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VERTICAL DISTRIBUTION OF AVAILABLE MACRONUTRIENTS IN RELATION TO PHYSICO-CHEMICAL PROPERTIES UNDER DIFFERENT LAND USES OF COLD ARID SOILS OF SPITI VALLEY IN HIMACHAL PRADESH

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ABSTRACT

To study the status and vertical distribution of secondary and macronutrients in soils of Spiti valley in Himachal Pradesh, Global positioning system (GPS) based 13 representative soil profiles were exposed to a depth of 1.5 m soil samples were collected randomly from cultivated and pasture lands using stainless steel spatula. The profile samples were analysed for available NPK, exchangeable calcium, magnesium and, available sulphur and physico-chemical properties *viz*. Soil pH, soil texture, bulk density, water holding capacity, electrical conductivity, organic carbon, cation exchange capacity, anion exchange capacity and $CaCO_3$ contents. The soils were found sandy loam to sandy clay loam in texture and slightly alkaline in their reaction (pH 7.7-8.1). Electrical conductivity was found between 0.19-0.50 dS m^{-1}. Available N contents were in low category whereas, P and K were found in medium category. Sand did not show significant relation with any of the physico-chemical properties studied in all the three land uses, whereas silt showed positive and significant relationship with WHC and EC.Clay contents were correlated positively and significantly with all the secondary nutrients (Ca, Mg and S).

KEY WORDS
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INTRODUCTION

AvailableMacro nutrients are important constituents in soil that promote plant growth. Concentrations of these macronutrients in the soil are generally determined before the site is disturbed in order to complete a site reclamation plan. Macronutrient are important for growth because it is major part of amino acid, which are the building block of all proteins, including the enzymes, which control virtually all biological processes. A good supply of macronutrients stimulates root growth and development, as well as the uptake of the other nutrients. Spiti region is a separate geographical unit separated from Lahaul by Kunzum pass (4551m amsl), a typical cold arid mountain much more difficult with a lowest point at 3050 m amsl. The major area is under barren and uncultivated land (77%) and pastures (22%). Major crops of the valley are Pea, Barley, Potato, Wheat, Rajmash, and Apple. Soil micro flora population is sparse due to poor soil structure, texture, very high sand and clay, low biological activity and freezing during long winter period in this region (Campbell and Claridge, 1987). The extremely high altitude of Himalaya probably provides a unique glacial climate on earth. In this area, sub zero temperature during maximum periods are responsible for different texture, mineralogy and very low soil development process indicating more advance stage of weathering. Altitude profoundly affects the soil's inherent fertility and runoff-erosion behavior (Bowman *et al*., 2002). Level of rainfall, snowfall, and temperature variation affects organic matter decomposition that affect accumulation of organic matter with elevation (Walker *et al*., 2000). These changes in microenvironment may affect physico-chemical characteristics of soil in this region hence there is need to study the physico-chemical characteristics of soil in this area.

MATERIALS AND METHODS

This study was designed with the objective to determine the altitude effect on available macronutrients and micronutrients properties of cold arid soils of Spiti Valley in Himachal Pradesh. The study area falls in extending between the latitudes 32º05′008″ N to 32º26′732″ N and longitudes of 077º45′744″ E to 078º06′636′′ E. The surface (0-15 cm) and subsurface (15-30) soil samples were analyzed for the properties *i.e*. soil texture was determined by rapid titration methods and water holding capacity as suggested by (Piper, 1950). Calcium carbonate was determined by Keen's box method as suggested by (Puri, 1930). Soil reaction by pH meter, electric conductivity (EC) by EC meter, organic carbon in soil was determined by Walkley and Black's rapid titration methods as suggested by Piper, 1966). Available N was estimated by using alkaline KMnO4 method as suggested by (Subbiah and Asija, 1956). Available P content of the soil was extracted with sodium bicarbonate by (Olsen *et al*., 1954). Cation exchange capacity, Exchangeable cations (Ca, Mg and Na) and available potassium by Neutral normal ammonium acetate extraction method suggested by (Jackson, 1967). Bulk density by Weighing bottle method suggested by (Lutz, J.F., 1947). Anion exchange capacity by 1N ammonium phosphatemethod suggested by (Sadana, 2007). Available Sulphur by Turbidimetric method as suggested by (Chesinand Yien, 1950). Available micronutrients (Zn, Fe, Cu, Mn, Ni, Pb) by DTPA Extraction as suggested by (Lindsay and Norvell, 1978). Mo by Ammonium Oxalate Extraction (pH 3.3) suggested by (Grigg,1953). Available Boron by Carmine method sa suggested by (Hatcher and Wilcox, 1950).

RESULTS AND DISCUSSION

Available nitrogen

The surface soils were having comparatively higher nitrogen content than the subsurface soils and the cultivated land (apple plantation) have more available nitrogen in comparison to cultivated lands (annual crops) and pasture lands which might be due to continuous addition of organic matter and frequent applications of nitrogenous fertilizers in orchards. The values of available nitrogen decreased with the increase in profile depth (Table 1). Decreasing clay and organic matter might have contributed to the decreased available N content with depth.These results authenticated the earlier findings of (Rajeshwar *et al*., 2009; Nayak *et al*., 2014 and Singh, 2012). who have also reported higher available N content at the surface and a decreasing trend with depth.

Available phosphorus

Data (Table 1) showed that available P content decreased with depth. Higher P content in the surface horizons of cultivated soils might be due to the confinement of crop roots to this layer and supplementation of the depleted phosphorus through additional phosphatic fertilizers. Similar results have also been reported by Rajeshwar *et al*, 2009; Sharma, 2011 and Chandravanshi *et al*., 2012. In general, surface soils are categorized as medium and sub surface soils as low to medium in available P content.

Available potassium

Available potassium was found decreasing with increase in soil depth in all the land uses under study (Table 1). High potassium in the pasture lands is due to the presence of yellow to brown coloured cretaceous age sand stone containing glauconite which is a potash rich mineral. These results are in line with the findings of Venkatesh and Satyanarayana, 1994; and Sharma, 2011.

Available Sulphur

Sulphur content increased with increase in soil depth (Table 1) certainly because of deposits of gypsum in the area associated with Lipak limestone in thick bands (Sharma and

Table 1: Available macronutrients distribution in different profile soils of Spiti valley

Location	Depth (cm)	Available nutrients (kg ha^{-1})				Exchangeble nutrients {cmol (p^{+}) kg^{-1} }	
		N	P	K	S	Ca	Mg
1	2	3	4	5	6	7	8
Cultivated lands (annual crops)							
Dankhar	0-10	156	42	153	11	15.3	2.8
	Mean* (10-124)	116.5	40.5	125.5	26.5	11.15	1.95
Geu	0-20	225	37	281	11	15.5	2.5
	Mean*(20-120)	197.5	24.5	204.7	16.5	12.8	1.8
Kaza	0-5	199	49	132	14	16.0	3.2
	Mean*(5-55)	189.7	42.7	111.7	19.2	13.42	2.7
Lalung	0-20	219	48	185	16	14.8	3.7
	Mean*(20-136)	149.6	27.8	128.1	48.5	10.8	2.4
Lari	0-15	285	53	143	36	14.4	2.8
	Mean*(15-120)	229.5	39.7	124.2	47.2	11.2	2.1
Pangmo	0-10	250	26	133	44	9.2	3.4
	Mean*(10-98)	220.2	42	108.6	54.8	8.8	2.0
pasture land							
Chicham	0-17	191	80	225	81	15.2	2.9
	Mean*(17-120)	186.4	66.4	165.0	37.8	13.1	2.0
Hull	0-5	194	42	261	36	16.1	2.4
	Mean*(5-95)	164.2	43.2	191.8	48.1	12.5	2.0
Kakti	0-10	344	24	201	56	13.7	2.5
	Mean*(10-58)	225.5	28.2	137.7	59.0	10.7	2.1
Kibber	0-17	203	53	214	11	14.8	3.3
	Mean*(17-90)	147.8	56	161.4	27.4	11.1	2.1
Lidang	0-7	194	17	158	33	12.3	2.8
	Mean*(7-95)	186.0	27.2	130.0	44.0	10.2	2.3
Lingti	0-30	174	27	148	48	11.5	3.2
	Mean*(30-128)	165.8	26.8	130.1	32.3	8.2	2.2
Shego	0-12	250	62	147	25	15.5	3.3
	Mean*(12-120)	204.8	40.6	121.4	39.4	12.3	2.4

Mean* = Average of below surface values

Table 2: Physico-chemical properties of different profile soils of Spiti valley

Location	Depth (cm)	Mechanical separates (%) Sand	Silt	Clay	Texture	Bulk density ($Mg\ m^{-3}$)	WHC (%)	pH	EC ($dS\ m^{-1}$)	OC ($g\ kg^{-1}$)	CEC [cmol (p^+) kg^{-1}]	AEC [cmol (p^-) kg^{-1}]	Ca CO_3 (%)
1	2	3	4	5	6	7	8	9	10	11	12	13	14
Cultivated lands (annual crops)													
Dankhar	0-10	57	37	16	SL	1.22	31.22	8	0.19	26.8	19.3	0.44	8.8
	Mean*(10-124)	58	32	8		1.27	27	8.1	0.19	21.7	15.0	0.31	5.5
Geu	0-20	56	21	21	SCL	1.22	24.0	7.8	0.32	18	14.1	0.43	6.5
	Mean*(20-120)	56	29	11		1.24	23.3	7.9	0.29	15.8	8.8	0.43	4.9
Kaza	0-5	63	14	20	S C L	1.33	28	8	0.49	20.7	23.7	0.56	12.3
	Mean*(5-55)	55	29	12		1.24	26.0	7.8	0.31	23.0	19.5	0.32	7.5
Lalung	0-20	58	24	16	SL	1.26	28	8	0.47	22.9	21	0.58	11.2
	Mean*(20-136)	56	28	13		1.21	21.0	7.8	0.21	13.0	17.3	0.33	6.4
Lari	0-15	49	31	16	L	1.17	33.33	8.0	0.52	24.7	21	0.53	9.2
	Mean*(20-136)	57	29	12		1.21	21.0	7.8	0.43	13.0	17.3	0.33	6.4
Pangmo	0-10	48	30	18	SCL	1.37	24	7.8	0.51	21.5	24.5	0.51	11
	Mean*(10-98)	51	35	11		1.22	22.9	7.8	0.30	20.3	19.7	0.33	7.7
1	2	3	4	5	6	7	8	9	10	11	12	13	14
Pasture lands													
Chicham	0-17	58	35	5	L	1.50	28	7.8	0.18	11.2	23	0.46	7.9
	Mean*(17-120)	55	33	11		1.48	27.4	7.9	0.20	6.2	18.6	0.30	4.9
Hull	0-5	55	32	11	SL	1.31	32	8	0.27	18.4	21.3	0.42	12
	Mean*(5-95)	55	33	9		1.23	29.9	7.9	0.15	14.4	17.9	0.30	9.9
Kakti	0-10	56	31	10	SL	1.27	25	7.9	0.25	15.0	19.3	0.33	10.3
	Mean*(10-58)	48	36	14		1.20	23	8.0	0.18	13.7	16.6	0.29	8.1
Kibber	0-17	58	31	10	SL	1.29	24	8	0.15	16.9	19.8	0.32	12
	Mean*(17-90)	56	29	14		1.32	21	7.8	0.27	8.8	16.8	0.27	7.8
Lidang	0-7	60	31	6	SL	1.49	24	7.8	0.17	27.4	21	0.32	7.1
	Mean*(7-40)	54	30	13		1.29	21	7.8	0.19	23.2	19.3	0.26	4.5
Lingti	0-30	56	24	18	SCL	1.37	20	8	0.14	27.4	20.5	0.61	9.6
	Mean*(30-128)	55	32	10		1.30	22.1	8.0	0.15	23.2	16.3	0.40	5.3
Shego	0-12	61	31	5	SL	1.39	31	7.9	0.29	7.6	22.1	0.47	7.8
	Mean*(12-120)	56	27	13		1.38	28.1	7.8	0.20	4.17	17.3	0.29	5.4

Mean* Average of below surface value

Singh, 1991). Comparatively lower content in the surface horizons may be due to the over exploitation by crops and grasses.

Exchangeable calcium

The contents of exchangeable Ca in all the soil profiles under all land uses were found to decrease in the subsurface which kept on decreasing with increase in soil depth (Table 1). Higher exchangeable Ca in the surface soils may be due to higher organic carbon, $CaCO_3$ and clay in the surface layer. (Nair and Chamuah, 1988 have also reported higher exchangeable Ca in surface horizons in soils of Meghalaya.

Exchangeable magnesium

Exchangeable Mg content in the surface soils was found high which might be due to the higher organic matter and decrease with depth owing to decrease in OC and clay with increase in depth. (Singh and Raman, 1982) reported a decreasing order of exchangeable Mg in sub surface soils.

Mechanical separates

Sand content decreased or increased or remained unchanged with soil depth but under pasture lands it tended to accumulate in the surface *i.e.* it decreased with increase in soil depth.The silt content in cultivated lands increased with increase in soil depth but under pasture lands it tended to accumulate in surface layers. Clay content in cultivated soils showed accumulation in surface layers whereas in pasture lands it tended to increase up to certain depth but the content were lowest at the lowermost depths *i.e.* mostly beyond one meter depth. The increasing tendency of clay with depth in pasture lands may be due to leaching during snowmelt. Pastures are generally located at mountain tops or comparatively at higher elevation as compared to cultivated landsand hence receive enough and regular snowfall whereas, it is very occasional in cultivated lands which are generally at lower valleys. The results are in close conformity with the earlier reports by Verma, 1979; and Sharma and Kanwar.,2010.

Water holding capacity (WHC)

The data on WHC under different land uses have been given in tables 2 data revealed that WHC decreased with increase in soil depth. It may be due to decrease in finer fraction (clay) of soils with depth as WHC of soils is influenced greatly with the amount of clay contents. These results are in line with the findings of Babhulkar *et al.*, 2000. Pasture lands were found to have comparatively lower WHC as compared to cultivated lands (annual crops) because of higher clay and organic matter content in cultivated lands (annual crops).

Bulk density

Bulk density decreased with increase in soil depth in all the soil profiles under study (Table2). This may be attributed to the decrease in fraction with depth. Parmar *et al.*, 1999 and Sharma and Kanwar., 2010 have also reported similar results for Spiti soils of HP.

Soil pH

The pH of cultivated lands (annual crops) was observed declining towards neutrality and comparatively low as

compared to pasture lands because of amelioration effect due to regular addition of FYM to annual crops. Similar findings have also been reported by Singh *et al.*, 2014 for the soils of cold desert area in district Lahaul and Spiti of Himachal Pradesh.

Table 3:Correlation between physico-chemical properties and macronutrients in different land uses in Spiti valley

Physico-chemical properties	Available Macronutrients					
	N	P	K	S	Ca	Mg
Cultivated lands (annual crops)						
Sand	0.113	0.134	0.166	-0.016	0.092	0.002
Silt	0.137	0.166	0.149	0.128	-0.128	-0.030
Clay	0.089	0.020	0.020	0.036	0.036	0.050
Bulk density	-0.105	-0.140	0.068	-0.005	0.001	0.129
WHC	0.106	-0.092	0.063	-0.107	0.197*	0.142
pH	0.097	-0.161	0.157	-0.059	0.197*	0.018
EC	0.063	0.142	0.136	0.030	0.110	0.077
OC	0.018	0.187	0.182	0.137	0.137	0.116
CEC	0.106	0.142	0.206*	-0.144	0.244*	0.210*
AEC	0.097	0.052	-0.066	0.066	-0.137	-0.041
$CaCO_3$	0.164	0.051	0.054	0.307	0.026	0.117
Cultivated lands (apple plantation)						
Sand	-0.223	0.189	0.199	-0.201	0.099	0.158
Silt	-0.671	-0.122	0.804*	0.410	0.011	0.814*
Clay	0.158	0.439	0.774*	0.153	0.535*	0.866*
Bulk density	-0.471	-0.122	0.304	-0.410	0.011	0.214
WHC	0.142	0.686*	0.927*	-0.440	0.762*	0.874*
pH	-0.307	-0.399	-0.377	-0.585*	0.860*	0.096
EC	-0.307	-0.189	0.977*	0.585*	0.869*	0.696*
OC	0.998*	0.782*	0.451	0.931*	0.708*	0.988*
CEC	-0.625*	-0.062	0.660*	-0.355	0.649*	0.778*
AEC	0.634*	0.650*	0.262	0.648*	0.160	0.403
$CaCO_3$	0.272	0.197	0.938*	0.330	0.999*	0.618*
Pasture lands						
Sand	-0.248	0.067	0.248	0.214	0.214	-0.274
Silt	-0.223	0.353	0.724*	-0.160	0.334	0.783*
Clay	0.166	0.820*	0.014	0.643*	0.591*	0.687*
Bulk density	-0.160	-0.009	0.204	-0.338	0.311	0.373
WHC	0.297	0.238	0.275	-0.117	0.513*	0.511*
pH	0.007	-0.712	0.202	0.336	0.606*	0.621*
EC	-0.065	0.230	0.645*	0.024	0.665*	0.710*
OC	0.327	0.802*	0.649*	0.315	0.661*	0.094
CEC	0.202	-0.378	0.583*	0.004	0.656*	0.772*
AEC	0.549*	0.579*	-0.331	0.616*	-0.313	-0.177
$CaCO_3$	0.594	0.181	0.089	0.278	0.670*	0.622*

*Significant at 5% level of significance

Electrical conductivity

Electrical conductivity values decreased with increase in soil depth (Table 2) in all the soil profiles under study. Similar results were reported by Dharkanath *et al.*, 1995 for arid region in Maharashtra state. EC values in the study area are in safe limits (<0.8 dS m^{-1}) without any salinity/ alkalinity hazards. Similar results were reported by Sharma and Singh, 1991. for Spiti catchment soils in Himachal Pradesh.

Organic carbon

Organic carbon content decreased with increase in soil depth in all the soil profiles (Table 2) under study. Incorporation of leaf litter and addition of decayed roots in the upper layers and their further decomposition might have resulted in accumulation of organic carbon in the surface layers. Similar vertical distribution pattern of organic carbon have been reported by (Parmar *et al.*, 1999).(Krishnan *et al.*, 2004) in HP soils.

Cation exchange capacity (CEC)

CEC of the soils of different profiles decreased with depth (Table 2). Relatively low CEC values might be due to dominance of clay minerals with low CEC and low clay contents in the lower horizons. The higher CEC values at surface might be due to higher organic matter at the surface of the profiles. These results are in conformity with the findings of (Minhas *et al.*, 1997).

Anion exchange capacity (AEC)

The AEC decreased with the increasing profile depth under all the land uses of Spiti valley because of decrease in clay and organic matter content with depth (Table 2). The similar findings were reported by (Toner *et al.*, 1989).

Calcium carbonate

Data in Table 2, indicated a decrease in $CaCO_3$ content with increase in soil depth certainly due to the arid conditions where no rains and no downward movements of salts. Findings corroborates with that of (Bassirani *et al.*, 2011) who have also reported the higher content of $CaCO_3$ in the surface and decreasing content with the depth.

Correlation

Correlation of sand, silt, clay and WHC was worked out with available macronutrients (Table 3). In cultivated lands (annual crops), correlation of sand with sulphur was found negative and non significant, whereas, it was positive and non significant with N, P, K, Ca and Mg. Silt showed negative and non significant relationship with Ca and Mg. Clay did not show any relationship with N, P, K, S, Ca and Mg. Similar were the findings of (Gupta and Dabas, 1980. pH showed positive and significant relationship with Ca only.In cultivated lands (apple plantation), correlation of sand was found negative but non significant with N and S, whereas, silt and clay showed the significant positive with K and Mg. The negative and non significant correlation of bulk density was found with N, P and S. WHC was found to have positive and significant relationship with P, K, Ca and Mg. A positive and significant correlation of pH was found with Ca only and significantly negative with S only. In pasture lands, a positive but non- significant correlation was observed between sand and P, K, S and Ca only. Silt showed positive and significant relationship with K and Mg only. Clay showed positive relationship with all macronutrients but significant with P, S, Ca and Mg only, whereas bulk density did not show any significant relationship with macro and secondary nutrients but showed negative non significant with N, P and S. $CaCO_3$ was found to have positive and significant relationship with Ca and Mg only.

Hence it is concluded that the soils of Spiti valley were found low in available N, low to medium in available K, medium to high in available P and high in available sulphur. Available sulphur increased with increase in soil depth certainly because of deposits of gypsum in the area associated with Lipak limestone in thick bands. The soils were moderately alkaline in reaction, medium to high in organic carbon and have high values of CEC. Bulk density was highly variable ranging from 1.2 to 1.67 Mgm^{-3}. EC, CEC, AEC and calcium carbonate contents were in safe and required limits. Sand did not show significant relation with any of the physico-chemical properties studied in all the three land uses, whereas silt showed positive and significant relationship with WHC and EC.

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