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Available sulphur and micronutrients status in the soils of the Nilgiris district, Tamil Nadu, India

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Abstract
A soil resource inventory was conducted at village level in all the blocks of The Nilgiris district, Tamil Nadu for assessing the secondary and micronutrient fertility in the soils. About 152 surface soil samples were collected at 4 samples / village in all the blocks along with geo coordinates and analysed for various soil physico-chemical properties, available sulphur and micronutrients (Zn, Fe, Cu, Mn and B) by adopting standard procedures. Based on the nutrient availability, the soils were grouped into deficient or sufficient category using the critical limits established for Tamil Nadu soils. Per cent sample deficiency status in each block was worked out at block level to understand the extent of sulphur and micronutrient deficiency to make suitable recommendations. The overall soil reaction (pH) of The Nilgiris district ranged from 4.10 to 7.90 with a mean of 5.68, indicating that the soils are acidic to neutral in nature. Most of the samples were reported to contain low salt status with a mean EC of 0.31 dS m^{-1}, rich in organic matter (>0.75%) and non calcareous in nature. The soils were predominantly Zn deficient in all the blocks with the overall per cent deficiency of 55.4. Next to Zn, Cu deficiency was observed in the soils to the tune of 21.3%, followed by B (15.8 %). None of the samples were deficient in Fe and Mn but S deficiency was noted to an extent of 5.83%. Similarly fertility rating of the soils computed indicated that the district has marginal Zn and B, adequate Cu, high S and very high Fe and Mn in the soils.

Keywords: Soil resource inventory, sulphur and micronutrients availability, fertility rating

Introduction
Land and water are the two eyes of farmers for achieving assured return from agriculture and conserves ecology of life system as a whole in the Earth. Soil is the precious natural resource which supplies essential nutrients for better plant growth and habitat for all living things. Soil survey and testing are proven practical methods for evaluating soil fertility and to prescribe balanced fertilizer management strategies to improve the crop productivity and to sustain the soil health. Micronutrient deficiencies in soils drastically affect growth, metabolism and reproductive processes in plants, animal and human beings. Particularly, Zn deficiency in soils and plants is a global disorder reported widely in many countries > 30 per cent, Shukla *et al.*, 2014) [15].

Generally, quantity and distribution of micronutrients in soils depends on parent materials, organic matter, pH, mineralogy, soil forming processes, drainage, vegetation, anthropogenic and natural processes (Baligar *et al*., 1988) [2]. Spatial variability analysis of nutrients is one of the key factor for precision agricultural management and helps in rational soil resources management to ensure sustainability of agricultural productivity. The soil nutrient concentrations reported as index values, can be used to predict soil fertility levels which provides a common scale for judging nutrient supply and balance in soil (Hardy *et al*., 2008). With this background a soil resource inventory was made in The Nilgiris district of Tamil Nadu, India with an objective of assessing the sulphur and micronutrients availability in soils to know the fertility status at block level.

Materials and Methods
Study area
The Nilgiris district is bounded in west by the state Kerala, in north by Karnataka, in south by Coimbatore district and in east by Erode district. It lies at an elevation of 1000 to 2600 M above MSL, locatated at 76.8° E latitude and 11.3-11.5° N longitude geographically classified under hilly zone of Tamil Nadu.

It receives rain during both South West and North East Monsoon periods. The average rainfall received in the district is 1920 mm and predominantly grown with horticultural crops. The major plantation crops such as tea, coffee, cardamom, pepper, rubber and vegetables like potato, carrot, beetroot, garlic and cabbage are cultivated throughout the year.

The district has four blocks with a total cultivable area of 2,552.5 km^2, comes under hilly zone of Tamil Nadu. A ground truth survey was carried out in the Nilgiris district covering all the blocks to collect surface soil samples (0 to 15 cm depth) at four per village along with geo referenced data using GPS (Garmin *etrex*) to assess, delineate and rate the soil available micronutrients status. About 152 surface soil samples were collected from four blocks representing 34 panchayat villages of the district and analyzed for various soil physic-chemical properties and soil available micronutrient status (Table.1).

Table 1: Details of geo-referenced soil samples collected from different blocks of The Nilgiris district

S. No.	Name of the Block	No of Panchayat villages	No of samples
1	Kothagiri	10	40
2	Coonoor	6	24
3	Gudalur	5	20
4	Udhagamandalam	13	68
Overall Mean		34	152

Table 2: Critical limits (mg kg^{-1}) for soil micronutrients

S. No.	Element	Low (Deficiency)	Medium (Moderate)	High (Sufficient)
1	Zinc	<1.2	1.2-1.8	>1.8
2	Iron	<3.7	3.7-8.0	>8.0
3	Manganese	<2.0	2.0-4.0	>4.0
4	Copper	<1.2	1.2-1.8	>1.8

Collection and analysis of soil samples

The collected samples were air dried, powdered, sieved (2 mm sieve) and analysed for soil physico- chemical properties (Jackson, 1973), available sulphur (Williams and Steinbergs, 1959) [17] and DTPA extractable micronutrients (Fe, Mn, Zn and Cu) as outlined by Lindsay and Norwell (1978) [9] and hot water soluble boron by Berger and Truog (1944). Based on the established critical limits, soil samples were grouped at block level as deficient (Low), moderate (Moderate) and sufficient (High) in status and the extent of micronutrient deficiency in each block was computed and expressed as per cent sample deficient.

Categorization of samples based on critical limits

The analytical results of soil samples were used to categorize them into low, medium and high and the per cent sample at each category was assessed at block level using Microsoft Excel page. The Nutrient Index values were worked out based on the following formula.

$$\text{Per cent sample category} = \frac{\text{No. of low or medium or high}}{\text{Total number of samples}} \times 100$$

$$\text{NIV} = \frac{[(P_H*3 + (P_M*2) + (P_L*1)]}{100}$$

Where

NIV = nutrient index value

P_L, P_M and P_H are the percentage of soil sample falling in the category of low, Medium and High nutrient status and given an weightage of 1, 2 and 3 respectively. The index values are rated in to various categories *viz*., very high (2.66), high (2.33-2.66), adequate (2.00-2.33), marginal (1.66-2.00), low (1.33-1.66) and very low (<1.33) for the nutrient supply (Ramamoorthy and Bajaj, 1969).

Results and Discussion

The present study was conducted with an objective of assessing the soil physico -chemical properties, available micronutrients status and to know the fertility ratings in the soils of The Nilgiris district, the hilly zone of Tamil Nadu and the results generated were discussed:

Soil physico - chemical properties

The overall soil reaction (pH) in The Nilgiris district ranged from 4.10 to 7.90 with a mean of 5.68, indicating that the soils are acidic to neutral in nature (Table 3). The lowest acidic pH (4.00) was noticed in all the blocks of The Nilgiris district except Gudalur block which registered the pH of 4.50. Out of the 152 samples, 82 % of the samples were acidic in nature, 16 % as neutral and only 2 % is found alkaline in soil reaction. This might be due to leaching of all basic cations with the receipt of high rainfall and also due to the presence of acidic parent material (granite types of rocks and charnokites). Similar results were reported by Vijay Kumar *et al.* (2015) [16] in the soils of Theni district of Tamil Nadu. The electrical conductivity (EC) of the soils in the district indicated non saline nature of the soil and the values varied from 0.10 to 1.89 dSm^{-1} with a mean of 0.31 dS m^{-1}. The highest mean EC value of 1.89 dS m^{-1} was registered in Kothagiri block. Most of the samples were reported to contain low salt status which might be due to the removal of salts with excess rainfall and free drainage condition. Similar results were reported by Awanish Kumar *et al.* (2014) [1] in the soils of Kabeerdham district of Chhattishgarh and Govind Singh *et al.*, (2018) [5]. More than 95 % of the soils were high in organic carbon status and non calcareous (0.50 to 3.00% free $CaCO_3$).

Table 3: Range and mean soil physico-chemical properties in the Nilgiris district

Name of the blocks	Sample size	Soil properties			
		pH		EC (dS m^{-1})	
		Range	Mean	Range	Mean
Kothagiri	40	5.27	4.10 - 7.50	0.33	0.13 - 1.89
Conoor	24	5.79	4.10 - 7.90	0.31	0.05 - 0.98
Udagamandalam	68	5.65	4.00 - 7.30	0.40	0.10 -1.63
Gudalur	20	5.99	4.50 -7.50	0.19	0.09 - 0.30
Overall Mean	152	5.68	4.00 -7.90	0.31	0.05 - 1.89

Available Sulphur and Micronutrients status

The soil available sulphur status in the district was high to very high and the values ranged from 3.03 to 92.3 mg kg^{-1}. The highest soil S availability of 92.3 and 91.3 mg kg^{-1} was noted in Udhagaimandalam and Kothagiri blocks while the lowest S status of 3.03 mg kg^{-1} was recorded in Conoor block (Table 4). The block level mean data showed sufficient S level in all the blocks which might be due to the application of complex inorganic fertilizers containing sufficient sulphur thus increased the availability in soils.

As regards the Fe and Mn availability, the soils were sufficient in both the elements and the values varied from 5.80 to 53.0 mg kg^{-1} for Fe and 2.29 to 32.5 mg kg^{-1} for Mn. Native mineralization of these elements from the parent rock and minerals might have resulted in the increased availability, thus the soils might be rich in Fe and Mn. Similar results were reported by Chitdeshwari *et al.*, (2017) [4] in the soils of Cuddalore district of Tamil Nadu and Vijay Kumar *et al.*, (2015) [16] in the soils of Thein district. Similarly, the mean values of all blocks in the district except Conoor block (0.66 mg kg^{-1}) showed sufficient Zn status and the values ranged from 0.40 to 6.54 mg kg^{-1}. Partial immobilization and release from organic compounds might enhance the availability in the surface soils. The Cu availability varied from 0.37 to 6.70 mg kg^{-1} with a overall mean of 1.89 mg kg^{-1}. The hot water soluble B availability in the soil was marginal as a whole with a mean value of 0.63 mg kg^{-1} in all the blocks. The values varied from 0.32 to 1.14 mg kg^{-1} and no much variability was noted with its availability among the blocks.

Table 4: Range and mean values of soil available sulphur and micronutrients status (mg kg^{-1}) in different blocks of The Nilgiris district

Name of the blocks	Sample size	DTPA -Fe		DTPA - Mn		DTPA -Zn		DTPA -Cu		HWS B		$CaCl_2$ -S	
		Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean
Kothagiri	40	22.3-46.7	34.3	2.90-32.0	14.3	0.15-3.43	1.49	1.03-6.70	2.41	0.36-1.14	0.64	7.33-91.3	31.1
Conoor	24	5.80-53.0	31.9	2.49-8.78	6.18	0.13-3.06	0.66	0.87-2.96	1.82	0.32-1.02	0.64	3.03-61.8	23.2
Udhagamandalam mm	68	24.5-49.5	37.9	2.29-12.6	5.88	0.04-6.54	1.35	0.37-3.78	1.75	0.36-1.14	0.66	11.6-92.3	37.9
Gudalur	20	10.9-46.6	28.8	2.98-32.5	14.3	0.43-3.52	1.55	0.96-3.92	1.56	0.39-0.92	0.58	9.63-85.0	21.8
Overall Mean	152	5.80-53.0	33.2	2.29-32.5	10.2	0.04-6.54	1.26	0.37-6.70	1.89	0.32-1.14	0.63	3.03-92.3	28.5

Extent of sulphur and micronutrients deficiencies in soils

Sulphur deficiency was observed at lesser magnitude in the soils of all the blocks and the extent of deficiency varied from 5.00 to 10.0% in the district. About 63.8 % of the soils were having high S status with 30.4 % under medium category. None of the soil samples collected form Udhgamandalam block was found deficient and almost 80 % of the samples were high in S availability.

The soils were predominantly deficient in Zn (55.4%) and Cu (21.8%) followed by boron (15.8%) and S (5.83%) with no Fe and Mn deficiency in the soils. The soils of Conoor block were highly deficient in Zn (83.3%), Udhagaimandalam block was highly deficient in Cu (52.9%) and Gudalur block in B deficiency (25%). About 98.9 per cent of the soils in the district were high in Fe status and 93.8% were high in Mn availability. Similar findings were reported by Saleem *et al.*, (2011) in the soils of guava orchards in Kohat district of Pakistan. The Fe and Mn deficiency in the soil was nil in all the blocks (Table 5). Similar findings were reported by Prabhavati *et al*. (2015) [12] in the soils of various Agro climatic zones of Belgaum district of Karnataka and Sharma *et al*., (2008) in the soils of Amritsar district in North West Pakistan.

The extent of Cu deficiency in the district varied from 5.00 to 52.9 % with a mean of 21.8 % and higher magnitude of Cu deficiency was noted in the soils of Udhagaimandalam block with no Cu deficiency in Gudalur block. About 17.5 and 60.7% soil samples collected from the district had medium and high Cu availability respectively. With regard to boron availability, the values were 15.8, 58.5 and 25.7% under low, medium and high status. The nutrient index values were worked out to know the fertility rating of the soils for sulphur and micronutrients indicated that the soils were very low to medium in Zn, medium in boron, Adequate to medium in Cu, high to very high in S and very high in Fe and Mn fertility. However within blocks the status varies with elements with the nutrient index values of 2.35 to 2.79, 2.96 to 3.00, 2.91 to 2.98, 1.29 to2.00, 1.88 to 2.55 and 1.75 to 1.97 respectively for S, Fe, Mn, Zn, Cu and B (Table 5).

Table 5: Per cent sample sulphur and micronutrients deficiencies in the soils of different blocks of The Nilgiris district

Name of the Blocks	Sample size	DTPA - Fe			DTPA – Mn			DTPA- Zn			DTPA - Cu			HWSB			$CaCl_2$ –S		
		D	M	H	D	M	H	D	M	H	D	M	H	D	M	H	D	M	H
Kothagiri	40	0.00	0.00	100	0.00	2.5	97.5	35.0	30.0	35.0	5.00	35.0	60.0	17.5	75.0	7.50	5.00	35.0	60.0
Conoor	24	0.00	4.17	95.8	0.00	8.33	91.7	83.3	4.17	12.5	29.2	29.2	41.7	20.8	75.0	4.17	8.33	20.8	70.8
Udhagamandalam	68	0.00	0.00	100	0.00	8.82	91.2	63.2	5.88	30.9	52.9	5.88	41.2	0.00	8.82	91.2	0.00	20.6	79.4
Gudalur	20	0.00	0.00	100	0.00	5.00	95.0	40.0	30.0	30.0	0.00	0.00	100	25.0	75.0	0.00	10.0	45.0	45.0
Overall Mean	152	0.00	1.04	98.9	0.00	6.16	93.8	55.4	17.5	27.1	21.8	17.5	60.7	15.8	58.5	25.7	5.83	30.4	63.8

D: Deficient **M:** Medium **H:** High

Table 6: Nutrient index values and fertility rating of soil available sulphur and micronutrients in different blocks of The Nilgiris District

S. No	Name of the blocks	Sample size	Nutrient Index values					
			S	Fe	Mn	Zn	Cu	B
1	Kothagiri	40	2.55	3.00	2.98	2.00	2.55	1.90
2	Conoor	24	2.63	2.96	2.92	1.29	2.13	1.83
3	Udhagamandalam	68	2.79	3.00	2.91	1.68	1.88	1.97
4	Gudalur	20	2.35	3.00	2.95	1.90	1.90	1.75
	Overall Mean	152	2.58	2.99	2.94	1.72	2.12	1.86
			Soil fertility rating					
1	Kothagiri		High	Very High	Very High	Adequate	High	Marginal
2	Conoor		High	Very High	Very High	Very Low	Adequate	Marginal
3	Udhagamandalam		Very High	Very High	Very High	Marginal	Marginal	Marginal
4	Gudalur		High	Very High	Very High	Marginal	Marginal	Marginal
	Overall Mean		High	Very High	Very High	Marginal	Adequate	Marginal

Very high: >2.67 High: 2.33-2.67 Adequate: 2.00-2.33 Marginal: 1.67-2.00 Low: 1.33-1.67 Very low: <1.33

Conclusion

Soil resource inventory made in The Nilgiris district showed that Zn was highly deficient in the soils (55.4%) followed by Cu (21.8%) and B (15.8%). None of the soil collected from the district showed deficient status of Fe and Mn but sulphur deficiency was noticed to an extent of 5.83 %. The soils were marginal in Zn and B, adequate in Cu and high to very high in Fe, Mn and S availability. Among the four blocks, Udhagamandalam and Gudalur blocks were having marginal soil fertility of Zn, B and Cu which needs attention. Hence prioritization of Zn fertilization in all the blocks of the district followed by Cu and B fertilization in the specific blocks is essential to enhance the crop yield and to sustain the soil fertility by avoiding the yield loss due to nutritional deficiency. Further lime application may be recommended to the acid soils all the blocks to neutralize the acidity so as to improve the applied fertilizer nutrient use efficiency.

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