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RESEARCH ARTICLE

Soil Suitability Assessment for Intercropping Cocoa in Coconut Gardens of Tamil Nadu

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ABSTRACT

Geo-referenced soil samples were collected from forty cocoa-growing locations across six districts (Coimbatore, Dindigul, Erode, Namakkal, Salem and Tirunuelveli) of Tamil Nadu. Analysis of data revealed that a vast majority of the samples were alkaline (83 %), non-saline, low in organic carbon (51.3 %), low in $KMnO_4$-N (75 %), medium in available phosphorus (60 %) and medium in available potassium (51.25 %). The soils were predominantly deficient in DTPA Zn (71.25 %) and DTPA Cu (32.5 %) in the sampling locations. About 20 % of the cocoa-growing locations were calcareous. The correlation between free $CaCO_3$ content of soil and pod yield revealed that cocoa productivity is drastically affected if the free $CaCO_3$ content of soil is more than 8.0%. Soil suitability assessment is highly imperative before undertaking cocoa intercropping in coconut gardens of Tamil Nadu.

Key words: *Calcareousness; Cocoa; Coconut; Intercropping; Pod yield; Soil Fertility*

INTRODUCTION

Coconut is an important horticultural crop that exerts a profound influence on the rural economy of the state of Tamil Nadu. It spreads over an area of 4.36 lakh ha with a total production of 5370 million nuts and productivity of 12291 nuts per ha (CDB, 2019). Despite its importance and expanding acreage, the crop turned out to succumb to an array of biotic and abiotic stresses, including rampant pest and disease attack and fluctuating price chart of copra (Maheswarappa *et al*., 2003). Monocropping of coconut is no longer viable and hence crop intensification is the way forward to transform coconut farming into a viable enterprise to tide over the challenges. Cocoa, nutmeg and banana are widely intercropped with coconut in Tamil Nadu owing to the favorable micro climate. Although cocoa was introduced in India during the early 20th century (Jaganathan *et al*., 2015), large-scale cultivation started in the late 1980s in Tamil Nadu. The acreage under this crop extends over 29,205 ha in the state (DCCD, 2018), which has been dwindling in the recent past because of an array of cultural and socio-economic factors thus widening the gap between demand and supply of cocoa. The global cocoa demand is on the rise and considering the diminishing income of cocoa farmers, increasing cocoa productivity is highly imperative. Potential cocoa yields are determined based on location and crop-specific characteristics such as climate and crop's natural life cycle (Van Vliet *et al.,* 2015). Soil suitability and soil fertility are highly imperative for improving the productivity of cocoa in the coconut intercropping system.

MATERIAL AND METHODS

A survey was conducted during 2017 in forty major cocoa growing locations distributed across six districts (Coimbatore, Dindigul, Erode, Namakkal, Salem and Tirunelveli) in Tamil Nadu (Table 1) based on multi-stage stratified sampling method. Details pertinent to the variety of cocoa, age of the plant/ coconut palm, irrigation, nutrient management, plant protection, harvesting, processing, marketing etc., were collected for both coconut and cocoa employing a survey questionnaire. Eighty geo-referenced soil samples were collected from cocoa gardens at 0 – 30 cm depth. Air-dried samples passed through 2 mm sieve were utilized for the determination of pH in 1:2.5 soil water suspension (Jackson, 1973). Available nitrogen (N) was estimated by alkaline permanganametry (Subbiah and Asija, 1956), available phosphorus (P) (Olsen *et al*., 1954; Bray and Kurtz, 1945), available potassium (K) by Flame Photometry (Stanford and English, 1976), organic carbon (OC) by wet digestion method (Walkley and Black, 1934), free $CaCO_3$ (Dewis and Freita, 1970), DTPA extractable micronutrients by Atomic Absorption Spectrophotometry (Lindsay and Norvell, 1978) and hot water-soluble boron by Azomethin – H reagent method (Berger and Truog, 1939).

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The nutrients were classified as low, medium and high categories for macronutrients and deficient, sufficient for micronutrients based on their soil fertility classification. Nutrient Index Values (NIV) were calculated by employing the procedure of Ramamoorthy and Bajaj, 1969. The index values were rated into various categories *viz.,* low (<1.67), medium (1.67-2.33) and high (>2.33) for OC and available NPK.

$$\text{Nutrient Index Value} = \frac{\text{(No. of samples in low category x 1) + (No. of samples in medium category x 2) + (No. of samples in high category)}}{\text{Total number of samples}}$$

RESULTS AND DISCUSSION

Soil Reaction, Electrical Conductivity and Organic Carbon

The pH of the soil samples ranged from 6.09 to 8.54, with a mean value of 7.28 across different sampling locations. About 6.25 % of the samples were acidic in reaction whilst 78.75 % of the samples remained alkaline and only 15 % fell in the neutral range. All the samples were non saline in nature. About 83 % of soils in Pollachi taluk, Coimbatore district are alkaline and pencil point syndrome is one of the alarming disorders as pointed out by Sudhalakshmi *et al* (2020). Selvamani and Duraisami (2014) reported that the pH ranged from 6.6 to 8.8 at 0 - 30 cm depth in coconut growing soils of Coimbatore and Tiruppur districts. In the present survey, only localized spots of acidity was witnessed and almost all the horizons were alkaline with kankar nodules.

Organic carbon content was low in 51.3 % of samples and high only in 15 % of samples analyzed. Due to the tropical climate prevailing in Tamil Nadu, there is rapid depletion of soil organic pool, falling in low to medium category. The nutrient index value for organic carbon was in the medium category as per the classification (Tables 1 and 4).

Table 1. Soil Reaction, Electrical Conductivity and Organic Carbon Status of the cocoa-growing soils of Tamil Nadu.

Location No.	Geographic Co-ordinates		pH		Electrical Conductivity (dSm^{-1})		Organic Carbon (%)	
	Location 1 (L_1)	Location 2 (L_2)	L_1	L_2	L_1	L_2	L_1	L_2
Coimbatore District								
1.	10° 31.483 N 76° 58.160 E	10° 31.507 N 76° 58.147 E	7.48	7.46	0.10	0.10	0.54	0.34
2.	10° 29.824 N 76° 55.517 E	10° 29.825 N 76° 55.519 E	7.43	7.72	0.21	0.16	0.45	0.54
3.	10° 29.483 N 76° 54.222 E	10° 29.482 N 76° 54.228 E	6.10	6.58	0.22	0.17	0.99	0.57
4.	10° 29.276 N 76° 54.205 E	10° 29.250 N 76° 54.194 E	6.29	6.09	0.50	0.65	1.28	0.87
5.	10° 29.251 N 76° 54.194 E	10° 29.598 N 76° 53.400 E	7.03	7.24	0.10	0.05	0.54	0.33
6.	10° 29.594 N 76° 53.405 E	10° 29.798 N 76° 52.877 E	6.55	7.20	0.09	0.06	0.18	0.29
7.	10° 29.796 N 76° 52.883 E	10° 32.928 N 76° 54.625 E	7.23	7.21	0.22	0.22	1.52	1.08
8.	10° 38.008 N 76° 53.378 E	10° 38.008 N 76° 53.372 E	8.06	7.78	0.09	0.16	0.57	0.36
9.	10° 37.298 N 76° 52.913 E	10° 37.298 N 76° 52.913 E	7.35	7.75	0.31	0.19	0.79	1.08
10.	10° 36.903 N 76° 52.651 E	10° 36.903 N 76° 52.651 E	6.97	7.04	0.13	0.11	0.99	0.87
11.	10° 38.108 N 76° 53.079 E	10° 38.102 N 76° 53.065 E	7.85	7.75	0.23	0.22	1.08	0.70
12.	10° 37.375 N 76° 56.192 E	10° 37.375 N 76° 56.192 E	7.71	7.68	0.19	0.23	0.90	1.55
13.	10° 38.642 N 76° 57.982 E	10° 38.634 N 76° 57.984 E	7.71	7.88	0.15	0.15	0.24	0.36
14.	10° 39.289 N 76° 53.168 E	10° 39.298 N 76° 53.186 E	6.71	6.72	0.11	0.11	0.54	0.27
15.	10° 38.477 N 76° 52.910 E	10° 38.477 N 76° 52.910 E	6.84	7.00	6.84	0.72	0.27	0.36

16.	10° 36.495 N 76° 56.216 E	10° 36.495 N 76° 56.216 E	7.23	7.31	0.13	0.11	0.51	0.30
Dindigul District								
17.	10° 24.698 N 77° 32.141 E	10° 24.698 N 77° 32.141 E	7.91	7.43	0.14	0.24	0.48	0.33
18.	10° 24.634 N 77° 32.168 E	10° 24.634 N 77° 32.168 E	7.73	7.59	0.14	0.24	0.33	0.24
19.	10° 22.609 N 77° 31.252 E	10° 22.609 N 77° 31.252 E	7.65	7.70	0.18	0.19	0.36	0.27
20.	10 ° 23.575 N 77 ° 32.373 E	10 ° 23.575 N 77 ° 32.373 E	7.74	7.62	0.19	0.26	0.66	0.31
21.	10 ° 24.698 N 77 ° 32.141 E	10 ° 24.698 N 77 ° 32.141 E	7.59	7.63	0.17	0.19	0.91	0.15
22.	10 ° 23.466 N 77 ° 29.177 E	10 ° 23.466 N 77 ° 29.177 E	7.45	7.90	0.13	0.17	0.13	0.11
23.	10 ° 24.249 N 77 ° 32.505 E	10 ° 24.249 N 77 ° 32.505 E	7.95	7.83	0.12	0.14	0.33	0.29
Tirunelveli District								
24.	9° 074.930 N 77 ° 37 E	9° 074.930 N 77 ° 37 E	7.80	7.80	0.43	0.47	0.31	0.24
25.	9° 005.280 N 77° 26528 E	9° 005.280 N 77° 26528 E	8.45	8.40	0.58	0.50	0.46	0.40
Erode District								
26.	11° 80.675 N 77° 37.524 E	11° 18.685 N 77° 37.525 E	8.24	8.21	0.47	0.48	1.08	1.55
27.	11° 18.427 N 77° 37.308 E	11° 18.433 N 77° 37.299 E	8.35	8.16	0.50	0.40	0.49	1.41
28.	11° 15.180 N 77 ° 43.596 E	11° 15.175 N 77° 43.614 E	8.05	8.39	0.71	0.35	1.24	0.23
29.	11° 15.325 N 77° 43.728 E	11° 15.316 N 77° 43.720 E	8.19	8.04	0.25	0.45	1.13	1.10
30.	11° 15.000 N 77 ° 44.302 E	11° 15.005 N 77° 44.301 E	7.80	8.15	0.54	0.40	1.48	1.41
Namakkal District								
31.	10° 29.291 N 76 ° 58.254 E	11° 18.668 N 78° 17.778 E	8.12	8.16	0.31	0.45	0.33	0.49
32.	11° 18.640 N 78° 17.837 E	11° 18.662 N 78° 17.927 E	8.34	8.42	0.28	0.36	0.29	0.33
33.	11° 38.631 N 78° 17.968 E	11° 38.627 N 78° 17.982 E	8.14	8.32	0.14	0.28	0.36	0.54
34.	11° 18.733 N 78° 17.542 E	11° 18.730 N 78° 17.540 E	8.22	7.86	0.26	0.51	0.26	0.48
35.	11° 18.680 N 78° 17.609 E	11° 18.674 N 78° 17.608 E	7.98	7.64	0.54	0.47	0.49	0.40
Salem District								
36.	11° 45.429 N 77° 48.013 E	11° 45.420 N 77° 48.008 E	8.24	8.32	0.34	0.27	0.52	1.73
37.	11° 45.868 N 77° 49.547 E	11° 45.838 N 77° 49.507 E	8.41	7.96	0.19	0.23	0.96	1.13
38.	11° 39.812 N 77° 47.073 E	11° 39.812 N 77° 47.066 E	8.54	7.92	0.20	0.49	0.31	0.63
39.	11° 36.372 N 77° 47.740 E	11° 36.370 N 77° 44.747 E	8.18	7.90	0.12	0.16	0.52	0.21
40.	11° 31.939 N 77° 45.075 E	11° 31.945 N 77° 45.074 E	8.50	8.13	0.22	0.31	1.13	1.22

Available macronutrients

The $KMnO_4$ N content ranged from 137 to 1140 kg ha^{-1} with a mean value of 258 kg ha^{-1}. Trend analysis revealed that the content was low (< 280 kg ha^{-1}) in 75 % of the samples tested, medium in 23.75 % of the samples and high (> 450 kg ha^{-1}) in only one sample. Olsen P was low (< 11 kg ha^{-1}) in 10 % of the samples, medium in 60 % of the samples and high (> 22 kg ha^{-1}) in 30 % of the samples analyzed. $1NNH_4OAc$ – K was low (< 118 kg ha^{-1}) in 7.5 % of samples, medium in 51.25 % of samples and high (> 280 kg ha^{-1}) in 41.25 % of samples. About 20 % of the samples were calcareous and 80 % were non-calcareous. Rao and Batra (1983) established a positive correlation between pH and ammonia volatilization. In the present study, alkalinity was observed in 78.75% of soil samples; hence the low status of available nitrogen (60 %) was noticed. The available P content ranged from 7.0 to 90.0 kg ha^{-1} with an average of 22.7 kg ha^{-1}. About 48 % of the samples fell in the medium category, 30 % in high status and only 10 % of samples were low in available phosphorus. In an earlier survey of coconut growing soils of Coimbatore and Tiruppur districts, Selvamani and Duraisami (2014) reported low status of available phosphorus in 0.76 per cent in coconut growing soils of Coimbatore and Tiruppur districts.

Table 2. $KMnO_4$ – N, Olsen P, $1NNH_4OAc$ – K and free $CaCO_3$ of the cocoa-growing soils of Tamil Nadu.

Location No.	$KMnO_4$ – N (kg ha^{-1})		Olsen P (kg ha^{-1})		$1NNH_4OAc$ – K (kg ha^{-1})		Free $CaCO_3$ (%)	
	L_1	L_2	L_1	L_2	L_1	L_2	L_1	L_2
Coimbatore District								
1.	244	244	35	57	108	109	3.00	2.88
2.	230	213	25	61	186	197	2.38	0.88
3.	291	314	54	21	408	148	0.75	0.81
4.	269	1140	82	90	750	1092	1.38	1.31
5.	196	190	29	24	227	132	1.75	0.31
6.	224	193	63	25	369	113	0.25	0.44
7.	294	258	31	20	276	328	1.19	1.56
8.	185	244	61	31	118	160	2.31	1.63
9.	347	280	28	20	555	299	1.56	2.38
10.	428	406	24	17	253	290	2.69	3.19
11.	286	339	20	28	368	360	5.38	5.88
12.	263	333	16	28	229	364	5.63	1.31
13.	224	238	12	18	274	188	2.00	2.69
14.	294	188	14	15	178	180	0.25	1.88
15.	188	137	15	13.2	180	196	1.88	0.25
16.	260	199	18.2	15	100	114	2.19	1.73
Dindigul District								
17.	252	255	20	26	853	266	2.88	2.25
18.	249	207	15	15	316	336	3.19	2.00
19.	173	272	20	14	138	151	2.56	1.31
20.	137	258	17	38	151	170	2.69	2.44
21.	258	244	15	21	291	298	1.88	1.88
22.	241	283	14	15	224	255	0.25	1.00
23.	218	224	16	15.2	474	168	0.88	1.19
Tirunelveli District								
24.	330	302	20	14	617	241	1.81	0.44
25.	288	353	17	42	225	637	8.20	8.75

Erode District								
26.	263	308	15	16	419	445	8.75	9.00
27.	260	277	21	27	480	573	8.20	8.75
28.	232	202	16	15	423	405	3.31	7.64
29.	260	344	15	53	346	911	3.44	6.85
30.	319	227	26	15	535	320	2.88	3.94
Namakkal District								
31.	198	224	11	16	118	154	3.12	1.14
32.	137	154	16	13	126	138	2.26	2.74
33.	156	241	12	18	144	212	1.88	1.14
34.	188	196	12	10.8	242	164	2.56	2.69
35.	224	218	9.8	11.1	241	229	2.31	1.63
Salem District								
36.	241	246	9.8	10.2	823	791	4.25	3.25
37.	244	258	12	7	173	239	2.19	7.81
38.	216	263	9	14	565	738	7.94	8.00
39.	213	185	9	12	142	120	0.94	0.63
40.	216	249	11.4	10.8	110	124	7.50	7.13

The available potassium content ranged from 100 to 1092 kg ha^{-1} with an average of 313.9 kg ha^{-1}. About 51.25 % of samples fell in the medium-fertility category (118 – 280 kg ha^{-1}) and 41.25 % of the samples were under high fertility status. Motsara (2002) reported that 36 % of the soils of Tamil Nadu fall under the medium category and 52 % under the high status of available potassium. About 20 % of the cocoa soils were calcareous in nature with free $CaCO_3$ content > 5 % and 80 % ranged from 1 – 5 %. Nutrient index values were 1.23 (low) for nitrogen, 2.2 (medium) for phosphorus and 2.33 (medium) for potassium (Tables 2 and 4). Index values of nitrogen, phosphorus and potassium were reported as low, medium and medium for the soils of Salem district of Tamil Nadu (Maragatham *et al.,* 2014).

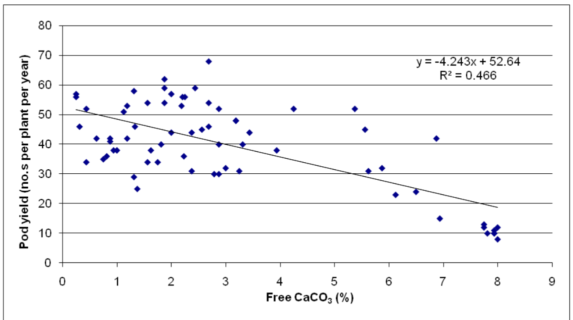

Fig. 1. Correlation between free $CaCO_3$ and pod yield of cocoa

Available micronutrients

The content of DTPA Fe ranged from 2.40 to 44.6 mg kg^{-1} with a mean value of 7.28 mg kg^{-1}. DTPA Fe was sufficient in 83 % of the soil samples and the rest of the samples were deficient. The DTPA Mn content ranged from 1.40 to 17.2 mg kg^{-1} with a mean value of 7.30 mg kg^{-1}. The nutrient was sufficient (> 2.0 mg kg^{-1}) in 92.5 % of soil samples and the deficiency (< 2.0 mg kg^{-1}) was witnessed only in 7.5 % of samples. The content of DTPA Zn ranged from 0.13 to 9.45 mg kg^{-1} with a mean value of 1.50 mg kg^{-1}. DTPA Zn was deficient (< 1.2 mg kg^{-1}) in 71.25 % of samples and sufficiency (> 1.2 mg kg^{-1}) was noticed across 28.75 % of the samples. The content of DTPA Cu in cocoa-growing soils ranged from 0.33 to 4.72 mg kg^{-1} with a mean value of 1.50 mg kg^{-1}. DTPA Cu deficiency (< 1.2 mg kg^{-1}) was noticed in 32.5% of the samples and sufficient (> 1.2 mg kg^{-1}) across 67.5% of the sampling locations. Hot water soluble boron content ranged from 0.75 to 8.52 mg kg^{-1} with a mean value of 2.24 mg kg^{-1} and was sufficient (> 0.46 mg kg^{-1}) in all the sampling locations (Tables 3 and 4).

Correlation between free $CaCO_3$ and pod yield

A correlation was established between free $CaCO_3$ content of soil and cocoa pod yield (Fig. 1). The pod yield ranged from 8 to 68 pods per plant per year across the cocoa growing locations surveyed. It is highly conspicuous that, of diverse soil fertility parameters, a prominent negative correlation exists between free $CaCO_3$ content of soil and pod yield of cocoa (Fig. 1). As free $CaCO_3$ content of soil increased above 7 %, there was a drastic decline in productivity and as it crossed 8.0 %, even the very establishment of cocoa plants was difficult.

Table 3. DTPA Fe, DTPA Mn, DTPA Zn, DTPA Cu and HWS -B of the cocoa-growing soils of Tamil Nadu.

Location No.	DTPA Fe		DTPA Mn		DTPA Zn		DTPA Cu		HWS B	
	(mg kg^{-1})									
	L_1	L_2	L_1	L_2	L_1	L_2	L_1	L_2	L_1	L_2
Coimbatore District										
1.	6.2	7.1	6.5	9.7	0.45	0.61	1.07	2.98	3.33	2.47
2.	9.1	7.4	10.4	9.0	0.44	0.37	1.60	1.31	1.98	2.06
3.	28.0	22.0	13.8	12.0	0.76	0.70	1.06	0.85	8.52	3.93
4.	27.4	44.6	7.2	7.3	3.63	5.05	1.91	1.79	2.56	3.33
5.	13.7	5.4	17.2	6.4	2.13	0.76	0.87	0.63	1.49	1.49
6.	15.2	13.1	10.9	9.2	1.05	1.50	1.32	1.24	2.31	1.73
7.	9.1	11.1	11.3	12.8	3.43	1.97	1.57	1.63	3.12	1.66
8.	5.8	4.6	8.8	4.6	0.61	1.01	0.72	0.84	1.65	2.13
9.	7.1	5.5	2.7	2.7	1.24	2.03	1.18	1.19	2.34	1.33
10.	8.9	5.6	4.9	7.7	1.00	0.66	1.39	1.16	2.95	1.07
11.	10.1	6.6	7.7	11.8	2.49	4.78	3.13	4.72	6.43	1.08
12.	6.9	5.4	9.9	13.2	1.40	1.68	1.97	1.77	4.29	6.74
13.	4.7	11.3	11.2	8.7	1.59	1.05	1.26	1.07	3.37	4.87
14.	2.4	4.9	2.6	10.3	0.18	0.59	0.41	1.46	0.75	0.85
15.	4.9	6.7	10.3	9.5	0.59	0.13	1.46	0.33	0.85	1.31
16.	7.2	5.3	6.3	8.4	1.10	0.65	1.13	1.11	2.40	1.54
Dindigul District										
17.	4.8	5.9	10.5	9.3	1.53	0.71	1.34	1.46	4.34	1.91
18.	4.8	6.4	7.9	6.2	0.56	0.41	1.38	1.41	2.40	2.29
19.	5.9	5.5	10.3	9.4	1.49	2.01	2.19	1.96	1.89	1.81
20.	7.2	6.8	7.8	6.8	0.85	0.58	2.08	1.79	1.65	1.00
21.	6.9	8.0	9.2	6.7	0.50	0.87	1.49	1.63	2.41	1.31
22.	5.3	3.8	8.8	8.2	0.42	0.47	1.52	1.37	1.24	1.16
23.	3.4	3.8	5.5	7.8	0.31	0.35	0.87	0.82	1.00	1.24
Tirunelveli District										
24.	3.9	4.6	14.5	10.6	1.57	0.47	1.69	1.69	2.17	2.01
25.	6.0	7.0	7.7	4.2	0.26	0.94	1.12	1.04	2.41	3.14
Erode District										
26.	4.7	4.5	9.3	6.8	1.31	0.92	1.38	1.57	2.16	1.31
27.	3.9	4.4	6.4	9.1	1.21	1.13	1.37	1.34	1.39	1.31
28.	4.2	4.5	6.7	6.7	1.00	0.79	1.68	1.80	1.62	1.77
29.	3.6	7.5	6.4	6.3	0.79	1.17	1.06	1.54	2.33	3.21
30.	6.1	4.5	11.6	7.6	9.45	8.73	1.76	1.66	4.22	1.62
Namakkal District										
31.	6.0	5.8	6.7	5.5	0.74	0.56	1.64	1.86	1.16	1.67
32.	8.2	7.8	6.6	6.8	0.78	0.83	1.87	1.98	1.31	1.94
33.	6.4	6.2	3.2	2.3	0.80	0.94	2.32	1.88	2.01	2.16
34.	3.6	4.2	2.1	2.5	0.68	0.72	1.52	2.08	1.24	1.16
35.	4.2	4.8	7.7	5.4	1.14	1.26	1.97	1.77	1.98	1.33
Salem District										
36.	3.6	4.4	2.1	2.5	1.87	2.55	1.81	2.59	2.01	2.33
37.	3.9	4.8	2.3	2.2	0.62	0.44	0.91	1.48	2.72	2.16
38.	3.9	5.0	2.1	1.9	0.24	0.28	0.77	0.76	3.76	1.94
39.	4.2	4.9	1.8	2.1	0.81	0.90	1.26	0.92	1.24	1.39
40.	3.8	5.1	1.4	1.5	0.72	1.82	0.98	1.38	1.93	1.16

A plethora of evidence states that carbonate activity in calcareous soils influences the rate of volatilization of ammonia (Ryan *et al*., 1981) and that carbonate affects the rhizospheric processes, especially in acidification factor. The presence of $CaCO_3$ directly or indirectly affects the chemistry and availability of nitrogen, phosphorus, iron, zinc, magnesium, calcium, potassium and copper (Marschner, 1995) through ammonia volatilization and phosphorus precipitation. In addition, iron, zinc and magnesium deficiencies are common in soils with high $CaCO_3$ and alkaline pH values (Marschner, 1995). Hillel (1986) recorded that emergence of bean seedlings in fine sandy loam soil was reduced from 100 to 0% when crust strength increased from 108 to 273 mbar because of calcareousness. The growers of cocoa commonly noticed Lime- induced iron chlorosis in calcareous soils. On foliar spraying with micronutrients, the plants reverted back to normalcy only for a brief period of time and again they turned chlorotic. In intensely calcareous soils, there was problem even with the very establishment of cocoa seedlings and it was more conspicuous in Erode and Salem districts of Tamil Nadu. Thus it can be concluded that cocoa cultivation is not remunerative if free $CaCO_3$ content in the soil is > 8 %.

Table 4. Nutrient Index Values of macro nutrients in the cocoa-growing soils of Tamil Nadu

S. No.	Parameter	Minimum value	Maximum value	Mean value	Standard Deviation	Nutrient Index
1.	pH	6.09	8.54	7.70	0.57	-
2.	EC (dSm^{-1})	0.05	6.84	0.352	0.751	-
3.	Organic carbon (%)	0.11	1.73	0.65	0.42	1.88
4.	$KMnO_4$ N (kg ha^{-1})	137	1140	258	115	1.23
5.	Olsen P (kg ha^{-1})	7.0	90.0	22.7	16.3	2.20
6.	1NNH_4OAc K (kg ha^{-1})	100	1092	313.9	215.5	2.33
7.	Free $CaCO_3$ (%)	0.25	9.00	3.04	2.50	-
8.	DTPA Fe (mg kg^{-1})	2.40	44.6	7.28	6.15	-
9.	DTPA Mn (mg kg^{-1})	1.40	17.2	7.30	3.48	-
10.	DTPA Zn (mg kg^{-1})	0.13	9.45	1.31	1.55	-
11.	DTPA Cu (mg kg^{-1})	0.33	4.72	1.50	0.62	-
12.	Hot water soluble B (mg kg^{-1})	0.75	8.52	2.24	1.34	-

CONCLUSION

From the survey conducted across six prominent cocoa growing districts of Tamil Nadu, it was found that about 78.75 % of the soils were alkaline in reaction and the electrical conductivity was non-saline across the sampling locations. The low status of $KMnO_4$-N, Olsen P and 1NNH_4OAc-K was witnessed in 75%, 10 % and 7.5 % of the sampling locations respectively. About 20 % of the cocoa-growing locations surveyed were calcareous in nature with free $CaCO_3$ content > 5 %. DTPA Fe was deficient across 17 %, DTPA Mn across 7.5 %, DTPA Zn over 71.2 % and DTPA Cu in 32.5 % of the sampling locations. Hot water soluble boron was sufficient all through the sampling locations. The correlation between free $CaCO_3$ and pod yield was negative. Pod yield is drastically affected to the tune of <10 pods per plant per year in intensely calcareous soils. Thus the survey revealed that intercropping of cocoa is not remunerative if free $CaCO_3$ content in the soil is > 8.0 %. Soil testing and crop suitability assessment are imperative for undertaking intercropping of cocoa in coconut gardens of Tamil Nadu to avoid huge economic losses by cultivating in unsuitable soils.

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