Appendix

Characteristics of Some Soils of Sikkim at Various Altitudes

TAPESH LAHIRI AND S.K. CHAKRAVARTI

Department of Chemistry, North Bengal University, Darjeeling, West Bengal, 734430

Abstract: *Soil samples from ten places in Sikkim having varying altitudes have been analysed for soil texture, NPK and micronutrient status and distribution and nature of organic matter. Soils contain high nitrogen, low available potassium and medium available phosphorus. The contents of available iron, manganese, zinc and copper as judged by the critical values seem to be adequate. The clay content decreases and organic matter increases with increase in altitude of the places. The ratio of the extinction coefficients at 465 nm (E_4) and 665 nm (E_6) of humic and fulvic acids are higher and the percentage of carbon in the humic acids are lower in the high altitude soils than that of the low altitude soils.* **(Key words:** Soil texture, mountain soils, organic matter, micronutrient status)

Sikkim is a mountaneous state in the Eastern Himalayan Region. It is located between 27° and 28° north latitudes and 88°-89° east longitudes. Physicochemical characteristics of the soils are very much governed by the ecosystem. No systematic emphasis has been given to this part of the country (Sikkim) to study the ecosystem of hill soils. Unscientific farming as well as heavy rainfall sometimes become the prime cause of soil erosion and environmental imbalance.

Attempts were made to study the distribution pattern and the properties of organic matter, soil texture and nutrient status as functions of altitude and climate.

Materials and Methods

Soil samples (0-20 cm) were collected from different altitudes of the Sikkim state. To get a good representative sample, repeated quartering technique was employed. The soil samples were then processed for analysis. The clay fraction (< 2 μm) was separated by the usual procedure followed in mechanical analysis.

The organic matter was extracted with 0.5*M* NaOH and freed from clay by repeated centrifugation. The acid soluble fulvic acid was separated by adding dilute HCl. The crude humic acid thus obtained was purified by repeated washing and extensive dialysis against water. Fulvic acid was preserved as Ba-salt.

Hydrogen forms of humic acids and clays were prepared by passing them through a column of H-form cation exchange resin

(Amberlite IR 120). The free fulvic acids were obtained by treating the Ba-salt with H-form cation exchange resin. The cation exchange capacity (CEC) of these acids were determined with Ba $(OH)_2$ in presence of $BaCl_2$.

Total organic matter was estimated by Walkley and Black's rapid titration method. Easily extractable organic matter of the soils was estimated from the soils after 24 h treatment with 0.5 *M* NaOH. Mechanical analysis of the soils was done by international pipette method. Total nitrogen was estimated by macro-Kjeldahl's method., available potassium in normal neutral ammonium acetate extract by using a flamephotometer and available phosphorus by Truog's (1930) method. Available micronutrients were estimated in DTPA extract with the help of atomic absorption spectrophotometer. Spectral studies were performed with a UV-visible spectrophotometer (Shimadju UV-240).

Results and Discussion

Almost all the soils contain low clay content. The clay content decreases and sand increases with increase in altitude (Table 1). This is probably due to the continuous removal of clays through heavy rainfall.

All the soils contain very high organic matter content. The percentage of total organic matter generally increases with increase in altitude (Table 2). The result is in conformity with that of Mukhopadhyay and Banerjee (1985). The high organic matter content of mountain soils is mainly because of their low temperature and heavy rainfall. Low temperature slows the decomposition of organic matter by restricting the microbial population. The easily extractable organic matter of all the soils is comparable, suggesting the lower extent of humus fixation in the high altitude soils.

All the soils are acidic in nature (pH 5.0–5.8). This is expected because of higher rate of leaching and very high percentage of organic matter in the soils. The decomposition of humus in the soil may lead to the formation of a number of organic acids much simpler in composition than humic acid resulting in lowering the pH (Mukherjee 1976).

These soils contain high amount of nitrogen. This is mainly due to the presence of high organic matter content. The available potassium content of the soils is low but the available phosphorus content is medium (except in Majhitar and Mamring), where this is low.

Micronutrient Status of Soils

The micronutrient status of the soils

Table 1. *Some characteristics and mechanical analysis of the soils*

Location	Altitude (m)	pH	EC ($dS\ m^{-1}$)	Clay (%)	Silt (%)	Sand (%)	Texture*
Gangtok	1600	5.06	0.183	7.1	20.2	75.6	sl
Nagi	1560	5.15	0.109	8.1	17.7	70.6	sl
Namthang	1392	4.92	0.280	8.8	19.2	67.3	sl
Turung	1290	5.30	0.266	8.7	18.0	71.2	sl
Central Pendum	510	5.28	0.075	9.6	25.6	62.6	sl
Narakjhora	503	5.81	0.040	9.6	30.0	55.1	sl
Singtum	391	5.50	0.111	13.0	31.0	50.5	l
Majhitar	390	5.40	0.202	10.8	38.5	47.0	l
Mamring	360	5.50	0.185	15.7	40.0	49.0	l
Rangpo	350	5.63	0.150	12.0	35.7	49.8	l

*sl: sandy laom; l: loam

Table 2. *Organic matter, NPK and micronutrient status of the soils*

Location	Total org. matter (%)	Easily extr. org. matter (%)	Total N (%)	Available nutrients (ppm)					
				K	P	Fe	Zn	Mn	Cu
Gangtok	7 68	2.66	0 101	12.3	20.35	98.7	2.5	5.0	0.2
Nagi	6 96	2 79	0.075	9.2	15.05	110 5	0.4	2.0	1.2
Namthang	5 64	2 60	0.054	17.6	14.16	89.8	1.0	12.6	2.7
Turung Central	6 22	2 47	0.067	18 7	27.77	94.2	0.8	7.5	0.6
Pendum	5 43	2.50	0.051	16 3	12.15	105.3	0.7	10.2	0.8
Narakjhora	4 35	2.15	0.043	13.8	27.55	72.5	1.9	5.8	2.1
Singtum	4 05	2.07	0.035	19.2	10.50	60.5	6.5	18.5	1.2
Majhitar	4.55	2.23	0.030	4.3	7.11	76.2	2.0	3.9	2.5
Namring	5.03	2.01	0.062	14.8	7.95	84.6	5.2	25.5	12.5
Rangpo	4.25	2.05	0.025	11.6	15.75	52.1	3.1	15.7	3.8

pertaining to available iron, manganese, zinc and copper is given in table 2. The soils under study are adequate in available Fe. The high altitude soils are high in available Fe than low altitude soils. This is due to the acidic pH and high organic matter content. The availability of Fe decreases with increase in soil pH (Biswas 1953; Biswas & Gawande 1964) as Fe is converted to highly insoluble oxides at high pH. Organic matter forms soluble complexes with iron and is easily available to the plant (Sauchelli 1969).

These soils contain 2.0 to 25.5 ppm of available Mn. If the critical limit for DTPA extractable Mn is taken as 2.05 ppm (Bansal *et al.* 1987), all the soils except Nagi contain adequate amount of available Mn. The available Mn content of the high altitude soils is lower than that of low altitude soils. As organic matter forms insoluble complexes with manganese, the manganese availability in the high altitude soils may decrease due to the presence of high organic matter.

Available Cu in these soils varies from 0.2 to 12.5 ppm. The low altitude soils are high in available Cu than high altitude soils. In the latter, organic matter fixes copper and prevents leaching of soluble copper (Sauchelli 1969). Taking the critical limit of 0.2 ppm (Lindsay & Norvell 1978) in respect of DTPA extractable Cu, the soils are sufficient in available Cu.

These soils contain 0.4 to 6.5 ppm of available Zn. If 0.61 ppm Zn is taken as critical limit for DTPA extractable Zn (Singh & Shukla 1985), all the soils except Nagi contain adequate amount of available Zn. The lower content of available Zn in the high altitude than the low altitude soils could be attributed to strong sorption of zinc by organic matter in these soils.

Nature of Organic Matter

The CEC of humic and fulvic acids of the soils are considerably high (Table 3). This is

Table 3. *Cation exchange capacity of soils clays, humic and fulvic acids*

Location	CEC [c mol (p⁺)kg⁻¹]		
	Clay*	Humic acid	Fulvic acid
Gangtok	16	455	802
Nagi	21	525	785
Namthang	9	487	635
Turung	12	492	702
Cental Pendum	18	470	690
Singtum	26	402	605
Mamring	13	427	585

*Freed from free oxides of the soils and organic matter

Table 4. *Optical density and carbon content of humic and fulvic acids of the soils*

Location	E_4		E_6		E_4/E_6		Carbon as % ash-free substance		HA C / FA C
	HA	FA	HA	Fa	HA	FA	HA	Fa	
Gangtok	0.672	0.465	0.148	0.105	4.54	4.43	42.5	30.8	1.38
Nagi	0.650	0.463	0.165	0.100	3.94	4.63	40.6	28.5	1.42
Namthan	0.705	0.466	0.176	0.102	4.00	4.57	48.7	38.5	1.25
Turung	0.802	0.450	0.235	0.111	3.41	4.05	43.6	25.7	1.69
Central Pendum	0.782	0.475	0.225	0.109	3.47	4.36	50.5	27.3	1.85
Singtum	0.975	0.501	0.240	0.125	4.06	4.01	53.3	41.0	1.30
Mamring	0.885	0.485	0.232	0.106	3.81	4.57	49.6	30.2	1.64

due to the more aliphatic side chain in these organic acids (Banerjee & Chakrabarty 1977).

The humic and fulvic acids of these soils have low optical density, suggesting thereby less condensed aromatic rings in these acids (Schnitzer 1971). The ratio of the extinction coefficients at 465 nm (E_4) and 665 nm (E_6) of humic and fulvic acids are high in high altitude soils. This indicates that the humus is of more recent origin (Cambell *et al.* 1967). The E_4/E_6 values of fulvic acids are higher than that of humic acids. This suggests that the fulvic acids have less condensed aromatic ring of carbon atom than the humic acids. The percentage of carbon in the humic acids are low in the high altitude soils than the in lower altitudes (Table 4). The percentage of carbon in these acids in low altitude soils increases on maturing. These features are considered indicative of the increasing degree of condensation of the aromatic rings in the humic acid molecules (Kononova 1975).

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References

Banerjee, S.K. & Chakrabarty, A.K. (1977) *J. Indian Soc. Soil Sci.* **25**, 18.

Bansal, R.L., Takkar, P.N. & Nayyar, V.K. (1987) *Fertil. Res.* **11**, 61.

Biswas, T.D. (1953) *J. Indian Soc. Soil Sci.* **1**, 21

Biswas, T.D. & Gawande, S.P. (1964) *J. Indian Soc. Soil Sci.* **12**, 261.

Cambell, C.A., Paul, E.A., Rennie, D.A. & Macallum, K.J. (1967) *Soil Sci.* **104**, 217.

Kononova, M.M. (1975) In *Soil Components*, Vol. 1 (Ed Gieseking J.E.), Springer Verlag, New York Inc., U.S.A.

Lindsay, W.L. & Norvell, W.A. (1978) *Soil Sci. Soc. Am. J.* **42**, 421

Mukherjee, S.K. (1976) *Bull. Indian Soc. Soil Sci.* **11**, 86

Mukhopadhyay, N. & Banerjee, S.K. (1985) *J. Indian Soc. Soil Sci.* **33**, 248

Sauchelli, V. (1969) *Trace Elements in Agriculture*, Van Nostrand Reinhold Co., New York

Schnitzer, M. (1971) *Soil Biochemistry*, Vol. 2, Marcel Dekker Inc., New York.

Singh, K. & Shukla, U.C. (1985) *Int. J. Trop. Agric.* **3**, 288

Truog, E. (1930) *J. Am. Soc. Agron.* **22**, 874

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