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EVALUATION OF NUTRIENT CONTENT IN SOILS AND TEA LEAVES OF THE LALMONIRHAT DISTRICT

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Abstract

Soil samples from 20 tea gardens of Lalmonirhat district were analysed for physical and chemical properties. The soil texture was mostly loam, while some samples were sandy loam, having 34.59-68.09% sand. Topsoils (0-15 cm depth) were acidic with pH 4.07-6.05, soil organic matter from 0.86-2.00%, and CEC from 3.00-19.00 cmol/kg. The corresponding values for subsoils (15-30 cm depth) were 4.27-5.97, 0.74-1.76% and 8.00-16.40 cmol/kg, respectively. Regarding the nutrient status of soils, the N content ranged from 0.004-0.020%, and available P from 2.99-25.72 mg/kg, K from 0.19-1.70 mg/kg, and S from 13.01-19.85 mg/kg. These values for subsoils were 0.007-0.019%, 1.19-23.57 mg/kg, 2.42-45.62 mg/kg, and 12.78-17.12 mg/kg, respectively. Tea leaves contained 2.63-4.99% N (16.41-31.17% protein), 0.16-0.67% P, 0.16-1.70% K, 0.16-0.33% S, 52.13-108.63 mg/kg Zn, and 187.32-470.07 mg/kg Fe. These results will help to determine the fertilizer requirements for tea gardens in the Lalmonirhat soils.

Introduction

Tea (*Camellia sinensis* L.) is the world's most popular non-alcoholic beverage. The origin of tea is rooted in East Asia, with native plants found in countries like Japan, China, Myanmar, and India. It is packed with mineral elements, sugars, amino acids, organic acids, and flavonoids (He *et al.* 2020), which offer various health benefits to consumers.

Tea is mainly an agro-based, export-oriented evergreen crop in Bangladesh. It is a perennial plant cultivated as a monoculture across extensive, contiguous areas (Ahmad and Hossain 2013). The country is gradually losing its export market because of the growing domestic demand for tea. To expand its export market, Bangladesh needs to boost tea production by increasing the land area dedicated to tea cultivation.

Tea productivity in the northern Bangladesh is closely linked to soil fertility. Tea is grown in three distinct ecological regions: Surma Valley in Greater Sylhet, Halda Valley in Chittagong, and Karatoa Valley in the Panchagarh district. Notably, almost all of the tea-suitable areas in greater Sylhet and Greater Chittagong have been fully utilized for tea cultivation (Rahman *et al*. 2018). The Bangladesh Tea Board has initiated smallholder tea cultivation in Lalmonirhat District, located 150 km from Panchagarh, and has set up several tea gardens since 2007. By utilizing the available flat cultivable land in Lalmonirhat, scope exists to increase tea production and meet the country's domestic demand.

This study aims to evaluate the physical and chemical properties of soils and tea leaves of Lalmonirhat district. The results will help to determine fertilizer requirements, improve tea leaf quality, and increase tea production.

Materials and Methods

The Lalmonirhat district is located in northern Bangladesh within the Rangpur division (Fig. 1). It lies within Agro-Ecological Zone (AEZ) 2 - the Active Teesta Floodplain. The climate features annual temperatures of 9.3-36.5°C, humidity of 45-97%, and rainfall of 2,547-2,931 mm (BAMIS 2023).

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Farmers in Lalmonirhat grow fast-maturing Indian tea varieties. Soil testing is essential to optimize fertilizer use and achieve better tea productivity. Samples were collected from 20 small tea gardens (5-15 years old) across four upazilas (Lalmonirhat Sadar, Aditmari, Kaliganj, and Hatibandha). In each garden, a 10 m × 10 m area was sampled using a composite of five subsamples (0-15 cm and 15-30 cm depths). The samples were air-dried, sieved, and prepared for analysis. Plant samples were gently washed with water, oven-dried (70-80°C), and ground for storage.

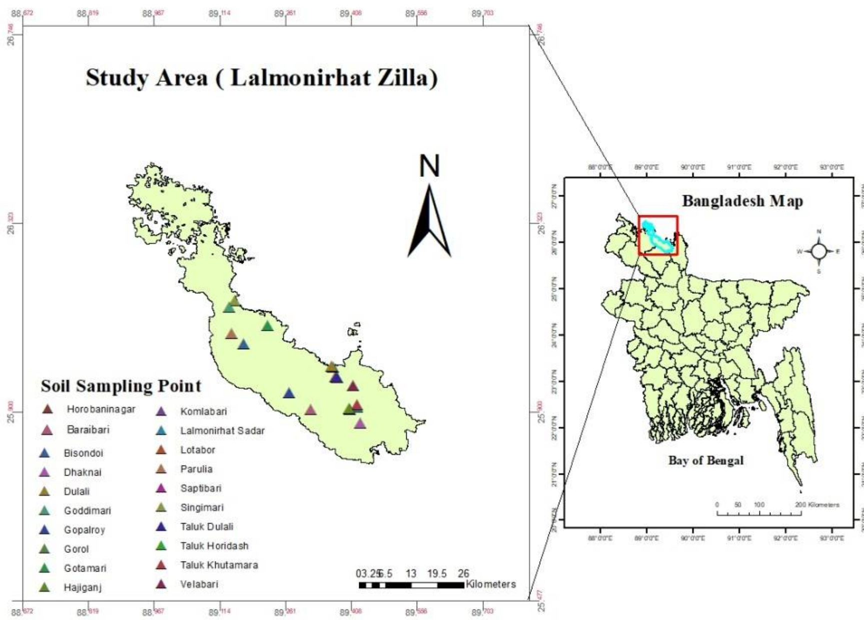

Fig. 1. Map of study area.

Particle size analysis was performed using the hydrometer method, and soil textural classes were identified by Marshall's textural triangle. Other parameters, such as soil pH (Jackson 1973), cation exchange capacity (CEC) (Black 1965), and organic carbon (Walkley and Black 1934) were measured; organic matter content was calculated by multiplying % OC by 1.724 (Van-Bemmelen factor).

Nitrogen was determined by Micro-Kjeldahl distillation (Huq and Alam 2005), phosphorus by Bray-Kurtz method (pH < 7.0), sulphur by using a Tween 80 stabilizer after extraction with Morgan's extractant (0.7N sodium acetate + 0.54N acetic acid at pH 4.8), and exchangeable potassium by 1N ammonium acetate (pH 7) extraction method. Total N in both soil and plant samples was determined using the Micro-Kjeldahl method. Experimental data were analysed using Minitab 21 and Microsoft Excel. Descriptive statistics and Pearson correlation were conducted with Minitab 21, considering relationships significant at $p < 0.05$.

Results and Discussion

Soil textural classes of the tested samples are presented in Table 1. The tea soils were loam (13 samples) and sandy loam (7 samples), having the mean compositions: sand (48.13%) > silt (34.24%) > clay (17.63%). The tea crop prefers a sandy loam texture as it allows water to drain through the soil column, since stagnant water is harmful to tea cultivation.

Table 1. Soil physical properties of Lalmonirhat District.

Sample ID	Location Name	Latitude	Longitude	Sand %	Silt %	Clay %	Textural class
S-1	Lalmonirhat Sadar	25° 54' 35.946" N	89° 25' 22.548" E	68.09	17.59	14.32	Sandy Loam
S-2	Taluk Khutamara	25° 54' 54" N	89° 25' 19" E	43.31	36.58	20.11	Loam
S-3	Dhaknai	25° 52' 29" N	89° 25' 48" E	52.44	30.52	17.04	Sandy Loam
S-4	Baraibari	25° 54' 17.4312" N	89° 19' 7.464" E	45.21	37.87	16.92	Loam
S-5	Komlabari	25° 58' 42.4308" N	89° 22' 28.6284" E	55.44	30.21	14.35	Sandy Loam
S-6	Saptibari	25° 54' 19" N	89° 24' 19" E	45.48	37.69	16.83	Loam
S-7	Hajiganj	25° 54' 22" N	89° 24' 16" E	35.42	45.23	19.35	Loam
S-8	Velabari	25° 57' 29.5272" N	89° 24' 48.3192" E	48.24	35.01	16.75	Loam
S-9	Taluk Horidash	25° 58' 36.3468" N	89° 22' 37.6356" E	50.55	35.14	14.31	Loam
S-10	Taluk Dulali	25° 58' 36" N	89° 22' 38" E	55.73	30.01	14.26	Sandy Loam
S-11	Lotabor	25° 1' 44.9112" N	89° 16' 10.668" E	63.07	25.12	11.81	Sandy Loam
S-12	Gopalroy	25° 56' 35.0592" N	89° 16' 12.5112" E	45.72	34.86	19.42	Loam
S-13	Gorol	26° 0' 1.9152" N	89° 22' 9.3216" E	39.67	40.63	19.67	Loam
S-14	Dulali	26° 0' 5.7348" N	89° 21' 52.9776" E	35.98	39.73	24.29	Loam
S-15	Horobaninagar	26° 57' 4.7448" N	89° 15' 15.6348" E	34.59	45.76	19.65	Loam
S-16	Bisondoi	26° 3' 5.8608" N	89° 10' 5.7576" E	41.16	37.12	21.72	Loam
S-17	Parulia	26° 4' 30.9036" N	89° 8' 25.6488" E	38.51	44.79	16.70	Loam
S-18	Singimari	26° 8' 52.1988" N	89° 8' 51.3816" E	41.34	39.53	19.13	Loam
S-19	Gotamari	26° 5' 35.7144" N	89° 13' 16.8672" E	56.27	24.52	19.21	Sandy Loam
S-20	Goddimari	26° 8' 4.9848" N	89° 8' 7.8288" E	66.42	16.91	16.67	Sandy Loam
Min	-	-	-	34.59	16.91	11.81	-
Max	-	-	-	68.09	45.76	24.29	-
Mean	-	-	-	48.13	34.24	17.63	-
SD	-	-	-	10.14	8.30	2.98	-

Table 2. Soil chemical properties of Lalmonirhat District.

Sample ID	pH		CEC (cmol/kg)		OM (%)	
	Topsoil	Subsoil	Topsoil	Subsoil	Topsoil	Subsoil
S-1	5.05	5.11	9.80	8.20	1.57	0.99
S-2	5.02	5.04	3.00	8.00	1.82	0.80
S-3	5.23	5.46	13.20	14.42	1.51	1.36
S-4	5.44	5.76	11.30	9.40	1.33	0.74
S-5	4.07	5.49	15.80	14.20	1.82	0.99
S-6	5.25	5.15	13.80	9.60	1.88	0.74
S-7	4.95	5.04	19.00	11.90	1.41	1.76
S-8	4.87	5.27	10.60	11.70	1.88	1.19
S-9	5.01	5.21	10.20	10.40	1.39	0.99
S-10	5.16	5.15	10.30	11.20	1.51	1.17
S-11	5.02	5.26	9.10	8.70	1.39	0.80
S-12	6.05	5.40	9.20	9.60	1.62	1.41
S-13	5.27	5.27	12.20	10.00	1.09	0.80
S-14	4.64	4.98	8.70	16.40	1.55	1.48
S-15	4.75	4.27	13.00	11.20	2.00	0.74
S-16	5.08	5.54	5.50	11.50	1.83	0.99
S-17	4.64	5.57	6.60	13.40	1.56	0.74
S-18	4.88	5.08	8.00	10.20	1.57	0.98
S-19	5.08	4.92	9.40	13.40	0.97	1.30
S-20	5.65	5.97	6.20	8.70	0.86	1.55
Min	4.07	4.27	3.00	8.00	0.86	0.74
Max	6.05	5.97	19.00	16.40	2.00	1.76
Mean	5.06	5.25	10.25	11.11	1.53	1.08
SD	0.40	0.35	3.68	2.29	0.31	0.31

The results of soil physico-chemical properties at different depths are given in Table 2. The data indicate that the pH levels in both topsoils (0-15 cm) and subsoils (15-30 cm) are acidic, with values ranging from 4.07-6.05 and 4.27-5.97, respectively. The average pH of topsoils and subsoils is 5.06 and 5.25, respectively. The tea crop grows well in acid soils, having a pH range of 5.0-5.6 (Wang *et al.* 2009). The growth of tea plants is gradually arrested when the soil pH exceeds 6.5, and they may die when the pH exceeds 7.0 (Su 2012). The organic matter content varied with an average of 1.53% in topsoil and 1.08% in subsoil. These results conform with Billah *et al.* (2008), who noted a slight deficiency, as highly fertile soils typically contain about 2% organic matter. The soil CEC values ranged from 3-19 cmol/kg in the topsoil and 8.00-16.40 cmol/kg in the subsoil. The average CEC for the topsoils (10.25 cmol/kg) and subsoils (11.11 cmol/kg) was nearly equal.

The nutrient content of tea leaves followed the order N > K > P > S > Fe > Zn (Table 3). Macronutrient levels were compared with standard ranges for tea nutrient levels: nitrogen (N) at 4.0-6.0%, phosphorus (P) at 0.2-0.4%, and potassium (K) at 1.5-2.0% (Wang 2018, Tseng and Lai 2022). In this study, nitrogen levels ranged between 2.63 and 4.99%. Potassium, the second most critical nutrient for tea cultivation, constitutes 1.5-2.0% of the dry matter in tea leaves (Wang 2018). However, the observed potassium content in tea leaves varied between 0.19 and 1.70%, with some samples falling below the critical level of 0.8% (Lin *et al.* 2013) showing insufficiency for maintaining high tea quality. Phosphorus content, ranging from 0.16 to 0.67% in tea leaves, was relatively low. Sulphur content in tea leaves ranges from 0.16 to 0.33%, as reported by Bonheure and Wilson (1992) that plants typically absorb sulfur in the form of sulfate ($SO4^{2-}$), with sulfur content in pluckable tea leaves ranging from 0.08-0.37% on a dry weight basis. The concentrations of micronutrients zinc and iron in tea leaves were found 52.13-108.63 mg/kg and 187.32-470.07 mg/kg, respectively. The protein content of tea leaves ranged from

Table 3. Nutrient and protein concentrations of tea leaves of Lalmonirhat tea gardens.

Sample ID	N (%)	P (%)	K (%)	S (%)	Zn (mg/kg)	Fe (mg/kg)	Protein (%)
S-1	3.29	0.163	0.21	0.162	52.58	359.32	20.53
S-2	4.99	0.499	1.65	0.218	93.51	234.07	31.17
S-3	3.68	0.494	0.67	0.245	70.83	187.32	22.97
S-4	4.46	0.534	1.02	0.236	59.33	215.07	27.89
S-5	3.65	0.660	1.35	0.223	101.63	254.32	22.78
S-6	4.20	0.488	1.16	0.275	59.23	296.32	26.25
S-7	4.99	0.470	0.19	0.192	82.36	212.57	31.17
S-8	4.20	0.470	1.55	0.245	55.28	270.82	26.25
S-9	4.73	0.528	0.90	0.240	81.93	470.07	29.53
S-10	3.60	0.308	1.32	0.248	52.13	292.07	22.50
S-11	4.73	0.488	1.70	0.236	83.06	315.32	29.53
S-12	4.99	0.517	0.84	0.226	77.31	238.32	31.17
S-13	2.63	0.285	0.34	0.201	76.46	458.57	16.41
S-14	3.68	0.296	0.53	0.182	56.06	243.32	22.97
S-15	4.73	0.668	1.50	0.272	87.58	260.32	29.53
S-16	3.68	0.511	1.27	0.267	69.58	277.07	22.97
S-17	4.99	0.610	1.40	0.326	108.63	383.82	31.17
S-18	3.94	0.441	0.75	0.282	65.46	284.82	24.61
S-19	4.46	0.325	0.26	0.192	54.81	251.57	27.89
S-20	3.15	0.343	0.83	0.245	74.01	366.32	19.69
Min	2.63	0.16	0.19	0.16	52.13	187.32	16.41
Max	4.99	0.67	1.70	0.33	108.63	470.07	31.17
Mean	4.14	0.45	0.97	0.24	73.09	293.60	25.85
SD	0.70	0.13	0.49	0.04	16.63	77.80	4.38

Table 4. Available nutrient content of topsoils and subsoils of tea gardens in Lalmonirhat District.

Sample ID	N (%)		P (mg/kg)		K (mg/kg)		S (mg/kg)	
	Topsoil	Subsoil	Topsoil	Subsoil	Topsoil	Subsoil	Topsoil	Subsoil
S-1	0.011	0.007	10.32	9.82	30.60	15.27	19.85	14.15
S-2	0.008	0.019	12.09	10.79	10.82	10.33	17.80	13.69
S-3	0.005	0.010	14.19	13.41	25.16	23.68	14.15	12.78
S-4	0.006	0.011	20.58	12.86	22.20	21.70	16.20	14.38
S-5	0.017	0.009	19.62	10.38	37.03	30.38	14.83	13.01
S-6	0.006	0.007	9.97	7.41	37.24	33.03	15.75	14.83
S-7	0.007	0.015	24.56	23.57	30.11	7.85	14.61	17.12
S-8	0.004	0.008	16.87	11.01	31.26	23.18	15.06	13.69
S-9	0.007	0.009	13.99	12.43	36.03	20.22	15.52	13.92
S-10	0.006	0.007	11.62	10.68	43.95	35.55	17.12	14.38
S-11	0.012	0.010	24.72	17.02	12.31	7.36	15.97	14.15
S-12	0.008	0.008	3.01	1.90	3.40	2.42	13.92	15.06
S-13	0.007	0.007	7.05	1.19	7.36	3.40	13.69	14.15
S-14	0.004	0.015	2.99	1.22	28.64	22.20	13.92	14.15
S-15	0.020	0.014	25.72	14.22	57.31	45.62	14.38	14.83
S-16	0.010	0.011	5.23	1.46	14.78	10.82	13.24	13.69
S-17	0.005	0.011	6.68	5.58	52.47	42.36	14.15	15.06
S-18	0.015	0.012	7.73	5.53	36.32	32.58	14.38	14.83
S-19	0.008	0.013	7.63	5.63	20.71	8.35	13.01	14.15
S-20	0.014	0.007	20.77	13.10	38.51	12.80	13.01	15.75
Min	0.004	0.007	2.99	1.19	3.40	2.42	13.01	12.78
Max	0.020	0.019	25.72	23.57	57.31	45.62	19.85	17.12
Mean	0.009	0.011	13.27	9.44	28.72	20.46	15.03	14.39
SD	0.004	0.003	7.33	5.97	14.85	12.86	1.72	0.95

16.41 -31.17%. The available nutrient contents (N, P, K and S) of topsoils and subsoils are presented in Table 4, showing generally low N and variable P and K availability across the tea gardens.

Table 5 presents the combined Pearson correlation analysis of soil available nutrients (N, P, K, S) and physico-chemical properties (pH, OM, CEC). The analysis reveals that pH is negatively correlated with OM (r = -0.39), CEC (r = -0.21), N (r = -0.24), P (r = -0.20), K (r = -0.33), and S (r = -0.06) in the topsoil, which is consistent with findings by Karyati *et al.* (2018). Conversely, in the subsoil, pH shows a positive but non-significant correlation with OM (r = 0.11), aligning with results reported by Gopan *et al.* (2022). In the topsoil, OM is positively correlated with all measured parameters, whereas in the subsoil, OM exhibits a negative correlation with K (r = -0.39).

Table 5. Correlation matrix (Pearson) among soil pH, CEC, and nutrient content.

	Topsoil						Subsoil					
	pH	OM	CEC	N	P	K	pH	OM	CEC	N	P	K
OM	-0.39	1					0.11	1				
CEC	-0.21	0.07	1				-0.11	0.35	1			
N	-0.24	0.13	0.07	1			-0.47*	0.05	0.23	1		
P	-0.20	0.13	0.42	0.53*	1		-0.37	0.03	-0.15	0.24	1	
K	-0.33	0.39	0.23	0.31	0.47*	1	-0.27	-0.39	0.40	0.04	0.18	1
S	-0.06	0.28	-0.04	-0.08	0.08	0.06	-0.06	0.37	-0.23	0.10	0.35	-0.12

***** means significant at 0.05% level.

The soils of Lalmonirhat tea gardens are loam to sandy loam and moderately acidic, conditions favorable for tea cultivation but limited by low organic matter and insufficient N, P, and K availability. The corresponding nutrient status of tea leaves reflects restricted uptake efficiency, highlighting the need for improved nutrient management. This study provides a baseline assessment of soil-plant nutrient relationships in the newly developed northern tea-growing zone of Bangladesh. To address the identified deficiencies, future work may explore slow-release or organo-mineral fertilizers, biofertilizers, microbial consortia, and biochar or compost-based amendments to enhance nutrient retention, microbial activity, and soil structure. Integrating these approaches with precision soil monitoring can promote sustainable nutrient cycling, reduce input losses, and strengthen the resilience of smallholder tea systems, supporting long-term soil health and environmentally responsible tea production.

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