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RESEARCH ARTICLE

Fertility status of the rubber growing tracts in agro- ecological units of Southern Kerala

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ABSTRACT : Natural rubber cultivation has crossed 100 years in its traditional belt in Kerala and it is in third or fourth cycle of replanting. Repeated cycles of past one century led to decline in soil health. Appraisal of current status of soil fertility parameters is of immense importance. Hence, the study was undertaken to adopt strategies for sustaining soil health and productivity. Geo referenced soil samples from 0-30cm and 30-60cm depth from different mature rubber plantations in the agro-ecological units of 1, 8, 9, 12 and 14 in southern Kerala were collected. Accordingly sixty five samples were analyzed for different parameters such as pH, E.C, oxidisable organic carbon, available phosphorus, potassium, calcium, magnesium, sulphur, iron, copper, zinc, manganese and boron. Soil samples were classified into different categories based on soil test values. All soil samples were acidic and majority were under extreme acidic condition. Available nitrogen, phosphorus and potassium status were in medium range. Severe deficiency of calcium and magnesium were noticed in the soil samples. Among micronutrients iron and manganese were in optimum range and boron and zinc were extremely deficient. All these factors can contribute to loss of productivity of soil. Hence ideal methodology suggested for soil health is discriminatory fertilizer application (DFA) by soil and leaf sampling and suggesting fertilizer recommendations.

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Kerala holds first position in area and production of natural rubber in India. The relative share of natural rubber in net sown area in Kerala is 20 per cent. Major rubber growing areas in India is confined to west coast of the country between $75^0$10' and $77^0$30'E longitudes and $08^0$15' and $12^0$35' N latitudes, confining to a narrow tract extending from Kanyakumari district in Tamil Nadu in South to Dakshina Kannada and Kodagu districts of Karnataka in the North and lying in general, west of Western Ghats and parallel to them for approximately 400 km. The rubber growing regions in the state of Kerala is mainly concentrated in the four agro ecological units (AEU) *viz.*, Southern and Central foothills (AEU 12), Northern foot hills (AEU 13), Southern high hills (AEU 14) and Northern high hills (AEU 15) (Kerala State Planning Board, 2013).

Commercial cultivation of rubber was initiated in India in 1902 at Kerala. So natural rubber cultivation has crossed 100 years in its traditional belt and it is in third or fourth cycle of replanting. Repeated cycles of long rubber cultivation resulted in increased soil acidity, reduced organic carbon, available K, Ca, Mg content and deficiency of zinc (Krishnakumar and Potty, 1992). Compared to natural forest organic carbon status has declined in rubber plantation (Abraham, 2015). Soils of rubber in general were deficient in available P status due to lateritic nature of rubber soils. High rainfall together with kaolinitic type of clay mineral favoured for depletion of available potassium in traditional rubber growing soils (Kartikakuttyamma *et al*., 2000). Ulganathan *et al*. (2012) reported that soils in traditional natural rubber belt region is deficient in available Ca, Mg, S, B and Zn. Based on the assumption that acid soils are sufficient in available micro nutrients, fertilizer recommendation of micronutrients was avoided. But intense weathering, high rainfall and present fertilizer use pattern have resulted in depletion of micronutrients. Studies by NBBS and LUP (1999) also revealed that 41 per cent of rubber growing tracts were deficient in available Zn. Cultivation of modern high yielding clones together with application of NPK fertilizers alone aggravated the depletion of secondary and micronutrient status. Hence, the present study was undertaken to evaluate the soil fertility parameters in the rubber growing agro ecological units of southern Kerala.

EXPERIMENTAL METHODOLOGY

Geo referenced soil samples from 0-30 cm and 30-60 cm depth representing agro-ecological units of 1, 8, 9, 12 and 14 in the rubber growing tracts of southern Kerala were collected. Total of one hundred and twenty soil samples including both surface and subsurface were collected, air dried, sieved and stored for analysis. The parameters analyzed for surface and sub surface soil samples were pH, E.C, oxidisable organic carbon, available phosphorous, potassium, calcium, magnesium, sulphur, iron, copper, zinc, manganese and boron following standard analytical procedures (Jackson, 1973). The soils were classified into different groups based on soil reaction as ultra acidic to slightly acidic. Soil samples were grouped into different categories based on soil test values. For primary nutrients the classification was very low, low, medium, high, very high and extremely high. Secondary nutrients were categorized as very low, low, adequate and high. Classification of micronutrients were deficient, adequate and high (Sureshkumar *et al*., 2018).

EXPERIMENTAL FINDINGS AND DISCUSSION

The soil test results for each parameter based on different classification system was discussed below.

Soil reaction:

Surface soil samples collected from different agro-ecological areas shows a distribution of pH between 3.5-5.2, comprising major share under extremely acidic condition (Fig. 1), followed by very strongly acidic condition. Sub surface soil samples have more acidity compared to surface samples. A slightly higher pH noticed in surface soil may be due to recycling of bases by canopy litter. Climatic situations prevailing in Kerala along with perennial nature of crop resulted in build up of acidity in soil. Continuous cultivation of rubber cultivation resulted in reducing pH level (Karthikakuttyamma, 1997).

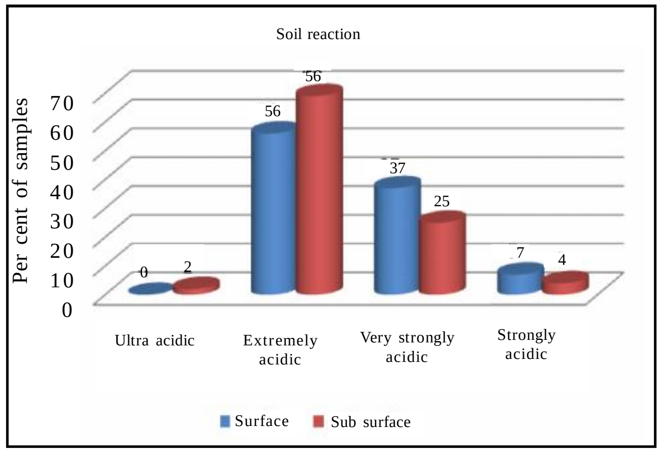

Fig. 1 : Frequency of soil reaction classes: Ultra acid <3.5 extremely acid: 3.5-4.4 very strongly acid: 4.5-5.0 strongly acid: 5.1-5.5

Even though acidity development in soil, liming is not a recommended practise in rubber cultivation. Report by Joseph *et al*. (2008) shows that pH remained under strong acidic condition even after liming due to strong buffering capacity of soil. Suitability of rubber cultivation under acidic condition also prevents farmers from doing liming practise.

Primary nutrients:

Available nitrogen:

Content of oxidisable organic carbon in the soil is taken as index for available nitrogen status of the soil. The study indicates that 12 per cent surface soil samples under very low N status, 22 per cent under low, 15 per cent medium class and 51 per cent under high to extreme high status. Coming to sub surface samples, 6 per cent are having very low nitrogen status, 11 per cent samples with low N status, 23 per cent has medium status, 25 per cent under high status and 35 per cent samples having very high nitrogen status (Fig. 2). So the survey indicates that there is wide variation in organic nitrogen status in different agro ecological units. It is also noticed that available nitrogen shows a declining trend as depth increases.

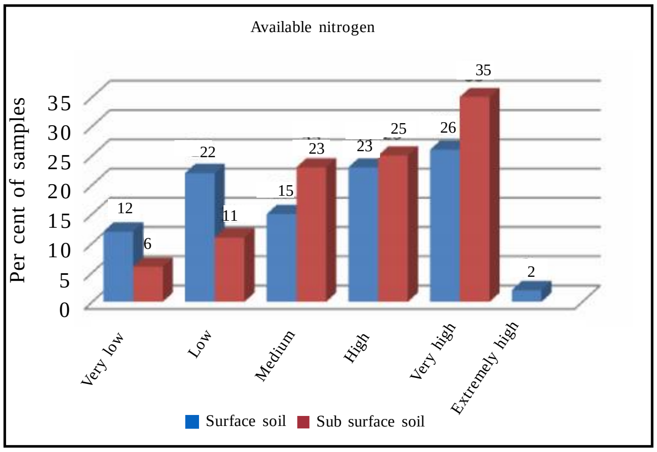

Fig. 2 : Frequency of available nitrogen classes in surface and sub surface soil

Majority of both surface and sub surface soil samples are coming under medium to high status of organic nitrogen. Rubber normally sheds leaves during December to February. This phenomenon is called wintering. Annual litter production by wintering accounts to be 6.0 tonnes ha^{-1} (Krishnakumar and Potty, 1992). Leaf litter accumulation in surface horizon along with superficial nature of rubber tree roots may be probable reason for more availability of oxidisable organic carbon in the surface soil. In surveyed areas, certain regions were planted with leguminous cover crops. In that region there was a build up of organic nitrogen. Quantity of nutrients accumulated by cover crop cultivation in a hectare over two years were 174 kg N, 13 kg P, 104 kg K, 65 kg Ca and 18 Kg Mg for *Pueraria* and 236 kg N, 15 kg P, 79 kg K, 56 kg Ca and 15 kg Mg for *Mucuna* (Philip *et al*., 2005). Closed canopy and absence of tillage also contributed for build up of organic nitrogen status in mature plantation.

Available phosphorus:

Coming to available phosphorus status, it is observed that majority of both surface and sub surface soil samples are coming under very low and low nutrient status (57

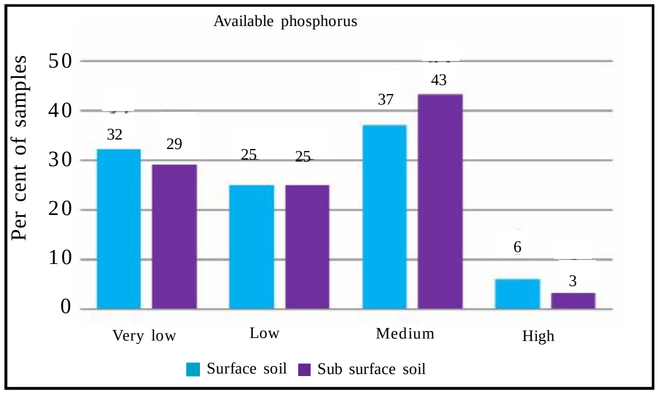

Fig. 3 : Frequency of available phosphorus classes in surface and sub surface soil

Table 1 : Range and mean of surface and sub surface soil fertility parameters

Sr. No.	Parameter	Range		Mean		Standard deviation	
		Surface soil	Sub surface soil	Surface soil	Sub surface soil	Surface soil	Sub surface soil
1.	Soil reaction (pH)	3.5-5.2	3.2-5.4	4.3	4.3	0.42	0.40
2.	Electrical conductivity (dS m^{-1})	0.04-0.23	0.04-0.24	0.12	0.12	0.04	0.04
3.	Organic carbon (%)	0.12-5.09	0.21-4.81	1.76	2.02	1.26	1.21
4.	Available phosphorus (kg ha^{-1})	0.34-35.5	0.78-28.37	11.26	10.78	8.23	8.27
5.	Available potassium (kg ha^{-1})	44-312	41-334	151.34	142.20	61.26	65.13
6.	Available calcium (mg kg^{-1})	55-307	60-298	147.48	141.62	56.23	50.73
7.	Available magnesium (mg kg^{-1})	7-125	6-116	43.03	45.29	25.64	24.64
8.	Available sulphur (mg kg^{-1})	1.1-94.50	1.4-79.5	28.54	26.54	25.94	23.49
9.	Available iron (mg kg^{-1})	10.65-95.51	11.36-142.80	44.17	41.67	15.38	23.92
10.	Available copper (mg kg^{-1})	0.06-8.82	0.11-15.52	1.84	1.90	1.83	2.17
11.	Available zinc (mg kg^{-1})	0.12-2.14	0.15-4.39	0.34	0.45	0.31	0.69
12.	Available manganese (mg kg^{-1})	0.49-15.08	0.06-9.89	4.41	4.71	2.71	3.02
13.	Available boron (mg kg^{-1})	0.01-0.52	0.01-0.25	0.07	0.07	0.09	0.07

% and 54 %, respectively), 6 per cent under high status for surface and 3 per cent for sub surface soil sample (Fig 3). Available phosphorus ranged from 0.34-35.5 kg ha^{-1} in surface soil samples and 0.78-28.37 kg ha^{-1} in sub surface samples (Table 1).

Investigation on south western region of peninsular India showed that available phosphorous content varied from trace to 1.22mg/100g in the soil profile, indicating that soils in all the regions were deficient in available phosphorous (Krishnakumar *et al*., 2003). Marschner (1986) reported that in acid soils below pH 5.5, cation exchange sites are occupied by aluminium and replacing cations such as Ca^{2+} and Mg^{2+} which act as strong adsorber of phosphorus resulting in declining of available P status in soil. Depth wise decrease in total P was observed by Kartikakuttyamma *et al*. (2000). It may be attributed to low mobility of the element.

Available potassium:

For a rubber tree, potassium plays a predominant role in flow of latex and its stability. The red and lateritic soil where rubber is generally grown is inherently deficient in K. Sixty eight per cent of surface soil samples and sixty per cent of sub surface samples were in medium range (Fig. 4). In general the availability of K on surface was higher than sub surface. It may be due to high organic carbon status of surface soils. Available K status ranged from 26 kg ha^{-1} to 152 kg ha^{-1} in major rubber growing regions of India (Joseph *et al*., 1990). Perennial crops are able to derive nutrients from a large volume of soil and can accumulate nutrients over time. It may be the reason for maintaining a medium range of K status in the surveyed area.

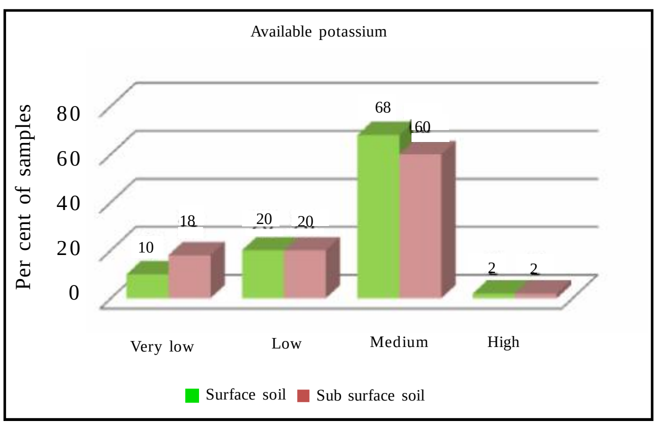

Fig. 4 : Frequency of available potassium classes in surface and sub surface soil

Secondary nutrients:

Available calcium:

Calcium plays a predominant role in cellular metabolic functions. Under heavy rainfall situations bases like calcium and magnesium get leached from soil profile. Hence available calcium status is low under red and lateritic soils. The study also reveals that 98 per cent of surface and 100 per cent of sub surface soil samples are coming under very low and low nutrient range (Fig 5). Available calcium ranged from 55-312 mg kg^{-1} in surface samples and 60-298 mg kg^{-1} in sub surface samples (Table 1).

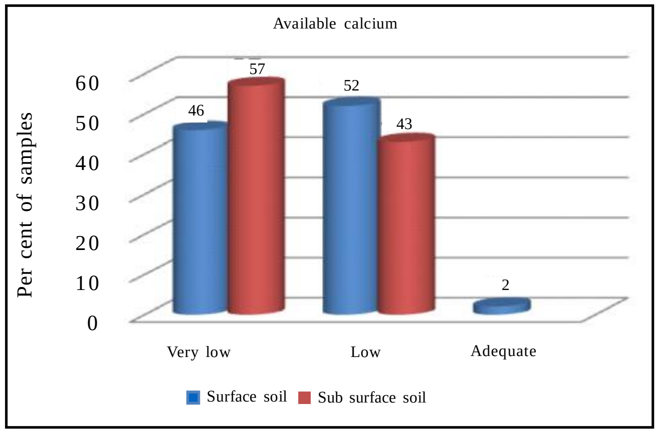

Fig. 5 : Frequency of available calcium classes in surface and sub surface soil

Calcium supply can significantly improve growth of plants. There is positive effect on volume of latex production by calcium application. Liming programme in rubber is not a recommended practise due to its adaptation under acidic condition. However, when liming is adopted it can supply calcium which help in maintaining base status. It can also result in temporary change in pH and will improve the availability of P and K and enhanced microbial activity of soil (Joseph *et al*., 2008).

Available magnesium:

Severe deficiency of magnesium was recorded in 82 per cent of surface and 72 per cent of sub surface soil samples (Fig. 6). Adequate status of magnesium was reported only in 2 per cent surface samples. In southern Kerala there was wide spread deficiency of magnesium. Hence, magnesium application is recommended during immature phase under these regions (Kartikakuttyamma *et al*., 2000).

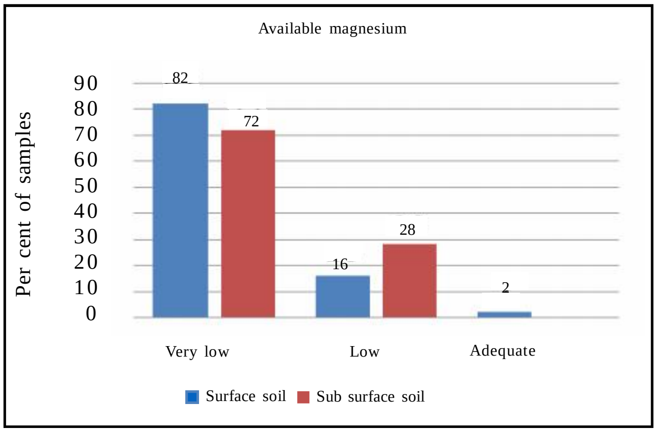

Fig. 6 : Frequency of available magnesium classes in surface and sub surface soil

Available sulphur:

Sulphur status in the region shows that 9 per cent surface and 15 per cent sub surface samples are under low class where as 40 per cent surface and 42 per cent sub surface samples under high status (Fig 7). Surface soil shows a range of 1.1-94.5 mg kg $^{-1}$ available S where as in sub surface it ranged from 1.4-79.5 mg kg $^{-1}$ (Table 1). There is wide variation in availability of sulphur at different agro ecological units. Available S status in traditional belt of natural rubber cultivation was reported to be in optimum level. Organic carbon status is positively correlated with available sulphur content (George *et al*., 1994). In the surveyed areas majority of soil samples are medium to high status of organic carbon, which may be the possible reason for maintaining adequate range of sulphur level.

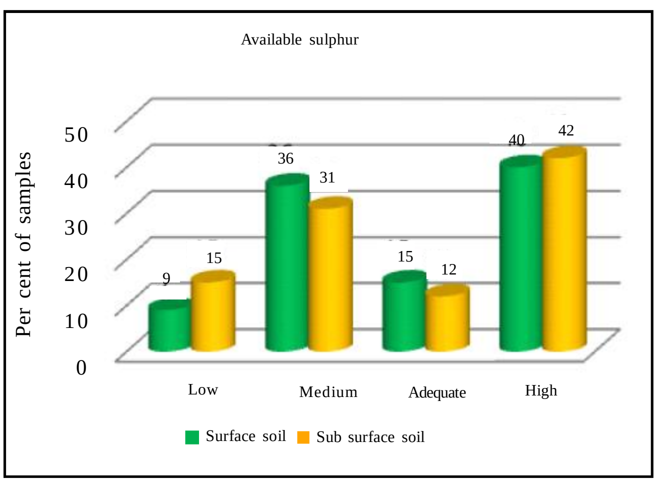

Fig. 7 : Frequency of available sulphur classes in surface and sub surface soil

Micronutrients:

Based on the assumption that acid soils are sufficient in available micro nutrients, fertilizer recommendation of micronutrients was avoided. Continuous cultivation of rubber with modern high yielding clones and constant use of high analysis fertilizers create deficiency of micronutrients in soil. In the traditional rubber growing regions its cultivation is in third or fourth cycle of replanting which can also contribute for micro nutrient deficiency.

Available copper:

Coming to copper status, 46 per cent surface and sub surface samples fall in low range, 20 per cent surface soil and 37 per cent sub surface soil samples were under adequate range and 34 per cent surface and 17 per cent sub surface samples under high status (Fig. 8). In general it was observed that southern region of Kerala were low in Cu status compared to other regions. The lowest value of 0.34 mg kg^{-1} was recorded from Thiruvananthapuram and highest value of 7.80 mg kg^{-1} was recorded from Pathanamthitta (Joseph *et al*., 1995). Study by Abraham and Philip (2017) shows that there is build up of Cu in natural rubber growing region compared to forest. Addition of copper in soil may be due to application of copper based fungicides in rubber plantation.

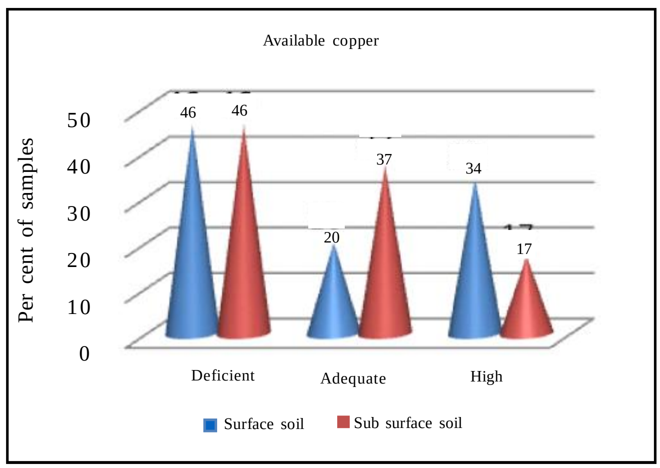

Fig. 8 : Frequency of available copper classes in surface and sub surface soil

Available zinc:

Zinc deficiency is common in immature stage of crop. The survey indicated that 95 per cent surface samples and 94 perc ent sub surface samples are under low nutrient status (Fig 9). According to Sudhakumari

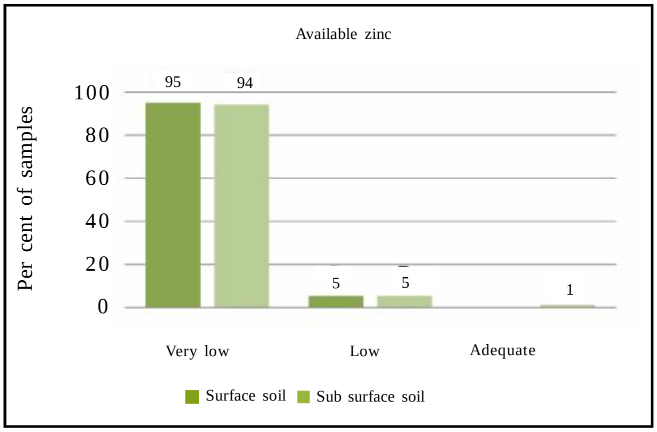

Fig. 9 : Frequency of available zinc classes in surface and sub surface soil

(2009), the major share of total zinc in rubber growing region of south India was present in residual fraction and plant available forms of Zn, *viz*., water soluble and exchangeable and organically bound Zn was only a small portion of total zinc.

Available iron:

Acid soils are relatively higher in iron content. The surveyed area shows that 100 per cent samples are having adequate range of iron content.

Available manganese:

Manganese content in the surveyed area shows that 98 per cent surface samples and 95 per cent sub surface are under adequate range where as 2 per cent surface samples and 5 per cent sub surface samples under low status (Fig 10). Acidity of soil results in build up of manganese in the soils.

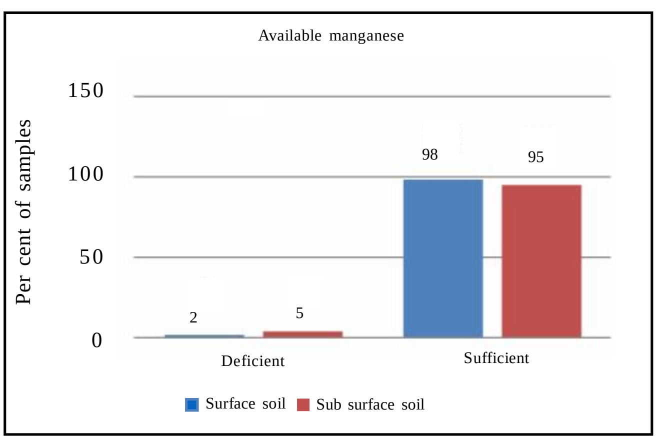

Fig. 10 : Frequency of available manganese classes in surface and sub surface soil

Available boron:

Coming to boron status, 100 per cent surface and sub surface samples are under deficient nutrient status as indicated in Fig. 11. Heavy rainfall, undulating land surface with steep slopes, inadequate ground cover are major factors contributing to the severe leaching loss of B.

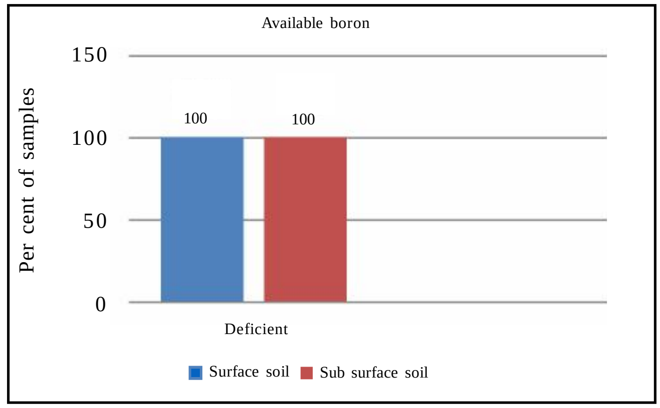

Fig. 11 : Frequency of available boron classes in surface and sub surface soil

Conclusion:

Extreme to very strong acidic condition coupled with very low base saturation especially calcium and magnesium are noticed in these areas. Available nitrogen, phosphorous and potassium status were in medium range. Among micronutrients severe deficiency of boron and zinc were reported. The natural rubber growing region in India is seen in highly weathered red ferruginous soils with high content of iron and aluminium oxides. Major share of soils developed are in sloppy land which can also result in depletion of nutrients. Extreme acidic pH with low base saturation, deficiency of Zn, B, continuous cropping with high yielding clones contribute to loss of productivity of soils. For an appropriate management of nutrient status, health of plants and saving the cost of fertilizer an ideal methodology suggested is discriminatory fertilizer application (DFA) by soil and leaf sampling and suggesting fertilizer recommendations.

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