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Soil Chemical Analysis of Kazi and Kazi Organic Tea Garden and Compared to Ordinary Tea Gardens of Bangladesh

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Abstract

Tea is grown in Bangladesh under marginal climatic and soil conditions. Its production is greatly influenced by many physical, chemical, biological and natural factors. The increasing land use intensity without adequate and balanced use of chemical fertilizers and with little or no use of organic manure has caused severe fertility deterioration of our soils resulting in stagnating or even declining of crop productivity. The need of the hour is to achieve substantially higher crop yield than the present yield levels from our limited land resources on a sustainable basis. A feasibility study was carried out of one and only organic tea garden namely Kazi & Kazi Tea Estate at Panchaghar and compared to ordinary tea gardens located at Sylhet namely Zareen Tea Estate, Nurjahan Tea Estate and Malnichara Tea Estate as secondary data to investigate the fertility status of soil. Results of the present study showed that soil solutions were acidic in nature in all seasons. Medium to high soil organic matter, medium to high available iron and phosphorous, and low availability of potash showed that soils were not sufficiently fertile for crop production. Student t-test values of all the parameters with control sample showed statistically significant results for SOM and available P. The critical values have been fixed at 0.1% for N and 1% for OM, 10 μg/g for P, 80 μg/g for K, 25 μg/g for Mg, 90 μg/g for Ca, 2 μg/g for Zn and 20 μg/g for S. The nutrient status is much higher in Kazi & Kazi organic tea estate in compared to other ordinary tea estates in Bangladesh.

Keywords

Camellia Sinensis, Soil Chemical Analysis, Nutrient Determination, Fertility Status, Organic Cultivation

1. Introduction

Tea (*Camellia sinensis* L.) is grown on different land elevation which is the oldest and best beverage in the world next to water. Tea is to be considered as the most popular and cheapest temperate drink in the world. Tea is an intensively managed perennial monoculture crop cultivated on large- and small-scale plantations situated between 21˚3'N and 26˚15'N latitude and between 89˚0'E and 92˚41'E longitude [1]. Tea cultivation in Bangladesh developed concurrently with the northeast Indian tea during early part of the 19th century. Bangladesh tea grows in the three fairly divergent ecological zones, namely Surma valley in greater Sylhet, Halda valley in Chittagong and Karatoa valley in Panchagarh district [2].

The tea industry of Bangladesh dates back to 1857. Now tea is an agro-based labor-intensive industry of Bangladesh. It plays an important role in the national economy through trade balancing and employment generation. At present, there are 166 tea estates in Bangladesh. On an average, Bangladesh produces 63 million kilograms tea annually. Today Bangladesh tea is occupying about 3% plantation area of world tea, producing as much as 2% of tea production in the world. It occupies the 9th position, out of 40 countries, in tea horizon as regards the plantation size and production-level, while the 8th position regarding per unit production [3].

Modern scientific technology encourages the use of chemical pesticides, herbicides, fungicides and chemical fertilizers for the high crops production. It creates the whole agriculture production chemicalization environment and soil become unhealthy all biodiversity and ecosystem have been sick and whole ecology becomes chemicalized. Whereas organic agriculture is a production system that sustains the health of soil ecosystems, biodiversity and cycles adapted to local conditions rather than the use of inputs with adverse effects. Organic tea Farming promotes and enhances biodiversity, biological cycles, soil biological activity through management practices that restore maintain and enhance ecological harmony. The organic tea production system is different from conventional tea production [4]. Organic manure is applied to tea as green manure or as one of many other organic materials, some of which have been allowed to decompose. In favorable circumstances soil fertility and structure are improved. A bed of humus is formed which supports an active micro fauna which speeds decomposition converting nutrients to an available form. Erosion is reduced and the infiltration of water improved [5].

Tea is grown in high water table soils and other types of shallow soils which occasionally include drained swamps. Tea is grown successfully on soils with textural grades ranging from fine sand to heavy clay. A deep soil is essential for successful tea cultivation. Soil depth is vitally important if the tea soil selection is done with any confidence. A soil profile pit, at least 2 m deep, is dug in representative sites and the various soil horizons are examined for their suitability for tea planting. The available depth should be taken 1.5 m as a minimum. Tea roots will not develop fully when the soil or the sub-soil is either saturated or even nearly saturated with water for more than a very short period [6]. The chemical requirement of tea soil is very specific, requiring 1) the absence of more than small amounts of calcium and 2) the presence of very definite acidity both in top soil and sub-soil. It seems probable that failure of tea in many areas has been due to high pH, although it has been attributed to climate and others cause.

Tea is grown in a wide variety of soil types and its growth is favored in acidic conditions, with pH values ranging between 5.0 and 5.6. Although it will grow in soil pH as low as 4.0, soil pH only marginally higher than 5.6 is considered unsuitable without pH adjustment. Soils with pH values > 6.5 are not amenable to treatment for commercial tea growing [7]. Therefore, the main objectives of this research were 1) to assess the chemical properties and nutrient status of tea soils, and 2) to encourage the organic farming system for long term fertility of soil.

2. Materials and Methods

2.1. Sampling Site

The sampling sites were selected for collecting the samples in organic tea gardens at Panchaghar namely as Kazi & Kazi Tea Estate. And for the experiments of evaluation and comparison, the selected ordinary tea gardens as secondary data [8] were Zareen Tea Estate, Nurjahan Tea Estate and Malnichara Tea Estate in Sylhet and Moulovibazar districts.

Zareen Tea Estate (ZTE) started in 1932 AD in Moulovibazar district. It covers about 276 ha of land. Its elevation is 18m. The land is medium flat. Temperature varies from 23˚C to 30˚C. The average rainfall is medium that is 3286 mm. Vegetation is mainly tea, shade trees of various species, rubber, eucalyptus, pineapples, lemons, bamboo, grasses, etc. The people are mainly day labors and tea labors.

Nurjahan Tea Estate (NTE) started in 1879 AD in Moulovibazar district. Its elevator is 20 m. The land area is 298 ha. The land is high flat. Temperature ranges from 23˚C to 33˚C. The average rainfall is high that is 3556 mm. Vegetation is mainly tea, Albizzia adorattissima, rubber, eucalyptus, pineapples, bamboo, grasses and lemons.

Malnichara Tea Estate (MTE) was started in 1854 AD. It is occupied by 1017 ha of land area. The elevation of this garden is 24 m. The land is mainly tillah. The temperature ranges from 23˚C to 34˚C. The average rainfall is 3300 mm that means high rainfall. The vegetation is similar to the above gardens.

Kazi & Kazi Tea Estate (KKTE) is the one and only organic tea garden in Bangladesh. It is situated in Panchaghar district. It was started in 2000 AD. The area of this garden is 1679 ha. The elevation is about 85 m from the sea level. The land is relatively high flat plain. Temperature varies from 25˚C to 35˚C. Average rain fall is low that is 1100 mm. Vegetation is mainly tea, besides Albizzia Lebeck, Albizzia adarattissima, various types of bushes and grasses are available here. Most of the peoples are day labors, the rest of the people are involved in various occupations.

2.2. Collection of Soil Samples

Soil samples were collected from the soil profiles are 0 - 5, 5 - 10, 10 - 15, 15 - 20 inch from Kazi & Kazi Tea Estate during 12th October to 18th November, 2018. Three pits were dug in each of the tea estates and 4 soil samples were collected from each depth of the profile. All of the soil samples of respective depth were well mixed and composite samples were prepared. They were brought to the laboratory and air-dried ground and sieved at 2 mm sieve. The ground samples were kept in a plastic bottle and preserved in the laboratory till chemical analysis. The following parameters of the soil were determined [9].

2.3. Soil Sample Preparation

Soil sample was collected from tea gardens and air dried for several days in a clean room avoiding direct sunlight and dust, after air drying, larger aggregates were broken by gentle hammering and then mixed thoroughly to make it a composite sample into soil pedology laboratory at Khulna University, Bangladesh. Dry roots, grasses and other particulate materials were discarded from the soil sample and then it was used for different investigations. 1 kg of the composite soil sample was ground into 4 particulars and screened to pass through 2 mm sieve. This sample was kept in plastic containers for chemical analysis and labeled properly [10].

2.4. Laboratory Analysis

Most of convenient methods were used in this chemical analysis. Soil pH was determined electrochemically with the help of glass electrode pH meter [11]. The ratio of soil water was 1:2.5. The organic carbon was determined volumetrically by wet oxidation method [12]. Organic matter was calculated by multiplying the percentage of organic carbon with conventional Van bemmelen's factor of 1.724 [13]. The total N of the soil was determined by micro Kjeldhal's method following sulfuric acid digestion [11]. The C/N ratio of the soil was calculated by dividing the percentage of total carbon by the percentage of total nitrogen. The available P of soil was determined by Olsen extraction; 0.5 N $NaHNO_3$ at pH-8.5 (Soil:Extractant = 1:10) using a chemico visible spectrophotometer at 882 nm wavelength as Molybdophosphoric blue color method in a sulfuric acid system [11]. Available Fe was extracted with 1N NH_4OAC (pH = 3.0). The extract was analyzed by spectrophotometer at 510 nm by Colorimetric method [11]. The exchangeable cations (Ca, Mg) of soil were extracted with 1N NH_4OAC (pH = 7.0) and titrated against 0.01 N EDTA by using titrimetric method. The exchangeable cations (Na, K) of soil were extracted with 1N NH_4OAC (pH = 7.0) [11] [13]. The extract was analyzed for Na and K by Galenchamp Flame Photometer at 589 nm and 767 nm.

2.5. Statistical Analysis

The experimental data were statistically analyzed. Analysis of variance (ANOVA) was computed. It was done to obtain the difference among different among gardens and depths.

3. Results and Discussions

Tea soils are highly weathered, extremely acidic and low in fertility status. Furthermore, these soils do not receive deposits of fertile silt by flooding; rather they suffer from erosion. The most suitable tea soil is thought to be light, friable and well drained having soil pH from 4.5 to 5.8 [14]. The critical values have been fixed at 0.1% for N and 1% for organic matter. The minimum level of nutrient status of tea soil should be 10 µg/g for P, 80 µg/g for K, 25 µg/g for Mg, 90 µg/g for Ca, 2 µg/g for Zn and 20 µg/g for S [1].

3.1. pH Values of Different Tea Soils

pH is an important parameter for tea cultivation. The pH values of the soils of the Tea estates were presented in **Table 1**. The pH values of the soils of different tea estates were around 4.5 in all depths of the profile. Such low pH might be due to the leaching of the base materials from the profiles by heavy rainwater in these hilly regions. This pH and the topographic conditions of the tea estates seem to be ideal for tea cultivation.

The pH of the surface soil is slightly higher than the subsurface soil in almost all the sampling places. Further the statistical analysis showed that there was no

Table 1. Distribution of pH in the soil profile of 4 tea estates.

Name of the garden	Depth (inch)	Topography	pH
Kazi & Kazi Tea Estate	0 - 5	High flat	5.65
	5 - 10		5.70
	10 - 15		5.55
	15 - 20		5.40
Zareen Tea Estate	0 - 5	Medium flat	4.50
	5 - 10		4.40
	10 - 15		4.55
	15 - 20		4.30
Nurjahan Tea Estate	0 - 5	High flat	4.40
	5 - 10		4.50
	10 - 15		4.00
	15 - 20		4.10
Malnichara Tea Estate	0 - 5	Tillah	4.30
	5 - 10		4.50
	10 - 15		4.60
	15 - 20		3.90

significant difference among tea ordinary estates but there was a significant difference among the depths of the profiles. But the pH value is much higher in Kazi & Kazi organic tea estate in compared to other ordinary tea estates.

3.2. Available P & Fe Content in Collected Soil Samples

The available P & Fe was determined and results were presented in Table 2. Approximate amount of available P & Fe was found in the soils of all tea estates. The mineralogy of the soils might be responsible for such phenomena.

The statistical evaluation of the results for available Phosphorus of the investigated soils did not differ significantly from each other in available Phosphorus contents. However, P was uniformly distributed in different depth of soil profile. Furthermore, there was no significant difference among tea estates but there was a significant difference among the depths of the profiles.

3.3. Content of Exchangeable Na, K, Ca and Mg

The contents of the exchangeable Na, K, Ca and Mg were present in Table 3. The exchangeable Na contents were higher than those of K. The highest concentration (0.65 - 0.95) meq/100g soil of exchangeable Na was measured in the soils of Nurjahan Tea Estate and the lower (0.13 - 0.18) meq/100g soil in Malnichara Tea Estate.

The statistical analysis showed that there was no significant difference among tea estates but there was a significant difference among the depths of the profiles.

Table 2. Distribution of available P & Fe content in the soil profile of 4 tea estates.

Name of the garden	Depth (inch)	Topography	P (mg/kg)	Fe (mg/kg)
Kazi & Kazi Tea Estate	0 - 5	High flat	33	32
	5 - 10		31	29
	10 - 15		35	35
	15 - 20		29	36
Zareen Tea Estate	0 - 5	Medium flat	21	16
	5 - 10		17	19
	10 - 15		31	24
	15 - 20		19	12
Nurjahan Tea Estate	0 - 5	High flat	33	38
	5 - 10		31	27
	10 - 15		20	41
	15 - 20		17	43
Malnichara Tea Estate	0 - 5	Tillah	22	30
	5 - 10		39	28
	10 - 15		25	36
	15 - 20		38	25

Table 3. Distribution of Na, K, Ca and Mg in the soil profile of 4 tea estates.

Name of the garden	Depth (inch)	Na^+ meq/100g soil	K^+ meq/100g soil	Ca^{2+} meq/100g soil	Mg^{2+} meq/100g soil
Kazi & Kazi Tea Estate	0 - 5	0.82	0.42	0.70	0.42
	5 - 10	0.73	0.37	0.91	0.45
	10 - 15	0.75	0.46	0.83	0.41
	15 - 20	0.61	0.39	0.58	0.39
Zareen Tea Estate	0 - 5	0.72	0.32	0.67	0.22
	5 - 10	0.49	0.25	0.61	0.15
	10 - 15	0.80	0.42	0.69	0.35
	15 - 20	0.85	0.40	0.58	0.27
Nurjahan Tea Estate	0 - 5	0.95	0.18	0.12	0.26
	5 - 10	0.65	0.19	0.16	0.31
	10 - 15	0.72	0.21	0.11	0.32
	15 - 20	0.93	0.14	0.17	0.38
Malnichara Tea Estate	0 - 5	0.14	0.11	0.14	0.11
	5 - 10	0.18	0.09	0.10	0.12
	10 - 15	0.16	0.14	0.32	0.30
	15 - 20	0.13	0.21	0.16	0.28

The results varied widely among themselves in exchangeable Na, K, Ca and Mg contents with the depth of profiles. Their contents were very low in the soils of all 3 tea estates probably because of leaching of these cations under very acidic conditions (pH = 4) prevailed in soils of 3 tea estates. Such low contents of these exchangeable bases might influence the CEC of the soils that affect nutrient retention of the soil profile. However, the nutrient status of Kazi and Kazi Tea Estate was remarkable and relatively high than other tea estates

3.4. Content of Soil Organic Carbon, Organic Matter, Total N and C/A Ratio

Organic carbon, Organic matter, and total N contents at different depths of the soil profile of 4 tea estates were presented in Table 4. The organic matter contents of the soils of ordinary tea estates were generally low (<1.5%) but enrich of Kazi & Kazi organic tea estate in the soil profiles influencing the contents of soil nitrogen. Organic matter (OM) content decreased with increasing depth of soil profile. In addition, cation exchange capacity and interrelated parameter to organic matter exhibit a similar trend like organic matter.

The ANOVA tests showed that there was no significant difference in %OC of the tea estates, while a significant difference exists within the soil profiles. Furthermore, the statistical analysis of the results showed that there was a difference in organic matter contents between organic tea estates and ordinary tea estate as well as in the different depth of the soil profiles. From the results further showed

Table 4. Distribution of total nitrogen, organic carbon (OC), organic matter (OM) and C/N in the soil profile of 4 tea estates.

Name of the garden	Depth (inch)	% OC	% OM	% Total N	C/N Ratio
Kazi & Kazi Tea Estate	0 - 5	1.816	3.124	0.140	12.97
	5 - 10	1.752	3.013	0.110	15.93
	10 - 15	1.768	3.041	0.120	14.73
	15 - 20	1.681	2.891	0.100	16.81
Zareen Tea Estate	0 - 5	0.710	1.221	0.068	10.38
	5 - 10	0.652	1.121	0.062	10.57
	10 - 15	0.674	1.159	0.060	11.25
	15 - 20	0.769	1.323	0.064	11.98
Nurjahan Tea Estate	0 - 5	0.632	1.087	0.121	5.22
	5 - 10	0.506	0.870	0.095	5.31
	10 - 15	0.572	0.984	0.110	5.20
	15 - 20	0.536	0.922	0.091	5.92
Malnichara Tea Estate	0 - 5	0.931	1.601	0.064	14.50
	5 - 10	0.924	1.589	0.078	11.82
	10 - 15	0.895	1.539	0.066	13.54
	15 - 20	0.866	1.490	0.064	13.53

that OC and N were the highest in the topsoils of the sampling locations and then declined with depth. The soil consisting of less than 0.1% N is considered poor for tea cultivation [15].

4. Conclusions

The soils at different profile depths were investigated for Kazi and Kazi Tea Estate and compared the nutrient status among Zareen Tea Estate, Nurjahan Tea Estate and Malnichara Tea Estate. This investigation showed that the 4 tea estates varied widely among themselves in chemical properties. The pH of 4 tea estates is in the lower critical level for tea cultivation compared to those of the other tea soils of the world. The exchangeable base of the soils is also very low due to leaching Ca, Mg, K and Na under acidic conditions. Such low contents of these exchangeable bases might influence the CEC of the soils that affect nutrient retention of the soil profile. The investigated tea estates are generally poor in plant nutrients. Malnichara tea state is particularly very different in nutrient elements. However, the nutrient status of Kazi and Kazi Tea Estate was remarkable and relatively high than other tea estates.

An abundant supply of nitrogen and organic matter is essential for the vegetative growth of tea plants. The present nutritional condition of Bangladesh old tea soil indicates that the nitrogen level is satisfactory but the level of organic matter is poor to marginal. Organic matter in the form of cow dung, compost or green manuring crops may be added to the soil in order to improve the fertility of the soils. This will also increase the cation exchange capacity and activity of microorganisms in the soil. The old tea soil of Bangladesh has been suffering from strong acidity resulting from the continuous application of sulphate of ammonium and high leaching by rainfall. The available phosphate content in the soils is very low. The application of soluble phosphate fertilizer may be proceeded by the application of lime.

The chemical properties of the soil samples as analyzed in the laboratory showed that chemical constituents of the soils are suitable for the growth of tea plants. Considering the climatic conditions like temperature, rainfall, etc. and also the physicochemical properties of soil are more or less identical to the best tea growing North East zone of Bangladesh and are congenial for the satisfactory growing of tea.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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Appendix

Table A1. Analysis of variance (pH).

S.V.	Df	SS	MSS	Computed F	Tabulated F
Location	3	0.28	0.094	3.22	
Depth	3	4.67	1.555	53.04	5% = 3.86
Error	9	0.26	0.029		1% = 6.99
Total	15	5.21			

Table A2. Analysis of variance (available P).

S.V.	Df	SS	MSS	Computed F	Tabulated F
Location	3	28.69	9.56	0.16	
Depth	3	271.19	90.40	1.55	5% = 3.86
Error	9	526.06	58.45		1% = 6.99
Total	15	825.94			

Table A3. Analysis of variance (available Fe).

S.V.	Df	SS	MSS	Computed F	Tabulated F
Location	3	139.19	46.40	2.26	
Depth	3	841.69	280.56	13.64	5% = 3.86
Error	9	185.06	20.56		1% = 6.99
Total	15	1165.94			

Table A4. Analysis of variance (available Na).

S.V.	Df	SS	MSS	Computed F	Tabulated F
Location	3	0.05	0.02	1.19	
Depth	3	1.10	0.37	27.37	5% = 3.86
Error	9	0.12	0.01		1% = 6.99
Total	15	1.27			

Table A5. Analysis of variance (available K).

S.V.	Df	SS	MSS	Computed F	Tabulated F
Location	3	0.02	0.005	2.47	
Depth	3	0.21	0.068	33.20	5% = 3.86
Error	9	0.02	0.002		1% = 6.99
Total	15	0.24			

Table A6. Analysis of variance (available Ca).

S.V.	Df	SS	MSS	Computed F	Tabulated F
Location	3	0.03	0.010	1.21	
Depth	3	1.18	0.394	48.90	5% = 3.86
Error	9	0.07	0.008		1% = 6.99
Total	15	1.28			

Table A7. Analysis of variance (available Mg).

S.V.	Df	SS	MSS	Computed F	Tabulated F
Location	3	0.03	0.009	2.48	
Depth	3	0.11	0.035	9.41	5% = 3.86
Error	9	0.03	0.004		1% = 6.99
Total	15	0.17			

Table A8. Analysis of variance (organic carbon).

S.V.	Df	SS	MSS	Computed F	Tabulated F
Location	3	0.0102	0.0034	1.65	
Depth	3	3.4323	1.1441	556.65	5% = 3.86
Error	9	0.0185	0.0021		1% = 6.99
Total	15	3.4610			

Table A9. Analysis of variance (total N).

S.V.	Df	SS	MSS	Computed F	Tabulated F
Location	3	0.0007	0.0002	2.38	
Depth	3	0.0085	0.0028	27.93	5% = 3.86
Error	9	0.0009	0.0001		1% = 6.99
Total	15	0.0101			