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Research Article

Comparative study of physico-chemical, nutrients availability and acidic properties of Arunanchal Pradesh soil under different land use systems

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Summary

Forty-eight soil samples were collected from 0-15 cm from each forest and cultivated areas of 12 different places of Arunachal Pradesh. Forest soils contained higher values of available N, organic carbon, whereas available P and K were found to be more in cultivated soils. Available S B and Ca+Mg were found to be higher in forest soils. Soil respiration in both land use showed ideal to high soil respiration rate, higher soil respiration rates exhibited in cultivated land than the forest soil. Exchange acidity exhibited higher in forest area than the cultivated area. The total acidity was found to be higher in forest land than the cultivated land. Exchangeable Al of the soils of Arunachal Pradesh in both the system came under medium range. Soil pH was found negatively correlated with organic carbon, available N, K, exchange acidity and lime requirement. With soil organic carbon, positive correlation was found with available N, K, exchange acidity and lime requirement, but negative correlation with total acidity. The results concluded that types of soil and land uses practices were responsible for the varying soil inherent properties. The pH, EC and organic carbon were varied 4.1-5.6, 46.6-150 ds/m and 0.068-3.28%, respectively. Whereas, macronutrients variations were recorded as N (213.2 to 470.3 kg ha^{-1}), P (22.2 kg ha^{-1} to 44.6 kg ha^{-1}) and K (188 to 246 kg ha^{-1}) found to be ranged under low to medium, were varied from 11-66 kg ha^{-1} ,0.22-0.99 kg $ha^{-1}$and 0.2-6.5 kg ha^{-1}, respectively, The total acidity on an average observed in soils of Arunachal Pradesh was 3.21 meq/100g and 5.40 meq/100 g in cultivated and forest area, respectively. Ranges came under medium in an average *i.e.* 0.83 meq/100 g in cultivated area and in forest area exchangeable Al ranged from 0.50 meq/100 g to 1.35 meq/100 g which observed to be range under medium. Average exchange acidity of 1.02 meq/100 g and 1.13 meq/100 g was exhibited in the samples of cultivated and forest areas, respectively.

Key words : Nutrients status, Acidic components, Physico-chemical properties

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Introduction

In India, acid soils cover a very large fraction of the country's land mass, out of the total geographical area of 328 m ha; approximately 100 m ha of land suffer from soil acidity (Mishra, 2004). Most of the North Eastern states of India soils are acidic reaction, Arunachal Pradesh, Assam, Manipur, Mizoram, Meghalaya, Nagaland, Tripura and Sikkim has almost entire area (more than 95%) having acidic reaction (Sharma and Singh, 2002). Soils are acidic in reaction due to leaching of base from the exchange complex under the prevailing high rainfall and hilly topography, highly acidic soils of the states pose a great challenge due to incidence of crop root damages due to high concentration of iron (Fe^{+2}) and aluminium (Al^{+3}) which also inhibit absorption of Ca^{+2} and Mg^{+2} and thereby soil biological health is adversely affected due to dominance of fungi in the acid soil. The problem of soil acidity appears to be more severe than that of soil alkalinity and has therefore, been recognised as an important agricultural problem which adversely affects the crop production, either directly or

indirectly.

The exploitation of marginal soils, improper cultivation and management practices and intensive agriculture without appropriate soil may arise the constraint for the production are either unfavourable physico-chemical properties of soil or some inherent land feature and environmental conditions limiting optimum growth of crops. In NE states top soil is degrading enormously due to shifting cultivation as such the productivity of these lands goes down to a considerable extent. The quality of the soils is declining annually and will continue to if means are not found to increase nutrient inputs. Appropriate formulation of land use plans based on the quality and type of soils could be achieve by proper knowledge and understanding of physico-chemical characteristics of soils. Evaluation and characterisation of soil fertility status of a region is an important aspect in content of sustainable agriculture production. So it is necessary to develop strategies prevent the degradation and deterioration of soil quality and assist in optimising land use that will ensure both economic prosperity and ecological security.

In appraising the productivity of the soils, one needs to have a fair knowledge of their physical, chemical and biological properties to prevent irreparable damage done to the land and water resources. Prediction of crop input requirements and relative responsiveness to the input applications requires knowledge of soil properties and their relationship to applications of crop production technology. So soil testing is important and foremost step to set for studying the changing pattern in soil fertility and to monitor the changes in soil nutrient status. So the study on the physico-chemical properties of the soils becomes essential to equipt the farmers with tools for maintaining the soil health and increasing the productivity. Therefore, to acquire a comprehensive knowledge and to general information on the above aspect a research investigation was undertaken to study the physico-chemical properties of soil.

Resource and Research Methods

A total sixty (60) soil samples were collected from different location of Arunanchal Pradesh under different land use systems (Forest and Cultivated). Cultivated land use for cultivation for many years. Forest land was naturally occurred. Soils in forest and cultivated land are classified as Typic Hapluequent , Pachic Umbrichrepts and Typic alfiaquent. Samples were processed and analyzed for physico-chemical properties by standard procedure (Jackson, 1973). The CEC was calculated with the sum of exchangeable Ca, Mg, Na, K. Particle size analysis was done by international pipette method. The available micronutrients cations were extracted with DTPA (Lindsay and Norvell, 1978). The micronutrients were estimated in the extracts with atomic absorption spectrometer (AAS). The soil and plant samples were prepared for analysis and analysed by standard procedure like available N (Subbaih and Asija 1956) P (Bray and Kurtz,1954) K (Jackson, 1973) pH (Richards, 1954) , OC (Jackson, 1973), and available S (Baruah, and Barthakur, 1997).

Research Findings and Discussion

The experimental findings of the present study have been discussed in three sub-groups *i.e.* (1) Physico-chemical properties (2) Nutrient status (3) Acidic properties.

Physico-chemical properties :

Data on pH, EC and organic carbon recorded under forest soils are presented in Table 1. The pH of forest soils of Arunachal Pradesh were all found to be acidic range from 4.6 to 5.4, indicating that the soils were strongly acidic to moderately acidic in reaction. Data revealed that the average pH is recorded to be 4.9. The pH of cultivated soils of Arunachal Pradesh ranged from 4.1 to 5.9 and average pH of the cultivated soils is 5.1. Soils are almost highly acidic in reaction due to downward migration of cationic bases and formation of some organic acids simpler in composition than humic acid during decomposition resulting lowering of soil pH. The soils of entire region of Arunachal Pradesh and Nagaland are acidic in reaction caused by heavy rainfall and leaching of bases to lower horizon. In an average soil pH range from 4.1 to 5.9 in cultivated and forest soils. Almost 84% soils of Arunachal Pradesh are considered strongly acidic (Panda, 1998).

The concentration of salts in soil is estimated from the electrical conductivity (EC). On an average, the electrical conductivity of the soil extract (1:2.5), obtained from both the land uses 11 to 150 µs/m in Arunachal Pradesh.

The value of EC of Arunachal Pradesh forest soil was found to be in range from 66 -50 µs/m. The average values of electrical conductivity is found 101.5 us/m. Electric conductivity is found highest in Banderdewa area *i.e.* 150 µs/m and lowest in Yazali area *i.e.* 66 µs/m, electric conductivity of cultivated area ranged from 20 to 93.3 µs/m. The average value of EC is 66.1 µs/m.

The organic carbon content of forest soils varied from 1.35% -3.28% which indicated high OC content. The lowest value 1.35% recorded in West Kameng area whereas the highest 3.28% was found in Kurung Kumey. The average value of organic carbon was found to be 1.73%. The organic carbon content of a cultivated area ranged from 0.53 to 3.12% and average OC was 1.57 %. The OC value was found to be highest in Kurung Kumey area *i.e.* 3.12% and lowest in Chimpu area *i.e.* 0.53%. Organic carbon content of the forests soils recorded higher than the cultivated soils for both the states. The forest soils were found to contain higher organic carbon % than the cultivated soils. Similar findings were reported by Chakrabortty and Banerjee (1977); Gupta *et al.* (1982) and Ellert and Gregorich

(1996). Organic carbon decreases when virgin soils are brought under cultivation which may be attributed to a slow microbial degradation of accumulated organic matter. The cultivation decreases the organic matter in soil (Retzer and Russel, 1941).

The average values of bulk density, particle density and total porosity of Arunachal Pradesh of forest and cultivated area are given in Table 1.

The bulk density of forest area was recorded to vary from 0.73 to 1.16 g/cc and the average value is 0.85 g/cc. The BD of cultivated area was range from 0.60 to 0.89 g/cc and average values found to be 0.77 g/cc‘ in cultivated area. Whereas, particle density of forest area was found to be varying from 1.50 to 2.71 g/cc and the average PD value recorded to 2.17 g/cc. The particle density for the cultivated areas of Arunachal Pradesh recorded to be range from 1.45 to 5.51 g/cc and the average PD recorded is 2.64 g/cc.

The total porosity of Arunachal Pradesh forest soils ranged from 39% to 71% and an average of 59.2%. Total porosity was highest in Ziro area *i.e.* 71% and lowest in Chimpu area *i.e.* 39%. The total porosity in cultivated area varied from 40% to 99% and average value was found to be 64.5%. In cultivated soils Ziro area recorded highest in total porosity *i.e.* 99% and lowest in Chimpu area *i.e.* 40%.

Generally, soils with low bulk densities exhibit favourable physical conditions. Forest land use was observed to contain more bulk density than cultivated land use areas. On an average bulk density of forest soils is 0.87 g/cc, and in cultivated soils average bulk density is 0.84 g/cc. Doran and Safley, (1997) found the dominating effect of organic matter on bulk density at some uncultivated podzolic soil. Bulk density is of greater importance than particle density in understanding the physical behaviour of soils. It is observed that in both the states particle density of the forest soils was higher than the cultivated soils. Soils containing high amounts of organic matter will have particle density reserves around 2.4. Gaur *et al.* (1995) compared two soil under cropped and un-cropped found that the particle density is increased at un-cropped area.

The bulk density varied indirectly with the total pore space present in the soil and gives a good estimate of the soil porosity. Forest areas were observed to contain more porosity per cent than cultivated areas. Retzer and Russel (1941) reported that the cultivation decreased the large size pores podzolic soil. The continuous cropping, particularly of soil originally high in organic matter often resulted in a reduction of total pore spaces. Ray *et al.* (2006) reported that bulk density, particle density and porosity etc. varied due to variation in land use system. The total porosity of Arunachal Pradesh forest soils ranged from 39% to 71% and an average of 59.2%. Total porosity was highest in Ziro area *i.e.* 71% and lowest in Chimpu area *i.e.* 39%. The total porosity in cultivated area recorded is varied from 40% to 99% and average value found to be 64.5%. In cultivated soils Ziro area recorded highest in total porosity *i.e.* 99% and lowest in Chimpu area *i.e.* 40%.

The soil respiration of forest soils of Arunachal Pradesh ranged from 41.2 to 83 kg CO_2/ha. Average value recorded

Table 1 : Values of EC, pH, bulk density, particle density, porosity and respiration of soils of Arunanchal under different land use practices

Places	pH		EC (ds/m)		BD (g/cc)		PD (g/cc)		Porosity %		Respiration		Organic carbon (%)	
	C	F	C	F	C	F	C	F	C	F	C	F	C	F
Ziro	4.7	4.6	60.0	75	0.60	0.73	5.51	2.71	99	71	138.6	41.2	2.7	1.63
Yazali	5.6	5.4	65	66	0.77	0.80	1.87	1.60	58	60	79	75.1	1.23	1.40
Banderdewa	5.4	5.1	50	150	0.78	0.85	2.81	1.91	75	55	170.5	52.9	1.20	1.36
Chimpu	5	4.8	46.6	77.5	0.89	1.16	1.45	1.50	40	39	60.7	55.5	0.53	1.36
Kurung Kumey	4.1	4.6	50.0	120	0.87	0.78	2.1	2.9	54	68	74.1	51.2	3.12	3.28
West Kameng	5.9	4.9	93.3	120.5	0.72	0.79	2.57	2.41	64	63.	88.5	83.0	0.68	1.35
Mean Value	5.12	4.9	60.12	101.5	0.77	0.85	2.72	2..17	65.0	59.33	101.9	59.82	1.57	1.73

Note: indication C for cultivated soil and F for forest soil

Table 2 : Values of available N, P,K,S B, Ca+ Mg (kg/ha)of soils of Arunanchal Pradesh under different land use practices

Places	N		P		K		S		Ca+Mg		B		OC %	
	C	F	C	F	C	F	C	F	C	F	C	F	C	F
Ziro	214.4	213.2	35.9	32.4	168.8	210.8	11.25	27.5	0.25	0.8	0.25	0.43	2.7	1.63
Yazali	225.7	230.0	48.78	44.6	233.5	246	11.7	12.7	0.65	1.9	0.65	0.90	1.23	1.40
Banderdewa	125.4	238.4	33.80	44	75.6	199.2	11	25	0.20	5.8	0.20	0.25	1.20	1.36
Chimpu	213.2	294.7	35.30	29	157.9	188	56.8	58	0.32	6.4	0.30	0.35	0.53	1.36
Kurung Kumey	351.2	470.3	50.20	22.2	137.4	223.2	26.2	11.8	0.36	6.4	0.36	0.31	3.12	3.28
West Kameng	230.8	348.1	41.8	39.6	222.3	230.1	64.7	66.2	0.22	6.2	0.22	0.28	0.68	1.35
Mean Value	226.78	299.12	40.96	35.3	165.92	216.22	30.27	33.93	0.33	4.58	0.33	0.42	1.57	1.73

Note: indication C for cultivated soil and F for forest soil

59.8 kg CO_2 ha/hr *i.e.* ideal soil respiration. Cultivated soils of Arunachal Pradesh varied from 60.7 to 170.5 kg CO_2 ha/hr *i.e.* ideal to high soil respiration. Average soil respiration of cultivated soil was found 101.9 kg CO_2 ha/hr.

Nutrient status :

The average values of available N, P and K recorded under forest and cultivated soils of Arunachal Pradesh are presented in Table 2.

The available N in the forest soils of Arunachal Pradesh varied from 213.2 to 470.3 kg ha^{-1} which indicated low to medium in available N content. The average value of available N was 299.1 kg ha^{-1}. Available N was found to be highest in Kurung Kumey area *i.e.* 470.3 kg ha^{-1} and lowest in Ziro area *i.e.* 213.2 kg ha^{-1}, whereas in cultivated areas the available N varied from 125.4 to 351.2 kg ha^{-1} which indicated low to medium in available N content. The average value of available in cultivated areas was 226.7 kg ha^{-1}. Kurung Kumey area found to be highest in available N *i.e.* 351.2 kg ha^{-1} and lowest in Banderdewa area *i.e.* 125.4 kg ha^{-1}. Available N is defined as nitrogen in the root zone in a chemical form absorbed by plant roots. As per the experimental findings, it was observed that the forest soils contained more available N than the cultivated soils. This is in line with the findings of Ellert and Gregorich (1996) who reported the forest soils contain more nitrogen than cultivated soils. Average available N content was observed higher in Nagaland soils and lower in Arunachal Pradesh soils.

The available P was found low in both forest and cultivated soils. The available P in forest soil varied from 22.2 kg ha^{-1} to 44.6 kg ha^{-1}. The average value of P was 35.3 kg ha^{-1}. Available P found to be highest in Yazali area *i.e.* 44.6 kg ha^{-1} and lowest in Kurung Kumey area *i.e.* 22.3 kg ha^{-1} to 44.6 kg ha^{-1}. Average value of P for the cultivated soils was 40.9 kg ha^{-1}. Available P found to be highest in Kurung Kumey area *i.e.* 50.2 kg ha^{-1} and lowest in Banderdewa area *i.e.* 33.8 kg ha^{-1}. The average available P of the soils in cultivated area was significantly higher than that in the forest areas. On an average soils of Arunachal Pradesh recorded higher in available P than Nagaland, and the available P in Nagaland and Arunachal Pradesh varied from low to medium, the available P content of the entire soil of North Eastern region are deficient in phosphorus (Prasad *et al.*, 1981a). It is reported that over 60% of the soils in Arunachal Pradesh were deficient in available P (Sharma *et al.*, 2001), these soils might be due to higher formation of phosphorus by Fe^{2+}, Mn^{2+} and Al^{3+}, also reported by Lahiri and Chakravarty (1989).

The available K of forest soil of Arunachal Pradesh found to be in range between 188 to 246 kg ha^{-1} *i.e.* medium in K availability. The average value of available K was 216.2 kg ha^{-1}. Available K was found to be highest in Yazali area *i.e.* 246 kg ha^{-1} and found lowest in Chimpu area *i.e.* 188 kg ha^{-1}. Available K in cultivated soils varied from 75.6 to 233.5 kg ha^{-1}. Available K was found to be highest in Yazali area *i.e.* 233.5 kg ha^{-1} and lowest in Banderdewa *i.e.* 75.6 kg ha^{-1} and an average available K was 165.9 kg ha^{-1}. Mishra and Saithantuaanga (2000) also reported the same. Kire (1992) reported low to medium available K content. On an average the available K content of Arunachal Pradesh soil found to low to medium.

The available Ca and Mg of a forest area ranged from 0.8 to 6.4 meq/100 gm, average value of Ca and Mg is found to be 4.5 meq/100 g. And in cultivated area the available Ca and Mg ranged from 0.8 to 6.4 meq/100 g and an average value of 4.5 meq/100 g. Data on average values of available S, available B and the Soil respiration of forest and cultivated soils of Arunachal Pradesh are given in given in Table 2 The available S in the forest soils of Arunachal Pradesh varied from 11.8 to 66.2 $kgha^{-1}$. Average value of available S was 51.8 kg ha^{-1}. West Kameng area was highest in available S *i.e.* 66.2 kg ha^{-1} and lowest in Kurung Kumey area *i.e.* 11.8 kg ha^{-1}. In cultivated area of Arunachal Pradesh the available S ranged from 11 to 64.7 kg ha^{-1}. Available S was found to be highest in West Kameng area *i.e.* 64.7 $kgha^{-1}$ and lowest in Banderdewa area *i.e.* 11 $kgha^{-1}$. Average value recorded was 30.2 kg ha^{-1}. Available S in cultivated and forest of Arunachal Pradesh was found to be medium and high, respectively.

The available B of the forest soils of Arunachal Pradesh varied11111 from 0.25 to 0.90 kg ha^{-1}. Average value of available B recorded for forest area was 0.42 kg ha^{-1}. Yazali

Table 3 : Values of exchangeable hydrogen, aluminum, exchange acidity, total acidity and lime requirement of soils of Arunanachal under different land use practices

Places	Exch. H		Exch. Al		Exch. Acidty		Total Acidty		LR	
	C	F	C	F	C	F	C	F	C	F
Ziro	0.73	4.7	0.73	1.35	0.84	1.8	2.91	2.17	11.6	12.1
Yazali	0.48	4.9	0.87	0.88	0.68	0.66	1.13	1.87	6.7	7.7
Banderdewa	0.70	3	0.70	0.50	1.75	0.54	1.87	1.91	7.7	9.1
Chimpu	0.47	4.8	1.30	0.78	0.87	1.02	2.99	8.52	9.6	10.6
Kurung Kumey	0.74	7.5	0.75	1.3	1.56	2	2.58	10.3	10.6	12.1
West Kameng	0.54	5.9	0.68	0.64	0.75	0.79	7.8	8.1	5	6.7
Mean value	0.61	5.13	0.83	0.91	1.07	1.14	3.22	5.47	8.53	9.72

Note: indication C for cultivated soil and F for forest soil

area was found to be highest in available B *i.e.* 0.90 kg ha^{-1} and lowest in Banderdewa area *i.e.* 0.25 $kgha^{-1}$. In cultivated soils the available B varied from 0.20-0.65 kg ha^{-1}. Average value was found 0.33 kg ha^{-1}. Available B was recorded highest in Yazali area *i.e.* 0.65 kg ha^{-1} and lowest in 0.20 kg ha^{-1}.

Acidic properties :

The total potential acidity of the forest area varied from 1.87 to 10.3 meq/100 g and an average value of total potential acidity was found to be 5.4 meq/100 g. The total potential acidity of the cultivated area varied from 1.13 to 7.8 meq/100 g. The average value of cultivated soil was 3.21meq/100g.

Total acidity termed as hydrolytic acidity or titratable acidity is present in soil in measurable quantities, in the pH range of 5.5 to 7.0, as hydroxyl Al polymers, predominate among acidic soil components. On an average, total acidity recorded higher in forest soils than the cultivated soils in Arunachal Pradesh *i.e.* 5.4 meq/100 g and 3.21 meq/100 g, respectively. In Nagaland soils both the land use soil recorded to be 3.74 meq/100 g. Kumar *et al.* (1995) reported that land use pattern affected the various forms of acidities considerably.

Exchange acidity is the acidity exchanged by a un-buffered neutral salt solution. It constitutes a significant part of the total acidity. Exchangeable acidity is virtually absent beyond pH 5.5. Exchange acidity of both the states reported to be higher in forest soils than the cultivated soils. The exchangeable Al of forest area ranged from 0.50 to 1.35 meq/ 100 g. Average value is recorded to be 0.91 meq/100 g. In cultivated area the exchangeable Al is recorded 0.83 meq/100 g and varied in range from 0.68 to 1.30 meq/100 g. Aluminium toxicity is the most important associated problem of acid soils, when pH drop below 5.0. As the soil becomes more acid *i.e.*, these minerals become more soluble, releasing Al into solution. Exchangeable Al reported higher in forest soils than the cultivated soils in both the states. In acid soils of NEH Region, the amount of exchangeable aluminium ranged from nil to as high as 7.1 meq/100 g soil of Nagaland (Datta *et al.*, 2001).

Values recorded for exchange acidity, total potential acidity and exchange H^+ for soils of Arunachal Pradesh under the forest and cultivated area are given in Table 3. Forest area of the exchange acidity varied from 0.54 to 2 meq/100 g. Average values of exchange acidity was 1.13 meq/100 g. The exchange acidity of the cultivated area found to be ranged from 0.68 to 1.75 meq/100 g. The average value of exchange acidity of cultivated soils was 1.02 meq/100 g. The exchangeable H^+ of a forest area was recorded to be in range from 3 to 7.5 meq/100 g with an average 5.1 meq/100 g. In cultivated area the exchange H^+ was found to vary from 0.48 to 0.74 meq/100 g. An average value for the cultivated soils was recorded 0.61 meq/100 g.

Lime requirement at pH 6.4 of forest area ranged from 7.7 -12.1 tha^{-1}. Lime requirement was found to be highest in Kurung Kumey area *i.e.* 12.1 tha^{-1} and lowest lime in Yazali area *i.e.* 7.7 tha^{-1}. The average value of lime requirement of forest soils was 9.7tha^{-1}. On an average the lime requirement at pH 6 for cultivated soils was from 5 -1.6 tha^{-1}. Lime requirement found to be highest in Ziro area *i.e.* 11.6 tha^{-1} and lowest in West Kameng area *i.e.* 5 tha^{-1} and in average lime requirement of cultivated area is 8.5 tha^{-1}.

Literature Cited

Baruah, T.C. and Barthakur, H.P. (1997). *A textbook of soil analysis*, Vikas Publishing House Private Limited, New Delhi, INDIA.

Chakrabortty and Banerjee (1977). Status of organic carbon, available N,P and K of Indian soils as depicted by soil fertility maps. *J. Soc. Soil Sci.,* **52** : 78-82.

Datta, M., Bhattacharya, B.K. and Saikh, H. (2001). Soil fertility – A case study of shifting cultivation sites in Tripura. *J. Indian Soc. Soil Sci.,* **49** : 104 – 109.

Doran, J.W. and Safley, M. (1997). Defining and assessing soil health and sustainable productivity. In : *Biological indicators of soil health.* (Eds C. E. Pankhurst, B. M. Doube, and V. V. S. R. Gupta.) pp. 1-28. (CAB International: New York).

Ellert, B.H. and Gregorich, E.G. (1996). Storage of carbon, nitrogen and phosphorus in cultivated and adjacent forested soils of Ontario. Soil Sci. : *Interdisciplinary Approach Soil Res.*, **161** : 587-603.

Gaur, A.C., Neelkantan, S. and Dargan, K.S. (1995). Recycling of organic materials as fertilizers. In Organic Manures. ICAR, New Delhi,pp.79-95.

Jackson, M.L. (1973). *Soil chemical analysis*, Prentice Hall of India Private Limited., New Delhi, INDIA.

Kire, K. (1992). Fertility evaluation, nutrient fixation and effect of liming on acid soils of Kohima district. Ph.D. Thesis, IARI, NEW DELHI (INDIA).

Kumar, K., Rao, K.V.P. and Singh, L.J. (1995). Forms of acidity in some acid Inceptisols under different land use in Manipur. *J. Indian Soc. Soil Sci.,* **43** : 338 – 342.

Lahiri, T. and Chakravarti, S.K. (1989). Characteristics of some soils of Sikkim at various altitudes. *J. Indian Soc. Soil Sci.,* **37** : 451–457.

Lindsay, W.L. and Norvell, W.A. (1978). Development of a DTPA soil test for zinc, iron, manganese and copper. *Soil Sci. Soc. America J.* **42** : 421.

Mishra, U.K. and Saithantuaanga, H. (2000). Characteristics of acid soils in Mizoram. *J. Indian Soc. Soil Sci.,* **48** : 437–446.

Motsara, M.R. (2002). Available N, P and K status of Indian soils as depicted by soil fertility maps. *Fert. News,* **47**(8): 15-21.

Panda, N. (1998). Soil of North- Eastern region and arrangement for sustanable production. Paper presented at the symp.On ICAR Research Complex for NEH region.

Patton, S., Sharma, S.K. and Singh, P.K. (2005). Characterization of acid soils of Nagaland. *Ann. Plant & Soil Res.,* **7** : 107–108.

Patton, S., Sharma, S.K. and Singh, P.K.(2007). Characterization of the acidity of soils under different land use patterns in India. *J. Ind. Soc. Soil Sci*., **55** : 134-138.

Ray, R., Mukhopadhyay, K. and Biswas, P. (2006). Soil aggregation and its relationship with physic-chemical properties under various land use system. *Indian J. Soil Cons.,* **34** : 28-32.

Retzer, J.L. and Russel, M.B. (1941). Difference in aggregate of a prairie and Gray Brown- Podzilic *Soil. Sci.,* **52** : 47-58.

Richards, L.A. (1954). *Diagnosis and improvement of saline and alkali soils. Agricultural Handbook* No. 60, USDA, Washington.

Sharma, S.K., Singh, P.K. Sharma, Anamika, Sharma, A. (2001). Status of available nitrogen, phosphorus , potassium and physico-chemical characteristics of acidic soils of North East Region with special reference to Nagaland state. *J. Interacademia,* **7** :123-126.

Singh, Athokpam Herojit, Singh, R.K. Kumarjit, Singh, L.N., Singh, N. Gopimohan, Chongtham, Nandini and Singh, A.K. Kumar (2006). Status and forms of sulphur in acidic soils of Manipur. *J. Indian Soc. Soil Sci.,* **54** : 351–353.

Subbiah, B.V. and Asija, A.L. (1956). A rapid procedure for the estimation of available nitrogen in soils. *Curr. Sci.,* **25** : 259-260.