-0.530**	1										
N	0.476**	0.215	-0.455**	0.707**	1									
P	0.715**	0.031	-0.418*	0.723**	0.203	1								
AK	0.273	0.515**	-0.316*	0.414*	0.219	0.062	1							
S	0.186	0.201	-0.281	0.507**	0.194	0.169	0.269	1						
WK	0.076	0.219	-0.162	0.376*	0.029	0.268	0.927**	0.074	1					
Ex K	0.172	0.520**	-0.366*	0.373*	0.019	0.061	0.939**	0.068	0.945**	1				
NEK	0.192	0.162	0.182	0.615**	0.271	0.171	0.707**	0.185	0.467**	0.787**	1			
HNO_3K	0.292	0.162	-0.292	0.494**	0.204	0.172	0.815**	0.085	0.464**	0.865**	0.991**	1		
Ex Ca	0.207	0.328*	-0.13	0.209	0.209	0.228	0.218	0.287	0.206	0.251	0.210	0.202	1	
Ex Mg	0.216	0.126	-0.11	0.217	0.083	0.107	0.094	0.211	0.110	0.109	0.262	0.213	0.163	1

AK= available potassium, WK= water soluble potassium, Ex K= exchangeable potassium, NEK= non exchangeable potassium
*** Significant at 1% level of significance (0.42), * Significant at 5% level of significance (0.30)*

from 53.1 to 86.7 mg kg^{-1} with mean of 62.1 mg kg^{-1} and CV 11.5%. Exchangeable K imparted 11.6 and 10.1% towards non-exchangeable and HNO_3 extractable K, respectively. Non-exchangeable K content ranged from 474 to 598 mg kg^{-1} with an average of 536 mg kg^{-1} and CV 7.2% and it constituted 88.0% of HNO_3 soluble K. The HNO_3 soluble K varied from 538 to 700 mg kg^{-1} with a mean of 609 mg kg^{-1} and CV 7.3%. Variation in distribution of K fractions might be due to variation in potassium mining by crops and degree of minerals weathering (Prasad, 2010). Non exchangeable and HNO_3 extractable potassium fractions reported more stable than available, water soluble and exchangeable K fractions as evidenced by CV. These results are confirmatory with those of Sharma, (2013) for acidic soils of Nagaland.

Correlations

Correlation values presented in Table 4 revealed that available N had significant positive correlation with pH and organic carbon (r= 0.476**, 0.707**) and negative with BD (r= -0.455**). Available phosphorus had significant positive correlation with pH and OC (r= 0.715**, 0.723**) and significant negative with BD (r= -0.418*). Available potassium exhibited significant positive correlation with CEC, OC, WK, EK, NEK and HNO_3K (r=0.515**, 0.414*, 0.927**, 0.939**, 0.707**, 0.815**) and negative with BD (r= -0.316*). Available sulphur manifested significant positive correlation with OC (r= 0.507**). Positive significant correlation between organic carbon and available N, P, K, S revealed that organic matter is prominent source of available nutrients and soil pH governs their availability. Exchangeable Ca had positive significant correlation with CEC (r= 0.328*). Positive significant correlation was observed between organic carbon and forms of K. Exchangeable K had positive significant correlation with CEC (r= 0.520**) and negative with BD (r= -0.366*). All forms of potassium were positively and significantly correlated with each other. Similar relationship among soil properties have also been reported by Longchari and Sharma, (2022).

The above results lead to a conclusion that the soils were strongly to moderately acidic in reaction and low in CEC. The soils were high in OC, medium in available K, low in available N, P and S. The soils of studied area have major problem of acidity; the application of lime is essential to improve soil fertility and better crop growth. Available nutrients have significant positive correlation with organic carbon which proved importance of organic carbon in nutrient supply in these soils. Organic carbon of soils showed significant and positive correlation with all forms of potassium. Highly significant and positive relationship was observed between different forms of K.

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