Indian J. Agric. Res., **48** (2) 120-126, 2014
DOI: 10.5958/j.0976-058X.48.2.020

AGRICULTURAL RESEARCH COMMUNICATION CENTRE
www.arccjournals.com

PHYSICO-CHEMICAL PROPERTIES AND WATER HOLDING CAPACITY OF CULTIVATED SOILS ALONG ALTITUDINAL GRADIENT IN SOUTH SIKKIM, INDIA

P. Deb, P. Debnath and S.K. Pattanaaik[1]

Department of Natural Resource Management,
College of Horticulture and Forestry ,CAU, Pasighat-791 102, India

Received: 29-12-2012 Accepted: 26-08-2013

ABSTRACT

An investigation was carried out to study the physical and chemical properties of soils and its relationship with water holding capacity along altitudinal gradient for cultivated soils of South Sikkim. The physiography of the study area was mainly hilly terrain with closely spaced contour on steep sloppy lands. The soil texture ranged from sandy loam to clay with slightly acidic (6.6) to highly acidic (4.2) in reaction. The organic carbon content varied from 1.22 to 3.45 per cent with a mean value of 2.31 per cent. The bulk density, particle density, porosity, volume expansion and water in air dry soils ranged from 1.08 to 1.54 gm/cc, 2.05 to 2.77 gm/cc, 42.44 to 61.73 per cent, 2.95 to 11.9 per cent and 0.68 to 4.32 per cent, respectively. The water holding capacity (WHC) ranged from 33 to 73.86 per cent with a mean value of 54.18 per cent. The results revealed that 80 per cent of the soil samples have medium to high WHC while only 20 per cent are of low category. A significant positive relationship was observed between WHC and organic carbon, clay and porosity, while, a negative relationship was found with pH and bulk density with sand and silt content.

Key words: Correlation, Sikkim, Soil physico - chemical properties, Water holding capacity.

INTRODUCTION

Sikkim is a small mountainous state of North East India having a total geographical area of 7096 sq. km. The state receives a substantial amount of average annual rainfall of 3500mm. The sloppy mountainous landform with high intensity of rain fall often causes extensive soil erosion and heavy losses of plant nutrients by runoff / leaching. Soils formed on the upper portion of a slope are washed down and get deposited at the base of the slope (Das, 2011). Generally, the farmers of Sikkim grow fruit crops in upper elevations and crops like rice, vegetables, maize, etc in middle and lower elevation during rainy season. Depending upon the availability of residual moisture, farmers grow vegetables and oil seed crops during winter. The productivity of crops in hilly terrain depends upon the availability of soil moistures as well as nutrient status of soils. The availability of residual moisture to crops during winter season depends upon the water holding capacity of soil. This is controlled primarily by soil texture and organic matter and other soil properties.

In hilly areas the properties of the soils vary in space and time due to variation in topography and climate condition (Sheik and Kumar, 2010 and Rajeswar and Khan, 2008). Information on the effect of elevation on dynamics of soil physical and chemical properties and water holding capacity is very limited for the soils of Sikkim. Hence, the present study was carried out to evaluate the status of physical and chemical properties and its relationship with water holding capacity along altitudinal gradient for cultivated soils of South Sikkim.

MATERIALS AND METHODS

The study area was located in South Sikkim between $27^0 18' 31''$ to $27^0 17' 3''$ N latitude and $88^0 26' 7''$ to $88^0 35' 9''$ E longitude (Fig.1). Thirty five soil samples from plough layer (0-20 cm) were collected from different locations of cultivated fields at different elevations with the help of GPS (Gramin 76CSX) (Table.1). The collected soil samples were separately air dried ground and passed through 2 mm size sieve for laboratory analysis. Particle size distribution was

* Corresponding author's e-mail: kanupran@yahoo.co.in
[1] School of Engineering and Technology, Asian Institute of Technology, P.O. Box 4 Klong Luang, Pathumthani-12120, Thailand

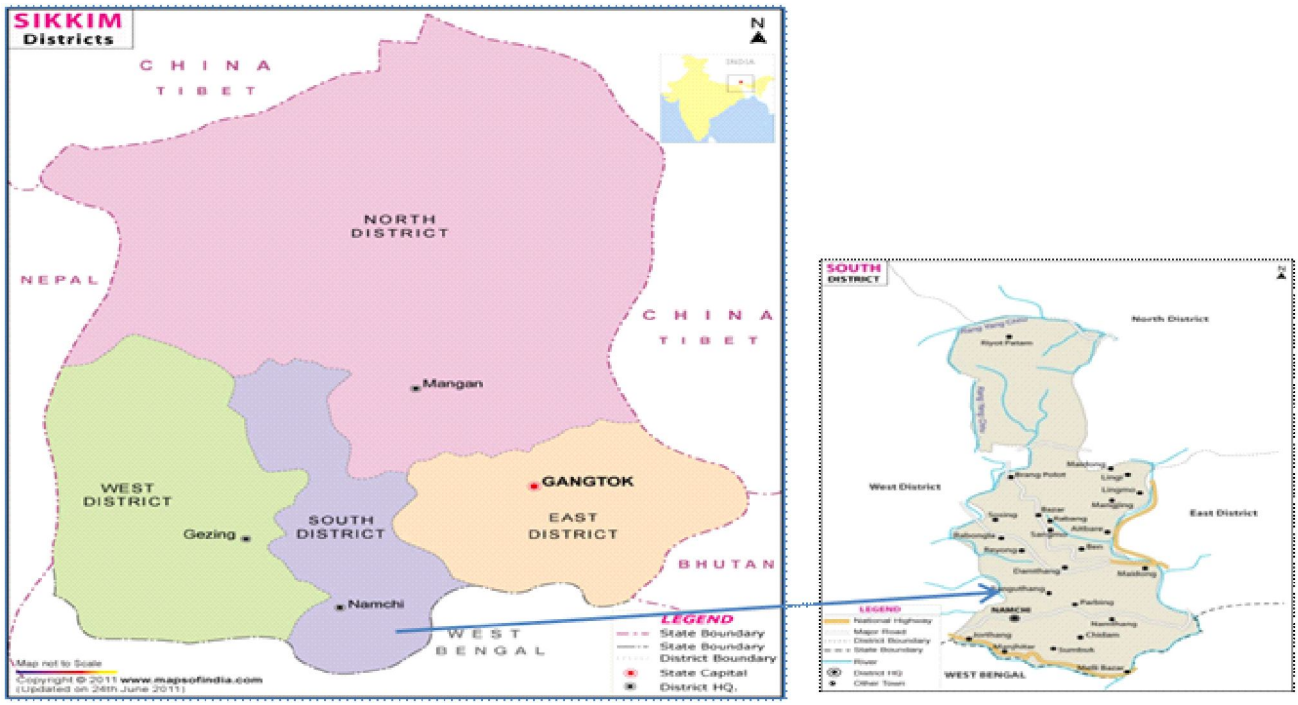

FIG.1: Location of study area(Source: www. mapofindia.com)

TABLE1: Site characteristics

Elevation	No. of soil Sample	Range of altitude (feet)
Lower	12	1500-2000
Middle	12	2000-2500
Higher	11	2500-3000

done by the standard Bouyoucos hydrometer method (Day, 1965). Soil pH was determined by glass electrode with calomel as standard (Jakson, 1973). Organic carbon was estimated by wet digestion method of Walkey and Black (Jackon, 1973). Bulk density, particle density, volume expansion, total porosity and water holding capacity (WHC) were determined by methods of Keen box (Piper, 1966). Correlation coefficient values between water holding capacity and each of the corresponding relevant soil properties was calculated following the standard procedures described by Gomez and Gomez (1976).

RESULTS AND DISCUSSION

Physical and chemical properties of soils: Data of water holding capacity and other physical and chemical properties of the soils of some selected areas of south Sikkim are presented in Table 2. The data show that soil texture varied from sandy loam to clay. Most of the samples belong to finer texture in lower elevation and reverse in higher elevation. The value of pH rangesfrom 4.2 – 5.5 with a mean of 4.9 in the higher elevation, whereas, a comparatively higher pH value was recorded in middle and lower elevation (Table 2). The pH in middle and lower elevation ranged from 4.5-6.5 and 4.9 – 6.6 with respective mean value of 5.5 and 5.8. The result indicates that soil acidity is more in higher altitudes as compared to lower altitude (Pradhan*et al.*1996). This happened due to removal of bases from higher altitude by leaching. The organic carbon status of soil samples of lower zone ranged from 1.85 – 3.45 per cent with a mean value of 2.50 per cent. With increasing in elevation the organic carbon content was decreased which ranged from 1.22-2.91 with mean value of 2.30 pe rcent in middle and from 1.36-2.96 with mean value of 2.11 per cent in higher elevation. The organic carbon status of the soils in lower elevations was higher because of intensive cropping associated with application of organic manures by the farmers during cultivation of different crops in their field as well as transportation and leaching of bases and clay particles from upper elevation to lower elevation. Debnath*et al.* (2009) also reported higher amount of organic carbon in rice growing soils of Terai zone of West Bengal where the farmers usually apply more organic manure.

TABLE 2: Water holding capacity and physical and chemical properties of the study area

Sl. No.	pH	Org. C (%)	Sand (%)	Silt (%)	Clay (%)	Textural Class	Bulk Density (g/cc)	Particle Density (g/cc)	Total Porosity (%)	Water in air dry soil (%)	Volume expansion (%)	Maximum Water Holding Capacity (%)
						Lower elevation						
1	6.4	2.63	46	32	22	L	1.44	2.58	48.14	2.01	11.16	64.26
2	5.3	2.88	50	26	24	L	1.26	2.24	52.19	2.69	7.26	65.7
3	5.4	3.06	29	38	33	cl	1.12	2.05	58.19	2.68	9.05	73.86
4	5.3	2.68	36	39	25	L	1.3	2.47	46.15	1.55	8.15	57.91
5	6	2.05	52	30	18	L	1.33	2.53	52.29	1.54	7.15	54.73
6	5.6	3.45	56	23	21	Sl	1.21	2.45	56.18	1.98	5.46	63.09
7	6.6	2.25	31	35	34	cl	1.09	2.5	60	0.68	5.7	64
8	6.1	2.12	40	30	30	cl	1.11	2.6	59.27	0.79	6.05	60.77
9	4.9	1.85	48	31	21	Scl	1.15	2.74	58.03	2.89	4.34	44.07
10	6.4	1.96	50	35	15	Scl	1.17	2.55	44.12	3.57	4.56	42.79
11	5.7	2.86	50	32	18	L	1.35	2.33	53.43	2.66	5.26	55.28
12	6.6	2.25	31	35	34	Cl	1.14	2.5	62	0.68	5.7	59
						Middle elevation						
13	5.5	2.24	30	41.5	28.5	cl	1.1	2.5	56	1.69	7.06	56.9
14	5.3	2.17	60	21	19	Sl	1.14	2.6	56.15	1.44	5.57	53.59
15	5.8	2.91	47	26	27	Scl	1.24	2.77	61.73	1.65	7.02	64.65
16	4.8	2.6	48	31	21	L	1.3	2.54	50	2.06	11.9	54.65
17	5.4	2.68	49	27	24	Scl	1.28	2.44	55.74	2.3	6.78	58.03
18	4.5	1.9	35	50	15	Sil	1.42	2.51	49	2.05	7.32	44.23
19	5.7	2.05	60	21	19	Sl	1.53	2.4	59.58	1.2	5.09	49.86
20	4.8	2.91	47	26	27	Scl	1.26	2.77	61.73	1.65	7.02	60.65
21	6.4	1.22	49	27	24	L	1.31	2.53	48.06	3.8	4.45	39.95
22	6	2.23	59.5	21	19.5	Scl	1.08	2.31	53.33	4.27	7.96	56.39
23	6.5	2.84	66	20	14	Sl	1.54	2.05	52.68	4.32	6.45	58.42
24	6	1.88	47	39	14	L	1.28	2.51	49	2.05	7.32	44.23
						Higher elevation						
25	5	1.78	50	36.5	13.5	L	1.37	2.38	42.44	1.09	2.95	33
26	5	2.11	57	27	16	Sl	1.38	2.43	54.73	2.01	8.51	55.13
27	5.2	2.03	56	25	19	Sl	1.45	2.45	59.18	1.98	5.46	54.09
28	4.2	2.43	50	32	18	L	1.22	2.33	60.43	2.66	5.26	52.28

29	5.3	2.96	45	34	21	L	1.28	2.21	60.18	2.96	7.47	60.73
30	5.2	1.78	40	46	14	Sil	1.37	2.38	42.44	1.09	2.95	43
31	4.9	2.17	60	21	19	Sl	1.34	2.6	56.15	1.44	5.57	53.59
32	4.8	2.09	47	26	27	Scl	1.19	2.77	61.73	1.65	7.02	54.65
33	5.5	1.36	52	30	18	L	1.28	2.57	49.84	3.96	4.05	41.89
34	5.2	2.45	55	26	19	Sl	1.43	2.45	59.18	1.98	5.46	55.09
35	4.5	2.12	60	26	14	Scl	1.36	2.61	51.72	4.06	6.24	46
Mean	5.48	2.31	48.4	30.48	21.01		1.28	2.47	54.31	2.20	6.42	54.18
Range value	4.2-6.6	1.22-3.45	29-66	20-50	13-34		1.08-1.54	2.05-2.77	42.44-62	0.68-4.32	2.95-11.9	33-73.86

Sl = sandy loam, L = loam, Scl = sandy clay loam, Cl = clay loam, Sil = silty loam

Clay content in soils influence the water holding capacity and water retention properties in soils. Content of clay in the lower elevation ranged from 15-34 per cent with a mean value of 24 percent. With increasing in elevation the clay content was decreased which ranged from 14 - 28.5 per cent with mean value of 21 per cent in middle elevation and 13 - 27 pe rcent with mean value of 17.12 pe rcent in upper elevation. But a reverse trend was found for sand content. The altitude variation revealed that clay content gradually increases from higher elevation to lower elevation. The result is in agreement with earlier works of Parihar(2004), Chen *et al*.(2003),Tiwari and Bajpai(2004) and Tahboub*et al*.(2008).

The bulk density, particle density and porosity are widely considered to be important factors contributing the water holding capacity of the soil. The mean bulk density values in lower, middle and higher elevations were 1.22, 1.29 and 1.33 gm/cc, respectively. There was not much variation with respect to porosity which ranged from 42.4-60 per cent with a mean value of 54.3 per cent in different elevations. However, the results revealed that 90 per cent of soils having a significant amount of porosity which indicate higher water holding capacity of soils.

Water holding capacity (WHC) of soils: Water holding capacity of soil influences crop growth, rooting pattern and ability to supply water to crops during dry period. The data on mean water holding capacity in soils indicated that the soils of lower elevation have distinctly higher percentage of water holding capacity (ranged between 42.79-73.86 percent with the mean value of 58.78 percent) (Table 2) than those of middle elevation (39.95-64.65 percent with a mean value of 53.46 percent) and higher elevation (33-60.73 percentwith a mean value of 49.95 per cent). Irrespective of all elevations, the range of water holding capacity was 33-73.86 per cent with a mean value of 54.18 per cent. Correlating the WHC with the altitude, it was observed that the mean percentage of WHC decreases with increase in altitude which corroborate with the study of Guo *et al*.(2011) and Bisht and Bhat (2010). From an experiment, Tandel *et al*. (2009) reported that the maximum improvement in water holding capacity was recorded in the higher elevation of instructional farm, ASPEE College of Horticultural and Forestry, Navsari, Gujrat with application of organic matter. The soils of present study were categorized into low, medium and high WHC in view of the irrigation scheduling by farmers. The results revealed that a quite large proportion of the soils were under medium to high category of WHC. Out of 35 soils only 7 samples were in the category of low WHC (< 45 per cent) and nineteen samples in the categories of medium (45 – 60 per cent) and rest nine number of samples in the category of high WHC (> 60 per cent)(Fig.2).

Relationship between water holding capacity and soil characteristics: The water holding capacity was found to be positive and significantly correlated with organic carbon (r= 0.8010**), clay (r= 0.6236**), water in air dry soil (r= 0.5712*) and porosity (r= 0.5717*) (Table 3). However, a negative relationship of WHC was also observed with pH (-0.2037), sand (-0.3152), silt (-0.2998), bulk density

(-0.2677) as sand has lower specific surface area as compared to clay. Similar relationships was also reported by Upadhyaya *et al.* (2003) and Paudel and Sah (2003). The WHC increases with increasing the level of organic carbon and clay (Ramesh *et al.* 2008). In order to study the effect of the physico-chemical properties on the predictability of water holding capacity in the soils of different elevations, step wise multiple regression analysis has also been done. The computed regression equations along with their contribution ($R^2 \times 100$) are presented in Table 4. The very low prediction value due to pH (14.1%) has been observed for the soils of different elevations. Inclusion of organic carbon, sand, silt, clay content and total porosity has increased the predictability of water holding capacity upto 91.8%. The results thus indicate that the organic carbon, clay content, sand and porosity were the key soil properties for predictability of water holding capacity of soil. The results further revealed that some additional parameters not included in the study might be influencing the water holding capacity of the investigated soils.

CONCLUSION

The study of soil physical and chemical properties is vital along the sloppy land of South Sikkim. The effect of different physical and chemical properties on water holding capacity with respect to altitudes indicate that the organic carbon, content of clay and sand and porosity directly influence water

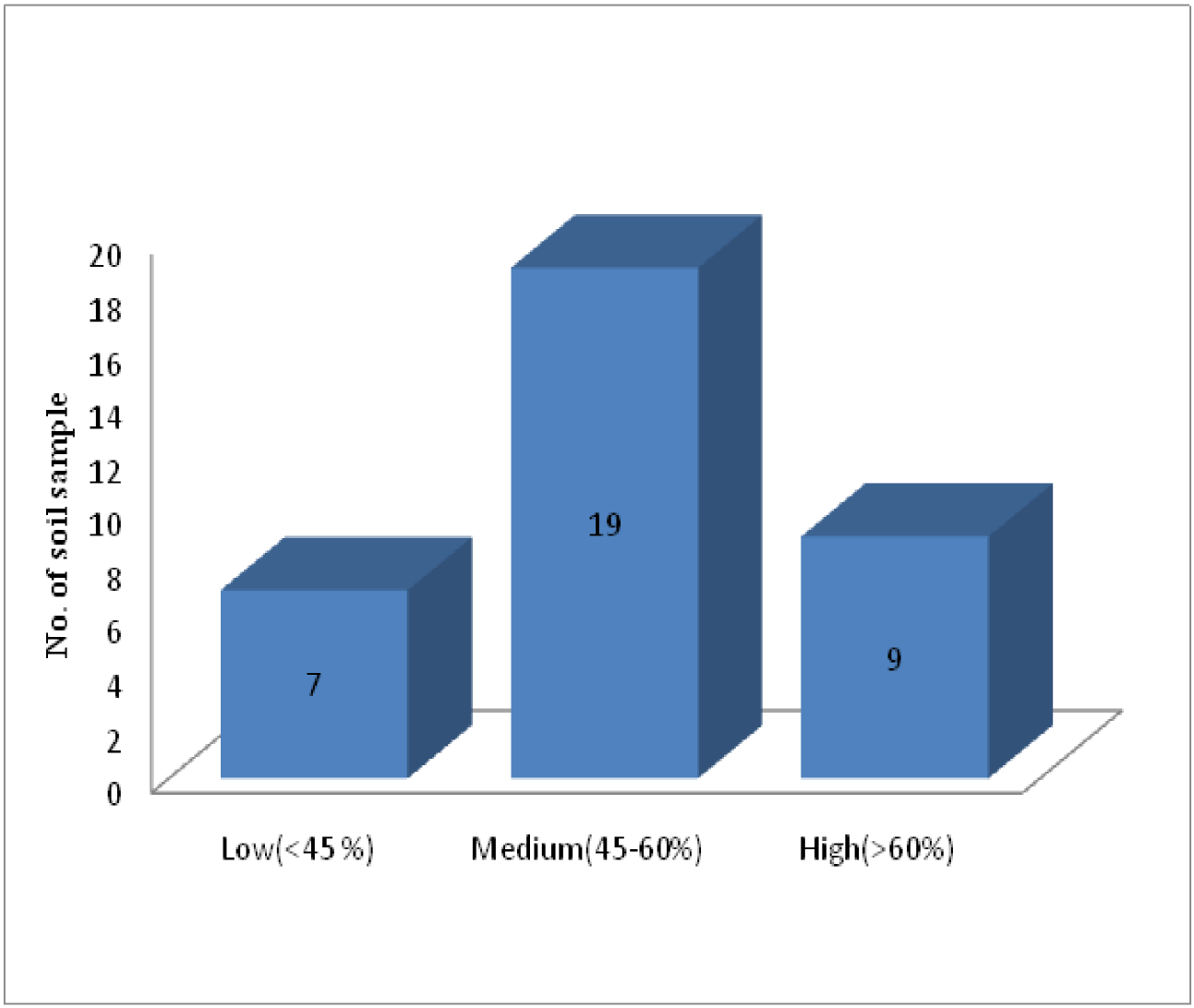

FIG.2: No. of soils under different category of water holding capacity

TABLE 3: Single correlation coefficient (r) between water holding capacity (WHC) and some relevant soil properties

Sl no	Variables	Lower elevation	Middle elevation	Higher elevation	Irrespective to all elevations
1	Soil pH vs WHC	0.0269	-0.0929	-0.0508	-0.2037
2	Organic Cvs WHC	0.6698**	0.9242**	0.7593**	0.8010**
3	Sand vsWHC	-0.4403*	0.1414	-0.2361	-0.3152
4	Silt vsWHC	-0.0194	-0.4076*	-0.6891**	-0.2998
5	Clay vsWHC	0.6344**	0.4681*	0.4208*	0.6236**
6	Bulk density vsWHC	-0.0114	-0.2541	-0.1240	-0.2677
7	Particle density vsWHC	-0.6807**	0.1093	-0.0677	-0.2307
8	PorosityvsWHC	0.3320	0.7388**	0.8872**	0.5712*
9	Water in air dry soilvsWHC	-0.3550	-0.1139	0.0706	-0.1794
10	Volume expansion vsWHC	0.6299**	0.2685	0.8006**	0.5717*

* Significant at 5 % level of significance, ** Significant at 1 % level of significance

TABLE 4: Soil characteristics on predictability of water holding capacity

Zone		Regression Equation	$R^2 \times 100$
Irrespective to all elevation	I	$Y = 90.968 - 6.629X_1$	14.1
	II	$Y = 78.526 - 8.548X_1 + 15.296X_2$	65.6
	III	$Y = 83.717 - 8.880X_1 + 15.559X_2 - 0.065X_3$	65.8
	IV	$Y = 130.951 - 7.249X_1 + 16.108X_2 - 0.625X_3 - 1.032X_4$	77.7
	V	$Y = 68.460 - 7.249X_1 + 16.108X_2 - 0.407X_3 - 0.625X_4$	85.6
	VI	$Y = 6.396 - 2.085X_1 + 11.192X_2 - 0.420X_3 + 0.510X_4 + 0.769X_5$	91.8

Note: $X_1 = P^H$; X_2= Organic C; X_3= Sand content; X_4= Silt content; X_5= Clay content; X_6= Total Porosity.

holding capacity of soil. In sloppy land the water holding capacity of soil decreases with increasing altitude. This helps the farmers to schedule irrigation for their crops.

ACKNOWLEDGEMENT

Assistance from the Central Agricultural University, Imphal, Manipur for conducting the study is duly acknowledged.

REFERENCES

Bisht, A.S. and Bhatt, A.B.(2010). Physico-chemical status of forest soils along altitudinal gradient in Western Uttarakhand Himalayas. *Indian J. Ecol.***37**(1):65-69.

Chen,H., Ping, H., YanPing, S. and Ming., H.(2003). Physico-chemical properties of the main agro-soils in Jiading District, Shanghai.*J. Shanghai Jiaotong Universities Agric. Sci.* **21**(4): 313-319.

Day, P.R. (1965). Particle fraction and particle-size analysis.*In Methods of Soil Analysis* (C.A. Black, Ed.) Agronomy No.9,PartI.American Society of Agronomy,Madison.WI,pp.545-567.

Das, D.K.(2011). *Introductory Soil Science*, KalyaniPublishers,New Delhi.

Debnath, P., Mahanta, M. and Ghosh, S.K. (2009).Distribution of available boron in the selected surface and subsurface soils of Terai zone of West Bengal in relation to physico-chemical properties.*J. Maharastra Agric. Universities* 3, 357 – 358.

Gomez, K.A. and Gomez, A.A. (1976). Statistical Procedures for Agriculture Research. 2nd ed IRRI. Los Banos. Philippines.

Guo,Q.,Wang,D.,Fang,K.andBao,J.(2011). Dependence of soil physical properties on altitudes in pinusaramandii forest ecosystem.*Bioinformatics and Biomedical engineering,5th international conference.*10-12th may,2011, Yangling, China.

Jackson, M.L. (1973). *Soil Chemical Analysis,* Prentice Hall of India Pvt. Ltd., New Delhi.

Parihar, S.S. (2004). Physico-chemical properties of soil and grain yield of rice (*Oryzasativa*) as influenced by organic and inorganic sources of nutrients.*Annals of Agric. Res.* **25:** 408-411.

Paudel, S. and Sah, J.P. (2003). Physiochemical characteristics of soil in tropical sal (*Shorearobusta*) forest in Eastern Nepal.*Himalayan Journal of Science* **1:**107

Piper, C.S.(1966). *Soil and Plant Analysis*, Hans Publishers, Bombay.

Pradhan,Y., Sachan,R,S. and Avasthe,R,K.(1996). Relationship between altitude and status of zinc and copper in some soils of Sikkim. *J. of Hill Res.* **9**(1): 11-17.

Rajeswar, M. and Khan,M.A.A.(2008).Characterization and classification of forest soils of Nizamabad district of Andhra Pradesh.*Asian J. Soil Sci.* **3**(1): 11-16.

Ramesh,V., Ballol,S.S., Sharma,K.L., Kausalya,R., Korwar,G.R. and Ramakrishna,Y.S.(2008). Characterization of soil for physical properties under different land use systems. *Indian J. Dryland Agric. Res. Dev.* **23**(1): 102-109.

Sheik, M.A. and Munesh,K. (2010). Nutrient status and economics analysis of soils in oak and pine forest in GarhwalHimalaya.*Journal of American Science.***6**(2):117-122.

Tahboub,M.B., Lindemann,C.W. and Murry, L.(2008). Chemical and physical properties of soil amended with peacan wood chips. *Hort Science*. **43**(3):891-896.

Tandel,M.B., Kukadia,M.U., Kolambe,B.N. and Jadeja,D.B.(2009). Influence of tree cover on physical properties of soil. *Indian Forester* **135**(3): 420-424**.**

Tiwari,R.K and Bajpai,S.P. (2004).Physico-chemical properties of soil from the core area in Kanha Tiger Reserve.*Plant Archives* **4**(1): 71-75.

Upadhyaya, A.U., Arunachalam,.K.A. and Arunachalam,K. (2003). Microbial biomass and physico-chemical properties of soils under the canopy of *Bambusabalcooa*Roxb. and*Bambusapallida* Munro.*Indian J. Soil Cons.* **31**(2): 152-156.