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SOIL NUTRIENT STATUS OF SLOPE LANDS UNDER *HEVEA BRASILIENSIS* IN MIZORAM AT VARYING ALTITUDES AND THEIR RELATIONSHIP WITH SOIL PROPERTIES

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The status of nutrients in the soils of slope lands under *Hevea brasiliensis* in Mizoram at different altitudes (100-750 m above mean sea level) was determined for better understanding of nutrient availability and crop productivity. The soils were low to medium in available nitrogen. About 74 per cent of the soils could be rated as deficient in Bray's-P. The total and available N, P and K contents, in general, was in the order of K>N>P. The soils contained adequate to toxic amounts of DTPA extractable Fe, Mn, Cu and tested low in available Zn especially for soils of higher elevation. Total and available N and P and DTPA extractable Zn had a significant negative relationship with altitude whereas DTPA-Fe and Cu were positively related. There was positive influence of silt on total N and of both organic carbon and silt on $KMnO_4$-N. The total and Bray's-P were significantly positively related with pH, silt and clay content. The NH_4OAc-K was positively related with CEC. The silt and clay contents had negative influence on DTPA extractable Fe and Cu while DTPA-Zn was positively related with silt, clay and pH.

Key words : Altitude, *Hevea brasiliensis*, Mizoram, Slope lands, Soil characteristics, Soil nutrients.

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INTRODUCTION

Slope lands are one of the most fragile of agricultural resources. The utilization of these slope land areas need attention, because unfavourable natural conditions can cause rapid soil erosion. Soil erosion by water accounts for about 55 per cent of total degradation of land (Oldeman, 1994) and soil losses of 200 to 300 t per ha per year are common. The vegetation at the soil surface slows down the surface flow and induces deposition and effectively controls the soil loss (Hashim, 1996). In tropical tree-crop ecosystems such as rubber (*Hevea brasiliensis*), leaf litter accumulates as a result of periodic leaf fall, providing a form of surface cover over the soil. In addition, leguminous cover crops and terracing help to reduce soil erosion while the trees are still immature (Soong *et al.*, 1980). In a mature rubber plantation the amount of litter fall is in the range of 4620 to 5320 kg per ha per year (Moris, 1993) and the decomposition of this litter plays an important role in soil nutrient recycling.

Mizoram, being a mountainous hill state, has endless variety of landscape and due to its complexity of physiography various micro-climates prevail from the higher elevation to the lower. Shifting cultivation (jhumming), the usual practice in the area leads to severe degradation of forest. Additionally, intense leaching of bases due to high rainfall in the area causes loss of bases and soil nutrients leading to soil acidity. Rubber cultivation is now being introduced in the foothills along the western belt of Mizoram as an alternative to jhumming. Information on soil fertility status is, therefore, of vital importance for appropriate management of the rubber plantations. Therefore, in the present study, an attempt was made to assess the status of some soils of Mizoram under rubber, in terms of total and available forms of nutrients and also to know their relationship with soil characteristics and altitude.

MATERIALS AND METHODS

The study area covers northern part of Aizawl district of Mizoram. It has distinct physiographic units *viz.*, steep to moderate slopes, to gentle slopes and valley at varying altitude from 100 to 750 m above sea level (Table 1). One hundred and thirty eight soil samples (0-0.3 m depth) comprising 39 strata were collected from 21 rubber plantations using stratified sampling technique according to the rule of proportionality. Soil samples were air-dried, pulverized and passed through a 2 mm sieve before analysis. Particle size distribution was estimated by the Hydrometer method (Bouyoucos, 1962) and water holding capacity (WHC) following the method described by Black (1965).

Standard methods were followed for determining soil pH (1:2 soil:water suspension), organic carbon (OC), cation exchange capacity (CEC) and exchangeable cations. Total nitrogen, phosphorus and potassium contents were estimated after Jackson (1973). Alkaline potassium permanganate, Bray's-I extractant and neutral normal ammonium acetate were used for estimation of available N, P and K respectively. Available (DTPA extractable) Fe, Mn, Zn and Cu were determined by Atomic Absorption Spectrophotometer (Lindsay and Norvell, 1978). The soils were categorized into low, medium and high status considering the critical limits as suggested by different authors (Table 6). The effect of soil characteristics on nutrient status was evaluated through simple correlations by the procedure described by Snedecor and Cochran (1968).

Table 1. **General characteristics of the soils of *Hevea* plantations at different locations in Mizoram**

Soil Location	Altitude (m asl)	Age of plantation (years)	No. of samples	Physiography	Drainage	Erosion
L1 – Pangbalkawn	100	4	26	Undulated gentle slope	Moderate	Moderate
*L2 – Tuichhuhen	150	5	26	Valley	Moderate	Moderate
*L3 – Tuichhuhen	150	11	56	Steep-gentle slope	Well	Moderate to severe
L4 – Phainum	200	10	10	Steep-moderate slope	Well	Moderate to severe
L5 – Bilkhathlir	400	10	10	Steep-moderate slope	Well	Moderate to severe
L6 – Thingdawl	750	5	10	Steep slope	Well	Moderate to severe

masl – metre above sea level
* Cover crop (*Pueraria phaseoloides*) maintained in the plantation

RESULTS AND DISCUSSION

Physico-chemical characteristics of soils

The soils, in general, were sandy loam to silty clay loam in texture (Table 2). The dominant texture was silty clay loam (39%) while 33 per cent soils were loam to clay loam and 28 per cent were sandy loam to sandy clay loam. The soils of lower altitude contained considerably higher amount of silt and clay fractions and their contents decreased with increase in elevation. It could be attributed to the removal of finer particles by erosion and/or transportation of soil particles from upper slopes and redeposition at valleys, which might have resulted in the textural differences of the lowland soils at altitude of 100 and 150 m above sea level. Similar observations were made by Das and Roy (1979) while characterizing catenary soils of West Bengal. The water holding capacity of the soils decreased from 68 to 35 per cent, with increasing elevation, which could be due to the differences in the texture.

The soils were very acidic to strongly acidic in reaction except in valleys where 12 per cent of soils were neutral in reaction. The pH of the soils ranged from 4.6 to 7.1 (Table 2) and soil acidity increased gradually with increasing altitude. This suggests that these soils have developed from non-calcareous parent materials under conditions of high rainfall and good drainage. The organic carbon content of the soils was high, varying from 12.1 to 24.9 g per kg with mean value of 18.0 g per kg (Table 2). The soils at 200 m altitude contained comparatively higher organic carbon (ranging from 16.8 to 24.9 g/kg) followed by the soils at 150 m altitude. The age of the rubber plantation also caused variation in soil organic matter content, due to the variation in amounts of leaf litter added.

Table 2. **Some physico-chemical characteristics of the soils under *Hevea* in Mizoram**

Soil location	Sand (%)	Silt (%)	Clay (%)	WHC (%)	pH (1:2.5)	Organic carbon (g/kg)
L1 – Pangbalkawn						
Range	34-47	21-27	28-40	49-68	4.8-5.7	12.1-18.1
Mean	39	24	38	57	5.2	17.1
L2 – Tuichhuhen						
Range	18-36	26-45	31-43	51-62	5.1-7.1	16.1-21.0
Mean	27	35	38	60	5.5	18.0
L3 – Tuichhuhen						
Range	16-49	25-45	26-42	41-58	4.6-5.2	16.4-22.0
Mean	28	38	34	56	4.9	19
L4 – Phainum						
Range	24-36	30-40	33-39	53-55	4.9-5.1	16.8-24.9
Mean	34	32	34	54	5.0	19.2
L5 – Bilkhathlir						
Range	40-62	13-21	22-39	48-53	4.9-5.5	14.0-19.2
Mean	53	17	27	51	5.2	17.4
L6 – Thingdawl						
Range	54-69	12-23	17-23	35-56	4.6-5.0	14.5-18.6
Mean	61	19	20	46	4.7	16.3

WHC : water holding capacity

Table 3. **Ion exchange properties and base saturation of the soils under *Hevea* in Mizoram**

Soil location	CEC (cmol(p+)/kg)	Exchangeable cations (cmol(p+)/kg)				PBS
		Calcium	Magnesium	Potassium	Sodium	
L1 – Pangbalkawn						
Range	6.3-10.8	1.7-2.4	0.7-1.9	0.4-1.0	0.2-0.5	48-54
Mean	8.9	1.8	1.6	0.6	0.3	49
L2 – Tuichhuhen						
Range	5.4-9.5	1.1-3.7	1.2-2.3	0.4-0.6	0.3-0.5	55-74
Mean	8.9	2.8	1.8	0.5	0.4	61
L3 – Tuichhuhen						
Range	8.6-10.5	1.6-1.8	1.4-1.7	0.4-0.6	0.3-0.4	42-45
Mean	9.2	1.7	1.5	0.5	0.3	43
L4 – Phainum						
Range	6.2-9.8	0.8-3.3	0.5-2.2	0.1-0.6	0.1-0.3	24-64
Mean	7.9	1.7	1.4	0.5	0.1	48
L5 – Bilkhathlir						
Range	8.9-12.7	1.1-1.8	1.6-1.8	0.2-0.7	0.1-0.3	27-36
Mean	9.7	1.3	1.7	0.3	0.2	35
L6 – Thingdawl						
Range	8.4-10.1	1.0-2.1	0.7-1.3	0.5-0.8	0.4-0.6	31-47
Mean	9.6	1.1	0.9	0.6	0.4	33

CEC : Cation exchange capacity; PBS : Per cent base saturation

Ion exchange properties of soils

The data on cation exchange capacity (CEC) and exchangeable cations are presented in Table 3. The values of CEC of the soils were generally low, varying from 6.2 to 12.7 cmol (p+) per kg and did not show any relation with varying altitude. This may be due to physical presence of preweathered parent materials (Schafer and McGarity, 1980). Calcium was the dominant cation followed by Mg^{++}, K^+ and Na^+ in the descending order. Similar observations have also been reported by Chavan *et al.* (1995). Base saturation of the soils was low except for L2 where values were relatively higher, probably due to accumulation of bases from higher slopes through leaching.

NUTRIENT STATUS OF SOILS

Nitrogen

The total N content in the soils varied from 1.53 to 2.45 g per kg (Table 4). The soils of higher altitudes were lower in total N content as compared to soils at lower altitude which may be due to heavy annual losses of NO_3-N through leaching (Panda, 1987). In general, $KMnO_4$-N content of the soils were low to medium (FAI, 1977) ranging from 156 to 358 kg per ha with the mean value of 277 kg per ha (Table 6). The soils of L1, L2 and L3 (lower elevation) contained relatively high $KMnO_4$-N, because of higher organic matter content and presence of cover crop. It is evident that despite the addition of leaf litter from the plantation, $KMnO_4$-N contents were low in higher elevation. Such variation in available N content have also been reported by Eshett and Omueti (1989) and Centurion *et al.* (1995) for rubber growing soils of South-Eastern Nigeria and Brazil, respectively.

Phosphorus

The total P content varied from 0.15 to 0.54 g per kg and Bray's-P from 4.6 to

Table 4. **Total and available nitrogen (N), phosphorus (P) and potassium (K) content of the soils under *Hevea* in Mizoram**

Soil location	Total nutrient (g/kg)			Available nutrient (kg/ha)		
	N	P	K	$KMnO_4$-N	Bray's-P	NH_4OAc-K
L1 – Pangbalkawn						
Range	1.70-1.92	0.15-0.28	16.5-23.5	244-312	4.6-12.9	183-326
Mean	1.84	0.19	19.5	281	8.4	296
L2 – Tuichhuhen						
Range	1.86-2.45	0.19-0.54	15.4-22.6	251-358	8.0-16.0	288-396
Mean	2.06	0.40	18.6	316	14.7	309
L3 – Tuichhuhen						
Range	1.79-2.16	0.18-0.44	13.0-22.0	218-306	8.3-16.0	281-398
Mean	1.93	0.27	17.2	297	11.9	316
L4 – Phainum						
Range	1.61-1.79	0.21-0.48	16.5-29.0	246-268	10.7-14.6	188-268
Mean	1.68	0.30	22.0	253	11.6	209
L5 – Bilkhathlir						
Range	1.53-1.86	0.20-0.35	18.6-22.5	156-258	11.1-14.3	298-349
Mean	1.68	0.25	20.0	226	12.1	322
L6 – Thingdawl						
Range	1.61-1.77	0.19-0.24	19.6-23.6	246-281	8.0-12.2	223-330
Mean	1.70	0.20	22.5	270	8.9	268

16.0 kg per ha. Majority of soils (74%) were low in Bray's P status as per the critical limit (Murthy and Hirekerur, 1980) (Table 6) which could be due to their high P fixing capacity under strongly acid soil environment resulting in the prevention of P availability in the soil solution (Badrinath *et al.*, 1986). The data in Table 4 show that the Bray's P content was relatively high in valley soils, which gradually decreased with increase in elevation due to differences in management. Sharma and Bhandari (1995) also reported similar results for orchard soils in Himachal Pradesh.

Potassium

The content of total potassium (K) varied from13 to 29 g per kg of soil. The high content of total K in the soils might be due to the presence of higher amounts of K-bearing minerals like micas and feldspars (Singh *et al.*, 1991). The NH_4OAcK in the soils ranged from 183 to 398 kg per ha with mean value of 291 kg per ha (Table 6). There was a large variation in both the forms of K in the soils and they did not follow any definite pattern with elevation. However, about 73 per cent of the soils studied were high in available K as per the standards of Murthy and Hirekerur (1980) (Table 6). Chamuah (1987) and Satisha and Badrinath (1994) came to similar conclusions for low altitude Assam soils and western ghats forest soils in Karnataka, respectively.

DTPA extractable iron (Fe)

The DTPA-Fe in the soils ranged from about 76 to 242 mg per kg with an average value of 157 mg per kg soil (Table 6). Lowest average DTPA-Fe was observed in soils in the valley (L2) and it increased with increase in altitude (Table 5). Exceptionally high average value (187 mg per kg) was found in soils of Phainum (L4) at 200 m altitude. Considering 4.5 mg per kg as

Table 5. DTPA extractable (mg/kg) iron, manganese, copper and zinc content of the soil under *Hevea* in Mizoram

Soil location	Iron	Manganese	Copper	Zinc
L1 - Pangbalkawn				
Range	76-239	26-168	0.56-2.20	1.42-3.63
Mean	149	88	1.61	2.68
L2 – Tuichhuhen				
Range	96-242	38-87	0.86-2.48	1.38-2.78
Mean	130	56	1.48	2.13
L3 – Tuichhuhen				
Range	96-239	23-115	0.82-2.42	0.56-2.96
Mean	140	60	1.49	1.89
L4 – Phainum				
Range	157-199	36-56	1.34-2.12	0.86-1.60
Mean	187	49	1.60	1.01
L5 – Bilkhathlir				
Range	170-197	43-67	1.36-2.10	0.94-1.60
Mean	178	49	1.60	1.01
L6 – Thingdawl				
Range	168-183	44-62	1.86-3.08	0.42-0.92
Mean	178	52	2.28	0.71

critical value (Lindsay and Norvell, 1978) or the higher value of 6.0 mg per kg, the critical limit suggested by Boer and Reisenauer (1973), all the soils under study contained adequate to toxic amounts of DTPA-Fe. High contents of DTPA-Fe in these soils may be attributed to the effect of high acidity and to the parent material (Gaikwad *et al.*, 1974).

DTPA-extractable manganese (Mn)

Manganese extracted by DTPA ranged from 23 to 168 mg per kg (Table 5). The highest average value of 88 mg per kg was recorded for soils at 100 m altitude and decreased with increase in altitude. On the basis of 1.0 mg per kg soil of DTPA-extractable Mn as the critical limit (Lindsay and Norvell, 1978) and the critical value of 3.0 mg per kg of DTPA-extractable Mn (Shukla and Gupta, 1975), all the soils were well supplied with available Mn.

DTPA extractable copper (Cu)

The DTPA-Cu in these soils varied from 0.56 to 3.08 mg per kg with average value of 1.66 mg per kg (Table 6). According to the critical limit of 0.7 mg per kg (Sakal *et al.*, 1983), 82 per cent of soils tested appeared well supplied while 5 and 13 per cent samples were low and medium in Cu, respectively. Further, it is apparent from the data in the Table 5, that lowest average value of 1.48 mg per kg soil was recorded for the soils at 150 m (L2) and the availability gradually increased with increase in altitude. But soils at 100 m (L1) contained relatively high available copper with a mean value of 1.61 mg per kg as compared to L2, L3, L4 and L5. Such variation in Cu content occurred presumably due to variation in geology and degree of weathering of these soils. Sen *et al.* (1997) observed similar results for soils of Manipur.

Table 6. **Per cent distribution of soil samples under different nutrient classes**

Nutrient	Range	Mean	Critical level	*Fertility class		
				Low	Medium	High
Organic Carbon (g/kg)	12.1-24.9	18	5.0	—	—	100
Available Nitrogen (kg/ha)	156-358	277	272	38	62	—
Available Phosphorus (kg/ha)	4.6-16.3	11	10.0	74	26	—
Available Potassium (kg/ha)	183-398	291	110	—	27	73
DTPA-Fe (mg/kg)	76-242	157	4.5 6.0	—	—	100 .100
DTPA-Mn (mg/kg)	23-168	59	1.0 3.0	—	—	100 100
DTPA-Cu (mg/kg)	0.56-3.08	1.66	0.70	5	13	82
DTPA-Zn (mg/kg)	0.42-3.63	1.64	0.6	14	12	74

* Per cent soil samples

DTPA extractable zinc (Zn)

The DTPA-extractable Zn in the soils was found to vary between 0.42 and 3.63 mg per kg showing decreasing trend with increase in elevation as noticed in Table 5. With 0.6 to 0.8 mg per kg soil as the critical limit for DTPA-Zn (Sakal *et al.*, 1984), about 74 per cent of the soils contained adequate available Zn while 14 and 12 per cent samples were low and medium in Zn, respectively. Further, low altitude soils were relatively high in DTPA-Zn than soils at 750 m altitude. These observations are in agreement with those of Panda (1987) for sedentary acid soils of Bihar and highly leached sandy laterite soils of West Bengal, and Nongkynrih *et al.* (1996) for Meghalaya soils.

Relationship between the nutrients and some soil characteristics and altitude

There were significant positive relationships of total N with silt and of $KMnO_4$-N, with silt and organic carbon (Table 7) in the soil, which could be due to the retention of NH_4^+ ions on silt particles. The total and Bray's P content of soils had significantly positive relation with silt content, pH and organic carbon content but significantly and negatively related to sand content (Table 7) in the soil. A significant positive relationship of total P with pH and of available P with organic carbon was also observed by Kumar *et al.* (1995). These observations suggest that the retention of P by organic colloids would go a long way in the build up of P in such types of soils. Total K content shows significant positive relationship with sand content but negative relation with silt and clay content of the soil.

There was significant negative correlation between DTPA extractable Fe and silt and clay content in the soil but it was significantly positive with sand content (Table 7). DTPA-Fe was not significantly related with organic carbon. Thus it can be concluded that DTPA extracted the easily exchangeable Fe held on fine sand particles and inorganic form of Fe, principally as precipitate of oxides and phosphates present in these soils (Arora and Sekhon, 1981). The DTPA extractable Mn does not bear any kind of relationship with soil properties. Among the soil properties, silt and clay content were significantly and negatively related with DTPA-Cu content, but positive

Table 7. Coefficient of correlation 'r' between the nutrients and some soil characteristics and altitude

Nutrient	Sand	Silt	Clay	pH	Organic carbon	CEC	Altitude
Total Nutrient							
N	-0.497**	0.460**	0.205	0.158	0.163	0.120	-0.490**
P	-0.271*	0.263*	0.175	0.314**	0.332**	0.199	-0.280*
K	0.476**	-0.442**	-0.404**	-0.184	-0.046	0.105	0.441**
Available Nutrient							
$KMnO_4$-N	-0.46-**	0.446**	0.206	0.099	0.240*	0.044	-0.350**
Bray's P	-0.278*	0.277	0.193	0.259*	0.281*	0.170	-0.265*
NHO_4Ac-K	-0.010	-0.027	-0.083	0.204	0.161	0.409**	-0.141
DTPA-Extractable							
Fe	0.404**	-0.386**	-0.287*	-0.042	0.055	0.186	0.341**
Mn	-0.071	0.029	0.125	0.162	0.160	0.140	-0.231
Cu	0.425**	-0.336**	-0.325**	-0.130	-0.042	0.317**	0.491**
Zn	-0.531**	0.365*	0.514**	0.372**	0.224	-0.047	-0.690**

** Significant at P ≤ 0.01 * Significant P ≤ 0.05

relation was observed with sand content and CEC (Table 7) of the soil. The DTPA-Zn was significantly positively related with pH, silt and clay content but it was negatively related with sand content. Similar results have been reported by Avasthe and Avasthe (1995).

There was a highly significant negative relationship between altitude and silt (r=-0.625**), clay (r=-0.809**), pH (r=-0.318**) and organic carbon (r = -0.357**) but sand content had a significant positive relationship with altitude (r = 0.809**). The total and available N and P had significant negative relationship with altitude (Table 7) whereas total K was positively related with altitude. Among micronutrients, DTPA-Fe and Cu were significantly positively related with altitude. Avasthe and Avasthe (1995) also reported a positive relationship between altitude and DTPA-Fe. Non-significant correlation between Mn and altitude and a significant high degree of negative correlation was observed between DTPA-Zn and altitude. This might be attributed to the higher leaching from surface soil due to intensive rains, higher degree of slope and light texture of soils, as the altitude increases (Rawat and Mathpal, 1981).

CONCLUSIONS

The high content of finer fractions resulted high WHC in lower elevation soils. This is a favourable physical property, which minimises dry season moisture stress. As a result of strongly acidic nature of the soils, there will be a nutritional imbalance due to increase or decrease in the concentration of ions in the soil solution. In addition, decomposing plant residues in the plantation might further contribute to acidity of soil. Further, low to medium N, P and K status, evident in available N, P and K, coupled with low CEC of these soils suggests that they are subject to decline in fertility and require specific management measures to maintain soil fertility. It is necessary to allow good soil-water balance and to enhance the decomposition rates of litter to build up available nutrient pools.

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