Survey Report

INFLUENCE OF SOME SOIL CHEMICAL PROPERTIES ON YIELD OF TEA (CAMELLIA SINENSIS) IN THE DOOARS REGION OF NORTH BENGAL, INDIA

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ABSTRACT

The soils of Dooars (the sub-Himalayan regions of North Bengal) are high in organic C and available S compared to the prime tea-growing areas of Assam. The effect of these two parameters as well as soil pH and available K, routinely tested in tea soils of Northeast India, on yield of tea was assessed. The results were compared with earlier observations made on the tea soils of Assam. Effect of soil pH and available K status on yield of tea is similar to that of Assam. The survey showed that the productivity of tea soils was often lower where the organic C is greater than 2% and/or where the available S was greater than 30 ppm. The possible reason may be due to the interaction of soil pH, organic C and available S in the tea soils of Dooars and their interactions on yield of tea.

Keywords: *Camellia sinensis, India, soil pH, available K, available S, soil organic C, tea yield*

INTRODUCTION

Tea (*Camellia sinensis*) plantations in Northeast India contribute substantially to the economy, not only of the region, but also of the country, and also support a large population of workers with little education. Economic tea production is linked to the productivity of land under tea hence sustainability of fertility in soils under tea is of paramount importance. Tea plants have a economically productive lifetime of over 50 years and traditional tea areas have been under tea cultivation for over a century, with at most two cycles of replantation. Except for a brief period of 18-24 months under grass for "rehabilitation", these soils have been continuously under tea for many decades. The tea soils of Dooars (Fig. 1), spread over a large area with relatively minor variations in climatic conditions, therefore provide a good opportunity to correlate the yield of tea with various soil chemical characteristics. The effect of soil pH, potash, sulphur and phosphorus has been studied for the tea soils of Assam (Fig. 1) (Ghosh *et. al*, 1994, Goswami *et. al*, 2001) but such information for Dooars is scanty. In this paper, we demonstrate that although the results obtained for soil reaction and available K are similar in both regions, the response of tea to soil organic C and available S (both of which are much higher in Dooars soils than in Assam soils) are unexpected. The possible reasons underlying this anomalous response are discussed.

Fig. 1. Map of Northeast India showing Dooars (1) the Brahmaputra Valley of Assam (2) and Cachar (3).

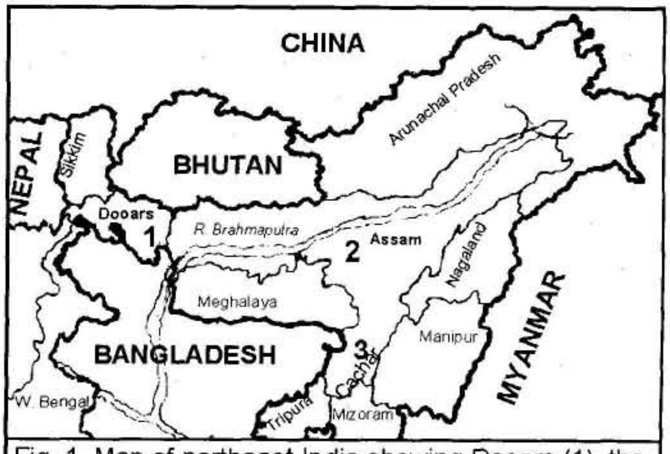

Fig. 1. Map of northeast India showing Dooars (1), the Brahmaputra valley of Assam (2) and Cachar (3)

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MATERIALS AND METHODS

Soil testing was done by standard methods for tea soils (*Jackson, 1967*). Soil pH was measured using 1:2.5 soil : neutral water solutions. Organic C was determined by the Walkley-Black titration. Available K was determined flame photometerically on solutions prepared by extracting soil with 1M neutral ammonium acetate. Available S was determined turbidimetrically on $CaCl_2$ extracts of soil. Available P was determined using the Bray II extractant followed by phosphomolybic acid.

More than 6000 soil samples from the tea areas of Dooars region of North Bengal (Figure 1) were analysed between 2000-2003 at the soil testing laboratory at Nagrakata for pH, organic C, available K and available S of 0-15 cm soil depth. The database generated from the results was screened and data for soils with pH values above 5.7 were not considered in the assessment as these soils are considered unsuitable for tea. This reduced the database to 5271 soils. The data for sections of tea which gave consistent results for at least two occasions were pooled, including earlier data of 1998 onwards. The yield and pruning data for the period 1997-2000 (one pruning cycle; 3-4 years duration) were obtained from the estates. The average yield was calculated for this period.. Tea yield is generally expressed as kg "made tea" (the product leaving the factory) per ha (KMTH), which is approximately 22% of the harvested green leaf. Data from sections yielding less than 1000 KMTH were also removed from the database as they represent either young tea sections or have other problems that affect yield. Data that represent a total of 1734 sections (40 estates, approximately 25% of the total area under mature tea in the Dooars) is considered as the yield database for this study. Sections yielding 1700 KMTH or less were considered as low and those above 2500 KMTH were considered as high, and the yields that fall between this range was considered as medium yielding. The average yield of tea in India is approximately 1800 KMTH and it is close to the average yield for the Dooars region.

RESULTS

Soil acidity

Tea is a plant known to thrive well in acid soils, with an optimum pH 4.5-5.5 (Othieno, 1992). For this study, the majority of the sections (50%) were found to be in the medium range of productivity irrespective of the soil acidity status (Table 1), while 30% of the sections were low yielding and 20% were high yielding. The impact of soil acidity was marginal compared to other parameters studied.

Table 1. Distribution of yield classes in various pH ranges

pH range	Number of sections	Frequency of yield class occurrence (%)		
		Low	Medium	High
<4.00	92	31.52	51.09	17.39
4.00-4.49	592	34.63	48.14	17.23
4.50-4.99	735	29.39	51.56	19.05
5.00-5.70	315	28.25	49.21	22.54

Organic C

Tropical and semi-tropical soils generally have relatively low organic C content, except where temperatures are in high elevations. However, compared to the tea growing areas of Assam (Figure 1) where organic C is normally around 1% and rarely exceeds 1.5%, the soils of Dooars are comparatively high in organic C, with most of the soils having more than 1% organic C (Table 2). The maximum proportion of high-yielding sections and the lowest proportion of low-yielding sections were found in soils where the organic C ranged from 1-2%. Above or below this range, the proportion of low yielding sections increased and the high-yielding ones declined.

Table 2. Distribution of yield in various organic C ranges

Organic C range (%)	Number of sections	Frequency of yield class occurrence (%)		
		Low	Medium	High
<1	210	38.57	45.24	16.19
1-1.49	531	27.31	51.41	21.28
1.5-1.99	431	29.23	50.12	20.65
2-2.49	364	34.62	48.08	17.31
>2.5	198	30.81	54.04	15.15

Available K

On the basis of theoretical considerations and from the data based on tea soils of Assam (Dey, 1967), TRA considers soils with less than 60 ppm available K (expressed as ppm K_2O) as low in potash, those with available K ranging from 60-80 ppm K_2O are considered as having moderate potash status and where the available K ranges around 100 ppm K_2O are considered as optimal. The data shown in table 3 supports these observations and extends the validity of these ranges to the tea soils of Dooars. There is no increase in the proportion of high yielding sections where the available K is greater than 100 ppm K_2O, and there is an apparent decline in the frequency of high yielding sections when the available K is greater than 300 ppm K_2O. Since this contains a small number of sections, the data are less reliable in this range. However, it is advisable for the estates to maintain the available potash levels in the soils between 100 to 200 ppm K_2O.

Table 3. Distribution of yield in available K ranges

Available K range (as ppm K_2O)	Number of sections	Frequency of yield class occurrence (%)		
		Low	Medium	High
<60	225	44.44	42.67	12.89
61-80	232	35.78	50.86	13.36
81-100	283	26.86	49.82	23.32
101-150	325	28.62	53.54	17.85
151-200	332	25.90	51.81	22.29
201-300	214	28.04	50.00	21.96
>300	123	33.33	47.15	19.51

Available S

Deficiency symptoms of sulphur, "tea yellows", were first shown in tea plantations of Malawi (Storey and Leach, 1933). Unlike in soils of Assam, tea soils of Dooars are relatively rich in available S (Chakravartee and Gohain, 1994). The critical limit of available S in tea soils that are relatively poor in sulphur in Assam has been established as 45 ppm S (Chakravartee and Gohain, 1994). There are very few soils in Assam which contain higher levels of available S than this limit. Results of this study show that there is a negative impact of high available S on yield. It can be seen that as the available S in soil increases with a concomitant decline in the proportion of high yielding sections (Table 4).

Table 4. Distribution of yield in available S ranges

Available S range (ppm S)	Number of sections	Frequency of yield class occurrence (%)		
		Low	Medium	High
<16	392	35.20	42.35	22.45
16-30	442	27.38	49.32	23.30
31-45	325	34.46	48.62	16.92
46-60	291	26.80	57.39	15.81
>60	284	31.69	55.28	13.03

DISCUSSION

A negative impact of soil organic C status above 2% on yield is unexpected in light of the common belief that the higher the organic C status, the more fertile the soil (Andrews *et al.* 2002). However, Prescott *et al.* (2000) suggested several reasons for reduction of biomass productivity in forest soils by soil humus. These reasons included nutrient immobilisation. Hattenschwiler and Vitousek (2000) have suggested that polyphenols in soil reduce fertility and productivity and the tea plant is high in polyphenols (Dev Choudhury and Bajaj, 1980). Tannins have also been implicated in reduction of nutrient availability through nutrient immobilisation, soil enzyme inactivation, and reduction of the microbiota (reviewed by Krause *et al.*, 2003). Since tea is cultivated for its polyphenols, the accumulation of polyphenols in soils under tea is a distinct possibility. Pandey and Palni (1996, 2004) have clearly shown that the tea plant exerts a "negative effect" on the microbiota of the rhizosphere, where there are fewer cultivable microbes in the tea rhizosphere than in the general soil.

Organic C is known to affect the retention of soil moisture. The soil-air-water relationship is critical in tea soils and it is a possibility that this may be suboptimal in soils where the organic C is greater than 2%.

In the present study, a relationship was observed between high soil organic C and high soil acidity (table 5). The proportion of soils with pH lower than optimal for tea (pH <4.5) increases from 20% in soils with less than 1% organic C, to over 45% in soils where the organic C is greater than 2 %. The distribution of yield ranges in two soil pH classes, low (pH <4.5) and optimal (pH 4.5-5.7) in the various organic matter classes are shown in table 6. In soils where the organic C is less than 1%, there is a greater frequency of high yielding sections where the soil pH is low. Concomitantly, there is a higher proportion of sections with low yield where soil pH is 4.5 or greater. The trend is reversed in soils of high organic C status. It can also be noted that the frequency of low yielding sections increases in the low soil pH range as the organic C status increases, suggesting that soil acidity is one factor contributing to relatively lower productivity of tea in soils with high organic C. However, in soils where the organic C is greater than 2.5%, there is no effect of soil pH on the frequency of yield class occurrence, suggesting that some other factor(s) could affect the yield of tea in these soils.

Table 5. Soil organic C status and soil pH

Organic C range (%)	Number of sections	Frequency of pH class occurrence (%)			
		<4	4-4.49	4.5-4.99	>4.99
<1	210	0.95	19.05	50.95	29.05
1-1.5	531	4.71	32.20	43.88	19.21
1.5-2	431	4.41	38.75	42.23	14.62
2-2.5	364	6.87	38.46	40.11	14.56
>2.5	198	10.61	37.37	33.84	18.18

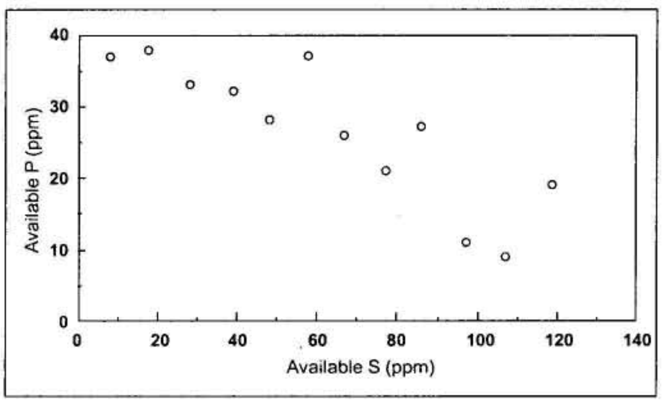
Table 6. Distribution of yield classes in low and optimal soil pH classes within soil organic C ranges

Organic C range (%)	pH class* sections	Number of	Frequency of yield class occurence (%)		
			Low	Medium	High
<1	Low	42	30.95	42.86	26.19
	Optimal	168	40.48	45.83	13.69
1-1.5	Low	196	28.06	56.12	15.82
	Optimal	335	26.87	48.66	24.48
1.5-2	Low	186	35.48	44.62	19.89
	Optimal	245	24.49	54.29	21.22
2-2.5	Low	165	43.03	42.42	14.55
	Optimal	199	27.64	52.76	19.60
>2.5	Low	95	30.53	53.68	15.79
	Optimal	103	31.07	54.37	14.56

* *low pH <4.5; optimal pH 4.5-5.7*

The negative effect of high available S is also unexpected. Chakravartee and Gohain (1994) summarised results of field trials in Assam and Bengal and found that there was no response to sulphur fertilisers in soils where the available S was within the range of 35-45 ppm. In fact, in these experiments, there was a slight decline in yield when sulphur was applied to soils with high sulphur status (>45ppm S). These workers have also shown that there is a negative relationship between available S and available P in the tea soils of both Assam and Dooars. Data on available P in Dooars soils is relatively scarce as this parameter is rarely estimated, but data is available for 1063 sections and the relationship between available S and available P is shown in Fig. 2 which supports the observations of Chakravartee and Gohain (1994). It is generally accepted that the phosphate requirement for tea is very low and the response to phosphate fertilisation is inconsistent (Barua 1989, Bonheure and Willson 1992, Othieno 1992, Zoysa and Loganathan, 2003). Very little work has been carried out on the effect of phosphate manuring on tea growing in tropical soils with high organic C.

Fig. 2. Relationship between available S and available phosphate in the tea soils of Dooars



Germida *et al.* (1992) have reviewed the effects of excessive levels of S in soil, either through atmospheric deposition or by the use of sulphur as a fertiliser or soil amendment. These include acidification of soil and a decline in microbial biomass. Earlier studies (Ghosh *et al.*, 2001) also indicated a relationship between soil acidity, high available S and high organic matter status in tea soils of Dooars, where they observed an abrupt decline in the frequency of soils with low available S (<16 ppm) as the organic C increased above 2.0%. In the present study, it is clearly seen that the frequency of sections with low available S (< 31 ppm) increases with increasing soil pH, while that of sections with higher levels of available S increases (Table 7).

Table 7. Soil pH and available S status

pH range	Number of sections	Frequency of available S class occurrence (%)				
		<16 ppm	16-30 ppm	31-45 ppm	46-60 ppm	>60 ppm
<4	92	4.35	16.30	26.09	23.91	29.35
4-4.49	592	14.86	20.95	23.14	20.78	20.27
4.5-4.99	735	24.90	28.98	14.97	15.65	15.51
>4.99	315	37.14	28.57	16.83	10.16	7.30

The relationship between soil reaction, available S and yield is shown in table 8. In both pH ranges, the frequency of medium yielding sections increases with high soil S and the frequency of high yielding sections decrease.

Table 8. Distribution of yield classes in soils of low and high available S classes in two pH ranges

pH range	S class*	Number of sections	Frequency of yield class occurrence (%)		
			Low	Medium	High
<4.5	Low	231	32.47	45.02	22.51
	High	453	35.10	50.33	14.57
4.5-5.7	Low	603	30.51	46.43	23.05
	High	447	27.07	56.82	16.11

** Low <31 ppm; High e"31 ppm*

The distribution of yield classes in high and low available S classes in five ranges of organic C is shown in Table 9. Again, there is an increase in the proportion of medium yielding sections in soils with high available S. As observed in the relationship to soil acidity (Table 6), there is a distinct difference in the impact of available S on yield between soils with less than 1% organic C and the other classes. In soils with low organic C, there is no difference in the frequency of high yielding sections, but in all other organic C ranges, there is a distinct reduction in this frequency.

Table 9. Distribution of yield classes in low and high available S classes within organic C ranges

Organic C range (%)	S class*	Number of sections	Frequency of yield class occurence (%)		
			Low	Medium	High
<1	Low	170	40.00	44.12	15.88
	High	40	32.50	50.00	17.50
1-1.5	Low	297	29.63	45.45	24.92
	High	234	24.36	58.97	16.67
1.5-2	Low	196	26.53	48.98	24.49
	High	235	31.49	51.06	17.45
2-2.5	Low	117	29.06	45.30	25.64
	High	247	37.25	49.39	13.36
>2.5	Low	54	31.48	46.30	22.22
	High	144	30.56	56.94	12.50

** Low <31 ppm; High e"31 ppm*

In summary, the soil pH and optimum level of K exert similar influence on tea productivity in both the regions of Dooars and Assam, though the soils of Dooars are distinctively different from Assam tea soils, the latter being predominantly alluvial in origin. On the other hand, there is a distinct optimum for organic C between 1-2% and a negative impact of S above 30 ppm in Dooars tea soils. Since organic C *per se* is unlikely to wield a negative influence on growth of plants, studies are required to determine the underlying causes for this observed effect, focusing on quality aspects of soil organic C, including the polyphenol and tannin content of high carbon soils.

In view of the differing responses of soils with low (<1%) organic C with respect to the impact of soil acidity and available S, this work suggests that such soil organic C status should dictate other management practices. The reasons for low productivity of tea in soils with very high organic C status (>2%) and ways of improving the productivity need to be investigated

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