



Soil Nutritional Status of Tea Plantations In Plains of Sub Himalayan West Bengal, India

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Abstract

Tea is the most consumed beverages after water. In *Terai* and *Dooars* region of sub Himalayan West Bengal, India, tea plantations are around 150 years. Exploitation of tea garden soil over centuries has led to decline in soil fertility and crop productivity after all initiatives of external inputs. As nutrients play a crucial role in quality and quantity of manufactured tea, the present initiative has been designed to quantify the soil nutrient status of tea growing *Terai* and *Dooars* region. 79.62% (*Terai*) and 84.72% (*Dooars*) of the soil samples were found to have normal pH. 47.21% (*Terai*) and 49.3% (*Dooars*) of soil samples was found to have normal organic carbon. 12.03% and 20.82% of soil from *Terai* and *Dooars* showed low total nitrogen. Both the organic carbon and nitrogen in soil are positively correlated. Phosphorus (as P_2O_5) content of soil is extremely site and depth specific. Almost all samples of the study area showed high potassium (as K_2O) content. Monoculture, change in rainfall pattern and inorganic additives have contributed enormous stress to soil but despite of all these odds the overall nutritional richness of these tea growing regions seems to be satisfactory.



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Introduction


Tea is the most popular beverages and an important plantation crop cultivated in India along with many

other areas of the world (Nath).¹ It is not only a much liked beverage of the people in the country but also fetches a good amount of foreign exchange

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(Karmakar and Banerjee).² Tea is produced from the leaves of tea plant scientifically called *Camellia sinensis* (L.) O. Kuntze. Tea plants are leafy perennial trees planted and pruned to desirable height with an objective of recurring harvest. The quality of tea leaf used for manufacturing is highly influenced by soil nutrients and tea clone. Concentration of nutrients in tea leaf is related with the soil environment (Özyazici *et al.*,³). Mineral content of harvested tea depend on the soil properties on which it is grown along with its agronomic practice (Kalita and Mahanta⁴). So, the contents of nutrient element of tea plant are related with soil environments.

In India, the tea plant was discovered growing wild in upper Assam (India) in 1821 (Roy).⁵ In West Bengal, the first tea garden was established in 1857 at Darjeeling, there after tea plantations started extending down to sub Himalayan *Terai* region from 1862 and *Dooars* from 1874 (Joseph).⁶ So, tea plantations of *Terai* and *Dooars* are around 150 years old. Being a plantation crop, the land is utilized for monoculture of tea. More than a century long exploitation of soil under tea cultivation in *Terai* and *Dooars* has led to degradation of soil fertility. Maintenance of soil nutritional quality is a massive economic burden to the local tea growers in view of a huge amount of chemical inputs sharing a good proportion of manufacturing cost every recurring year. In addition injudicious application of chemical fertilizers in large quantities without having a fair qualitative knowledge of tea plantation soil results in destabilization or decline of yields. Adequate soil testing can regulate the quantity of fertilizer loads providing a clear idea of how much exactly chemical inputs are required, and thus can restrict imprudent usage of excess soil nourishment agents.

Soil being one of the most important factors for quality tea produce has not been investigated to a great extent. There are some scattered literature on soil nutrient status of Mengding Mountain, China (Zheng *et al.*,⁷), Fujian Province, China (Ping),⁸ Black sea region, Turkey,³ Dibrugarh and Sivasagar district of Assam, India.¹ But, soil nutrient status of *Terai* and *Dooars* region are extremely lacking. So the present study was conducted to determine the pH, total nitrogen, phosphorus and potassium in tea plantations of *Terai* and *Dooars* region of sub Himalayan West Bengal, India.

Materials and Methods

Study Area

Terai (plains of Darjeeling district) and *Dooars* (plains of Jalpaiguri and Alipurduar districts) regions are located in plains of sub Himalayan West Bengal, India. These two regions have cool winter with warm and humid summer. Rainfall is common almost throughout the year with heavy downpours during the rainy season. Six tea plantations of *Terai* and nine tea plantations of *Dooars* region were considered for the present study of soil nutritional status.

Soil Sampling

In our study area, a total number of 126 soil samples were collected by means of a screw type auger of which 54 samples were from *Terai* and 72 samples were from *Dooars* region. Each sample was gathered by mixing five presamples collected from the corners of an imaginary square of ten metres side and from its diagonal bisector. About five hundred grams of soil samples were brought to laboratory in airtight zipper bags for downstream analysis. Soil samplings were performed early in the morning before application of fertilizers. Topsoil (0-15 cm) and sub soil (15-30 cm) were dug under the canopies of tea bushes.

Preparation of soil Samples for Analysis

The collected soil samples were completely air dried. Debris from the samples like roots, pebbles etc were removed by hand. The clean air dried samples were passed through 2mm sieve and crushed with mortar and pestle. For organic carbon determination, the samples were further passed through final mesh sieve (0.5mm).

Estimation of Soil pH

pH of soil samples were measured on precalibrated pH meter following protocol of Baruah and Barthakur.⁹

Determination of Soil Organic Carbon Content

Quantification of soil organic carbon was conducted by Chromic acid method proposed by Walkley and Black.¹⁰

Determination of Total Soil Nitrogen, Available Phosphorus and Potassium

Total soil was determined by Kjeldhal method (Jackson).¹¹ Estimation of phosphorus as phosphate and potassium as potash requires diacid digestion of soil. One gram sample was subjected to diacid

digestion.⁹ Available phosphorus in the digested sample solution in form of phosphate was conducted by the protocol developed by Bray and Kurtz.¹² Determination of available potassium form of Potash was conducted by the protocol developed by Chapman and Pratt.¹³

Nutritional Index

Nutritional index for soil organic carbon, total nitrogen, available phosphorus (as P_2O_5) and potassium (as K_2O) were calculated to determine the soil nutritional status of *Terai* and *Dooars* region. Nutritional index was calculated following Sharma, *et al.*,¹⁴

Statistical Analysis

Descriptive statistics in the form of mean, minimum, maximum value and standard deviation (SD) were analysed using SPSS software and MS Excel.

Result and Discussion

Soil pH

Soil reaction is measured by pH of a suspension of soil in water. In tea plantations the pH within the range of 4.5-5.5 has been recommended (<https://www.tocklai.org/activities/tea-cultivation/>). The pH of the soil samples collected across the study area was variable (table I). In the top soil of *Terai* region soil pH ranged 4-5.30 with an average of 4.42; while in the sub soil it ranged 3.86-5.18 with an average of

4.47. In the top soil of *Dooars* region it ranged 4.77-4.90 with an average of 4.84; while in the sub soil of it ranged 4.91-4.96 with an average of 4.93. The soil pH of *Dooars* region was found to be more than the *Terai* region. The influence of dolomite brought down by rivers from neighbouring Bhutan may be the main reason behind such pH. In both *Terai* and *Dooars* tea plantations, pH of the subsoil was found to be more than top soil. In top soil of *Terai* region the pH was lower than the recommended pH but pH of the sub soil was within the range. In the *Dooars* region the pH of both top and sub soil was within the recommended range.

Percentages of soil samples with low, normal and high pH are depicted in table II. 79% of the collected soil samples from *Terai* and 84.5% samples from *Dooars* region were found to have normal pH. Rest samples showed either low or high pH. The sub-Himalayan *Terai* region comprises of the plains of Darjeeling district. In this region the soils are mostly sandy, highly acidic, heavily leached and poor in plant nutrients (Bhattacharya).¹⁵ In the *Dooars* region, rivers flowing from neighboring Bhutan carry a large quantity of dolomite dust along with silt that sediment on the soil of tea plantations during floods occurring in the rainy season. So this might be a reason for well maintenance of soil pH of this region by natural means.

Table 1: pH, organic carbon, total nitrogen, phosphorus and potassium of soil samples

Soil parameter	Region	Top soil		Sub soil	
		Average	Range	Average	Range
pH(4.5-5.5)*	<i>Terai</i>	4.42±0.25	4-5.30	4.47±0.26	3.86-5.18
	<i>Dooars</i>	4.84±0.43	4.77-4.9	4.93±0.42	4.91-4.96
Organic carbon(1.0-2.0%)*	<i>Terai</i>	2.18±1.04	0.46-4.46	2.09±1.21	0.41-5.96
	<i>Dooars</i>	1.7±0.71	1.6-1.8	1.42±1.22	1.33-1.48
Total Nitrogen(0.1-2.0%)*	<i>Terai</i>	0.15±0.05	0.01-0.31	0.13±0.04	0.04-0.25
	<i>Dooars</i>	0.14±0.03	0.13-0.14	0.12±0.04	0.12-0.12
Phosphate as P_2O_5 (10-20 ppm)*	<i>Terai</i>	24.31±26.75	1-140	9.7 ±13.58	1-80
	<i>Dooars</i>	59.98±59.87	58.41-60.95	41.05 ±40.13	39.62-43.91
Potassium as K_2O (60-80 ppm)*	<i>Terai</i>	207 ±6	80-410	175 ±58	70-331
	<i>Dooars</i>	153 ±28	145-161	150±24	149-152

*=standard as recommended by Tea Board of India

Organic Carbon

Soil organic matter is the summation of non mineral matter present in soil, and a series of product from decayed plant and animal tissue. The role of soil organic matter for fertility and physical conditions of soil, are well accepted. Decomposition of organic matter by micro-organisms in soil and stabilization of soil structure plays an important role in nutrient cycling (Dick *et al.*,¹⁶ Quilchano and Maranon;¹⁷ Singh *et al.*,¹⁸).

A rich tea garden soil has 2% organic carbon while below 1% need attention (<https://www.tocklai.org/activities/tea-cultivation/>). Organic carbon content of the soil of *Terai* and *Dooars* region are within the Tea Board of India (1-2%) recommended range or slightly high (table I). The percentage of organic carbon content both top (2.18%) and sub (2.09%) soil of *Terai* region was above the Tea Board of India recommended standard. But, the quantity of organic

carbon content in both top (1.7%) and sub (1.42%) soil of *Dooars* region was within the recommended range.

Percentage of soil samples with low, normal and high organic carbon content are depicted in table II. Maximum number of collected soil samples was found to have normal organic carbon. A few samples showed low organic carbon. In *Terai* region 46.29 and 40.74% of samples showed high organic carbon in top and sub soil respectively. 37.5 and 19.44 percentage of samples of *Dooars* region showed high organic carbon in top and sub soil respectively. Soil biochemical activities have been found to be very responsive in organic cultivation,¹⁷ Miller and Dick²⁰; Bergstrom *et al.*,²¹ The application of chemical fertilizers to ensure fertility of soil and crop productivity may negatively act on the complex mechanism of biogeochemical cycle (Tilman *et al.*,²²; Adesmoysce and Kloepper²³).

Table II: Percentages (%) of soil samples with low, normal and high pH

Soil parameter	Soil layer	<i>Terai</i>			<i>Dooars</i>		
		Low	Normal	High	Low	Normal	High
pH(4.5-5.5)*	Top	15	77	7	11	83	5.5
	Sub	9	81	9	7	86	7
Organic carbon (1-2%)*	Top	5.5	48	46	16	46	37.5
	Sub	13	46	40	28	53	19
Total Nitrogen (0.1-2.0%)*	Top	11	88	00	14	86	00
	Sub	13	86	00	28	72	00
Phosphorus as P ₂ O ₅ (10-20ppm)*	Top	39	13	48	4	8	87.5
	Sub	72	13	14	8	16	75
Potassium as K ₂ O(60-80ppm)*	Top	0	1.8	98	0	0	100
	Sub	0	4	96	0	0	100

*=standard as recommended by Tea Board of India

Total Nitrogen, Available Phosphorus and Potassium

Nitrogen (N) is one of the most important constituent of plant parts and plays a crucial part in plant physiology. Total nitrogen content of tea plantation soil of *Terai* and *Dooars* regions was normal (table I). Total nitrogen content estimated in both top (0.152%) and sub (0.139%) soil of *Terai* region, and total nitrogen content of both top (0.141%) and sub (0.125%) soil in *Dooars* region was within the range

(0.1-2.0%) recommended by Tea Board of India. Soil samples with low, normal and high total nitrogen are depicted in table II. 88% of the tested soil samples of *Terai* and 79% of samples from *Dooars* showed normal total nitrogen percentage. 12% and 21% of samples from *Terai* and *Dooars* region showed low total nitrogen content. There is a positive correlation (0.9233) between organic carbon and nitrogen percentage in soil. Chief reason for low nitrogen content in some region may be due to low use

efficiency of the externally applied fertilizers by plants as well as their long term application. Since 1980s, the use of nitrogen in tea plantations has been increasing rapidly; though several researchers are being involved in the study on tea, research work on mineral nutrition is rare (Luczaj and Skrzydlewska).²⁴

Phosphorus (P) is also an essential macronutrient, after nitrogen (N) for plants and its deficiency is the most limiting factor for growth and development of plants (Kumar *et al.*,²⁵). Application of phosphorus fertilizer is usually recommended for enhancing soil phosphate availability (Vance *et al.*,²⁶; Lambers *et al.*,²⁷). However, only less than 20% of phosphorus can be utilized by the plants and the 80-90% of applied phosphorus is fixed into the soil.²⁷ Due to the limited availability and resources of phosphate fertilizers and their effects on environment, their extensive use can be a threat to the agriculture.²⁶⁻²⁷ Available phosphorus in form of phosphate of tea plantation soil of *Terai* and *Dooars* regions are extremely variable (table I). In *Terai* region the phosphate content of top soil (24.314ppm) was found to be above the range but the sub soil (9.703ppm) was below the range (10-20ppm) recommended by Tea Board of India. In *Dooars* region both top (59.986ppm) and sub (41.055ppm) soil was found to contain phosphate above the range recommended by Tea Board of India. Percentages of soil samples with low, normal and high phosphate are depicted in table II. The soil samples collected from different sites showed extremely variable results. Top and subsoil samples collected from *Dooars* region showed high percentage of phosphate in soil. While, sub soil of about 75% soil samples of *Terai* region has low phosphate content. The probable reason is, soil of *Terai* region expresses different texture where it is mainly sandy compared to *Dooars*.

The tea growing areas generally have moderately to highly acidic soil and it is well established that under the acidic or calcareous soil large amount of phosphorus is fixed (Gyaneswar *et al.*,²⁸). The problem of phosphorus deficiency is of particular concern for acid soil like tea garden soil, as tea prefers a low pH (4.5-5.5) soil (Zoysa *et al.*,²⁹); which cause unavailability of phosphorus due to binding to soil mineral surfaces and fixation into organic forms²⁷; (Kochian *et al.*,³⁰). Additionally, when concentration

of phosphate in soil exceeds the natural soil-phosphate holding capacity, phosphate can be carried downward, or leached; commonly referred to as phosphate leaching (Bolan *et al.*,³¹). The subsoil of both *Terai* and *Dooars* have less pH than the top soil, so the phosphate binding capacity of the top soil is quite good and there is no concern about phosphate leaching. Potassium is required in large amounts since it is involved in almost all biological reactions. After nitrogen, potassium is the second major nutrients required for tea cultivation and constitute 1.5-2% of tea leaf dry matter (Verma^{32&33} & Xunet *et al.*,³⁴). Potassium deficiency occurs in the tea plantation mainly due to excessive leaching as a consequence of higher precipitation and more demands by plants as well.^{33&34} Available potassium in form of potash of tea plantation soil of *Terai* and *Dooars* regions is high (table I). In *Terai* region the potash content of both top soil (207.037ppm) and sub soil (175.851ppm) was far above the range recommended by Tea Board of India (10-20ppm). In *Dooars* region too both top (153.8479ppm) and sub (150.694ppm) soil was found to contain potash well above the range recommended. Percentages of soil samples with low, normal and high potash are depicted in table II. Leaving a few illustrations all samples of *Terai* region exhibited high potash content while all soil samples collected from *Dooars* region too showed high potash content.

Nutritional Index

Nutritional index determines the overall nutritional quality of soil. The overall nutritional quality of *Terai* and *Dooars* tea plantation soil were medium to high except some isolated cases. Nutritional index of organic carbon, total Nitrogen, available phosphate and potash in soil samples of *Terai* and *Dooars* were determined and represented as table III. In the soil samples of *Terai* region organic carbon content of top soil and available potash of both top and sub soil showed high nutritional index. Organic carbon content of sub soil and available phosphate content of top soil showed medium nutritional index. Only available phosphate content of sub soil showed low nutritional index. Both *Terai* and *Dooars* region nutritional index of Nitrogen was at medium range. In *Dooars* region nutritional index of both top and sub soil in terms of available phosphate and potash were high.

Table III: Nutritional index (NI) of tea plantation soil of sub Himalayan West Bengal

Soil parameter	Soil layer	Terai				Dooars			
		Low <1.67	Medium 1.67-2.33	High >2.33	NI <1.67	Low 1.67-2.33	Medium >2.33	High	NI
Organic Carbon	Top	3	26	25	2.40	12	33	27	2.20
	Sub	7	25	22	2.27	20	38	14	1.91
Total Nitrogen	Top	6	48	0	1.88	10	62	0	1.86
	Sub	7	47	0	1.87	20	52	0	1.72
Phosphorus as P ₂ O ₅	Top	21	7	26	2.09	3	6	63	2.83
	Sub	39	7	8	1.42	6	12	54	2.66
Potassium as K ₂ O	Top	0	1	53	2.98	0	0	72	3
	Sub	0	2	52	2.96	0	0	72	3

Conclusion

The majestic beauty of sub-Himalayan West Bengal is for its landscape, forests and Tea gardens. The economy of this region is dependent on three T's- Tea, Timber and Tourism. The tea gardens spread over every corner of this region practice monoculture of tea which has partially declined the soil nutritional quality thereby adversely affecting quality of manufactured tea. Moreover change in rainfall pattern and deteriorated water-holding capacity resulted in loss of soil biota and acidification. All these deteriorative features reduce plant root growth and plant health. The experimental findings too clearly depicts that proper pedological analysis can restrict use of excess chemical inputs and ascertain the soil nutrient level predicting which sort of nourishment elements are actually required

for the benefit of the plantation providing a fiscal advantage to the tea growers. Thus, scientific fertility replenishment initiative must be implemented on an emergency basis to save tea plantations and boost the economy of the region.

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Conflict Of Interest

There is no conflict of interest

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