Survey Report

AVAILABLE SULPHUR STATUS OF DOOARS TEA SOILS

J.J. Ghosh*, U. George# and N. Barpujari+

ABSTRACT

Available sulphur was determined on 5077 soils from the tea growing areas of Dooars (North Bengal), received for routine soil testing between 2000-2003. Over 43% of the soils had more than the critical limit of 40 ppm available sulphur. A distinct geographical trend in sulphur availability was observed, with the four western sub-districts showing a greater frequency of high available sulphur than the three eastern sub-districts. As expected, increased organic carbon in the soils could be correlated by a quadratic equation to the available sulphur status. Three sub-districts, Chulsa, Binnaguri and Dalgaon did not show a high correlation between organic carbon and available sulphur. Surprisingly, a negative linear relationship could be observed between soil pH and available sulphur, in all but the Jainti sub-district. This may be compounded by a negative correlation between soil pH and organic carbon status, in all but the Binnaguri, Kalchini and Jainti sub-districts.

Keywords: *Available sulphur; Camellia sinensis; Dooars; inter-relationships; soil acidity; soil organic carbon; subdistricts;*

INTRODUCTION

Tea is the economic life-blood of North Bengal. Approximately 80,000 hectares of the Dooars region is under this crop, with an average yield of 1800 KMTH (kilograms "made tea" per hectare). "Tea yellows" or sulphur deficiency of tea was first described in 1933 by Storey and Leach in Malawi, though such overt deficiency symptoms have rarely been observed in northeast India.

Nevertheless, with urea replacing ammonium sulphate as the nitrogen fertilizer of choice (primarily for economic reasons), and with increasing soil productivity arising from improved cultivars and agro-techniques, there is increasing concern that there may be depletion of sulphur from tea soils. To monitor the possibility, the Tea Research Association has been testing available sulphur routinely in all soils sent for testing in its seven soil testing laboratories from May 1998. Soil samples from the Dooars are sent to the laboratory at the Nagrakata sub-station. This paper reports the sulphur status of Dooars soils based on the more than 5000 soils received between 1998 and 2003, as well as on the relationships observed between the pH, organic carbon and sulphur status of these samples, in the Dooars as a whole as well as in the seven sub-districts.

MATERIALS AND METHODS

Soil testing was done by standard methods for tea soils (Goswami et al., 2001). Soil pH was measured on 1:5 soil : neutral water solutions, organic carbon was determined by the Walkley-Black titration. Available sulphur (expressed as ppm S) was determined turbidimetrically on $CaCl_2$ extracts of soil. Available phosphate was determined using the Bray II extractant followed by

*Tea Research Association, Nagrakata Substation, Nagrakata 735 225, West Bengal, India

#Tea Research Association, Tocklai Experimental Station, Jorhat 785 008, Assam, India.

+Corresponding author, Orgrintec, 3, Anandapath, Ambikagirinagar, RG Baruah Road, Guwahati 786 024, Assam, India. email <nibirbarpujari@yahoo.co.in>

Table 2. Available sulphur in the tea soil of sub-districts of Dooars

Sub-district	Frequency of occurrence (%) of sulphur class (ppm S)				
	<20	21-40	41-60	61-80	>80
Dam Dim	26.76	28.25	24.63	11.09	9.28
Chulsa	30.29	25.85	22.46	11.11	10.29
Nagrakata	20.91	18.73	24.18	15.64	20.55
Binnaguri	21.20	28.62	26.27	12.49	11.42
Dalgaon	65.94	24.16	7.07	1.41	1.41
Kalchini	69.61	19.49	7.66	1.86	1.39
Jainti	69.35	20.97	7.26	2.42	0.00

phosphomolybic acid. A database of over 6000 soil samples was then created. Nursery soils, which are only tested for pH, were removed from the database. Samples where the pH was greater than 5.74 were omitted as such soils are unsuitable for growing tea. Similarly, soils showing abnormal levels of potash or sulphur were removed, as these were probably recently manured or amended. The final database had 5077 soils, the sub-district distribution of which is shown in Table 1. It can be seen that the study was based on samples comprising all seven sub-districts of the Dooars (shown from west to east in the first column of Table 1).

Table 1: Number of estates and samples comprising the database of Dooars tea soils

Sub-district	Number of	
	Estates	**Samples**
Dam Dim	23	938
Chulsa	20	855
Nagrakata	14	550
Binnaguri	16	1401
Dalgaon	17	778
Kalchini	19	431
Jainti	5	124
Total	**114**	**5077**

The survey included 114 out of approximately 180 member estates of the association. The fewest number of samples was received from the Jainti sub-district, which borders Assam, while the Binnaguri sub-district (Central Dooars) and Dam Dim sub-district, which is the western-most subdistrict of the Dooars were well represented in terms of soil samples.

RESULTS AND DISCUSSION

The distribution of available sulphur in the Dooars is shown in Fig 1. Compared to the tea soils of the Assam valley, the soils of Dooars are relatively high in available sulphur as reported by Chakravartee and Gohain (1994) on the basis of 98 soil samples. They also reported that 40 ppm available sulphur was the critical limit for tea. Approximately 43% of the tea soils of Dooars tested were higher in available sulphur than this critical limit.

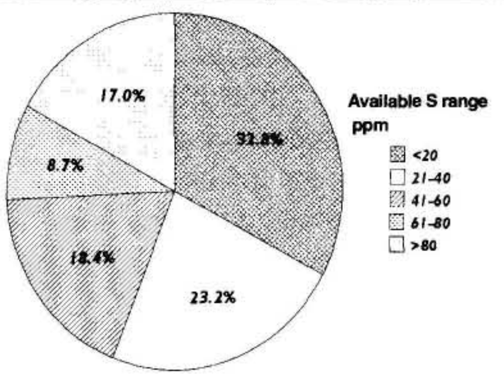

Fig. 1. Available sulphur status of 5077 tea soils of Dooars (frequency of occurence (%))

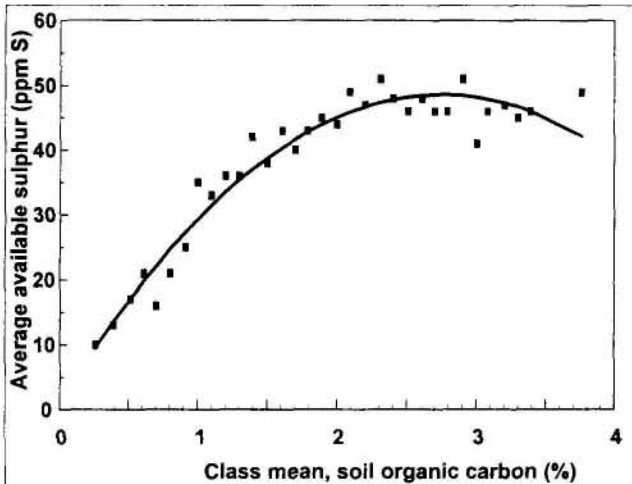

Fig. 2 Organic carbon status and available sulphur in tea soils of Dooars

The available sulphur status of the seven Dooars subdistricts is shown in Table 2.

There is a distinct difference between the four western districts on one hand and the three eastern ones on the other. The western districts have a lower proportion of soils with low available sulphur and higher proportion (over 40%) with sulphur levels higher than 40 ppm. In Nagrakata and Binnaguri district the proportion increases to over 50% and 60% respectively. On the other hand, only 10% or fewer of the soils of the three eastern districts have more than 40 ppm available sulphur. This cannot be related to soil texture as the Dam Dim and Binnaguri subdistrict soils are predominantly sandy, Chulsa and Nagrakata are loamy and Kalchini is silty. We speculate that the west to east gradient in available sulphur is due to climatic and soil formation factors. This needs to be studied further.

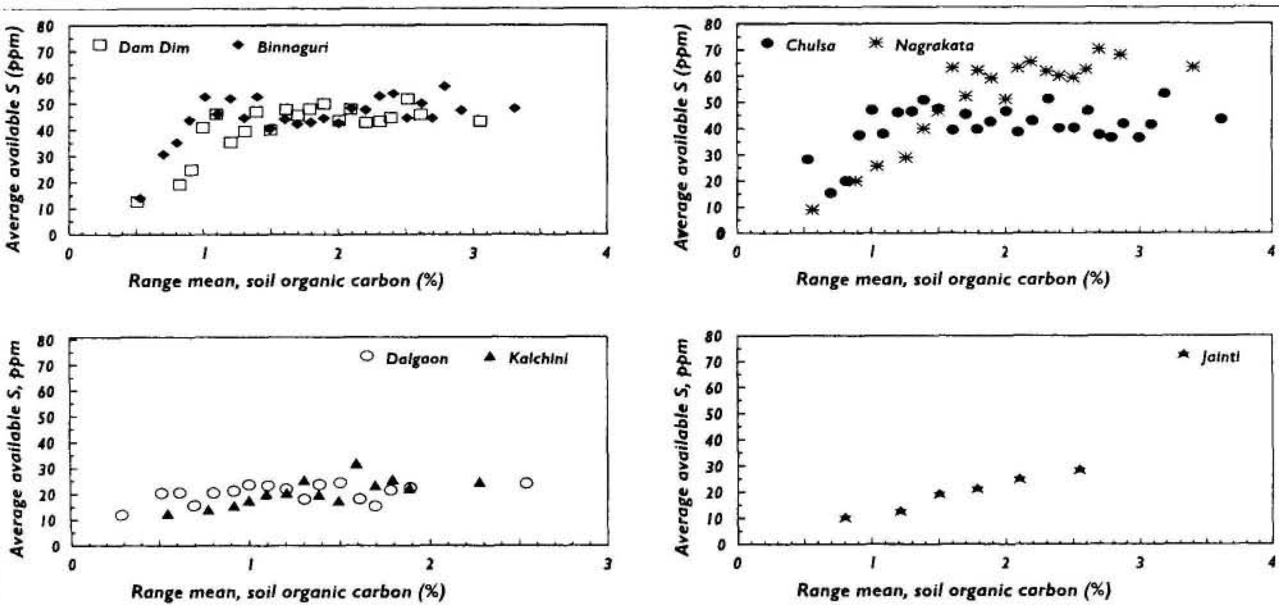

Fig. 3. Relationship between organic carbon and available sulphur in the tea soils of Dooars sub-districts

Chakravartee and Gohain (1994) correlated available sulphur to the organic carbon status of soils both in Assam and in Dooars. This was also observed in the present study (table 3). The frequency of low sulphur availability (<20 ppm S) is highest in soils

Table 3. Available sulphur in different organic matter classes of Dooars tea soils

Soil organic carbon range	No. of soils	Frequency of occurrence (%) of sulphur class (ppm S)				
		<20	21-40	41-60	61-80	>80
<1%	756	70.37	16.93	6.35	2.91	3.44
1-2%	2829	35.10	26.23	20.04	9.23	9.40
2-3%	1340	20.30	27.46	26.79	13.58	11.87
>3%	152	15.79	32.89	30.92	11.18	9.21

Table 4. Derivation of the relationship between organic carbon and available sulphur in tea soils of Dooars sub-districts

Sub-district	Organic carbon		Equation	Correlation (r^2)
	Lower grouping	Upper grouping		
Damdim	<0.75%	>2.64%	y = -11.925x2 + 51.813x - 7.7296	0.77
Chulsa	<0.65%	>3.24%	y = -5.0781x2 + 24.107x + 16.548	0.32
Nagrakata	<0.75%	>2.94%	y = -12.243x2 + 68.453x - 29.099	0.91
Binnaguri	<0.65%	>2.94%	y = -5.9431x2 + 28.151x + 16.743	0.45
Dalgaon	<0.45%	>1.94%	y = -1.8888x2 + 7.6623x + 14.469	0.23
Kalchini	<0.65%	>1.94%	y = -6.3281x2 + 25.635x - 0.9351	0.62
Jainti*	<1.05%	>2.24%	y = 11.048x + 1.2302	0.97

*Grouping for Jainti subdistrict at intervals of 0.3% organic carbon

Table 5. Available sulphur in different pH classes of Dooars tea soils

Soil pH range	No of soils	Frequency of occurrence (%) of sulphur class (ppm S)				
		<20	21-40	41-60	61-80	>80
<4	277	13.00	24.91	25.99	16.97	19.13
4-4.49	1649	22.07	25.41	26.32	12.67	13.52
4.5-4.99	1999	37.72	26.56	18.86	9.05	7.80
>4.99	1152	57.90	23.35	11.98	3.91	2.86

Table 6. Relationship between pH and available sulphur in the tea soils of subdistricts of Dooars

Subdistrict	pH range	Constant	Slope	Correlation
Damdim	4.15-5.74	142.00	-21.18	0.91
Chulsa	3.85-5.64	146.73	-22.37	0.92
Nagrakata	3.95-5.54	227.47	-38.27	0.91
Binnaguri	3.65-5.74	107.22	-13.48	0.84
Dalgaon	3.95-5.64	60.01	-8.12	0.74
Kalchini	4.15-5.54	77.09	-11.70	0.69
Jainti	4.45-5.44	50.45	-6.25	0.13
All Dooars	**3.55-3.74**	**138.17**	**-21.28**	**0.97**

Table 7. Frequency of occurrence (%) of organic carbon ranges in various soil pH ranges in tea soils of Dooars

Soil pH range	Organic carbon range				Number of soils
	<1%	1-2%	2-3%	>3%	
<4	2.53	55.96	35.38	6.14	277
4.0-4.5	5.28	59.79	31.66	3.27	1649
4.5-5	15.46	58.28	23.81	2.45	1999
>5	30.64	45.40	21.18	2.78	1152

where the organic carbon is less than 1% and decreases with increasing available sulphur. The trend is reverse in case of higher available sulphur ranges where the frequency increases with increasing organic carbon.

Chakravartee and Gohain (1994) postulated a linear relationship $y = 4.03 + 82.62x$ between organic carbon and available sulphur with a correlation $r^2 = 0.77$. In the present study, the mean available sulphur value was determined for each 0.1% organic carbon range (e.g. 1.05-1.14%, 1.15-1.24%), except where organic carbon was <0.35% or > 3.44%, giving 33 different organic carbon classes. The relationship, which is illustrated in fig. 2, can be described by a quadratic equation $y = -6.2922x^2 + 34.63x + 0.9551$, $r^2 = 0.9391$. It can be seen that the relationship is linear, upto about 1.5% organic carbon, levelling off thereafter. Examination of the graph presented by Gohain and Chakravartee (1994) also indicates a similar trend.

A similar analysis was conducted for each sub-district, with similar intervals but somewhat broader groupings at the lower and upper values of organic carbon as shown in table 4, which also shows the

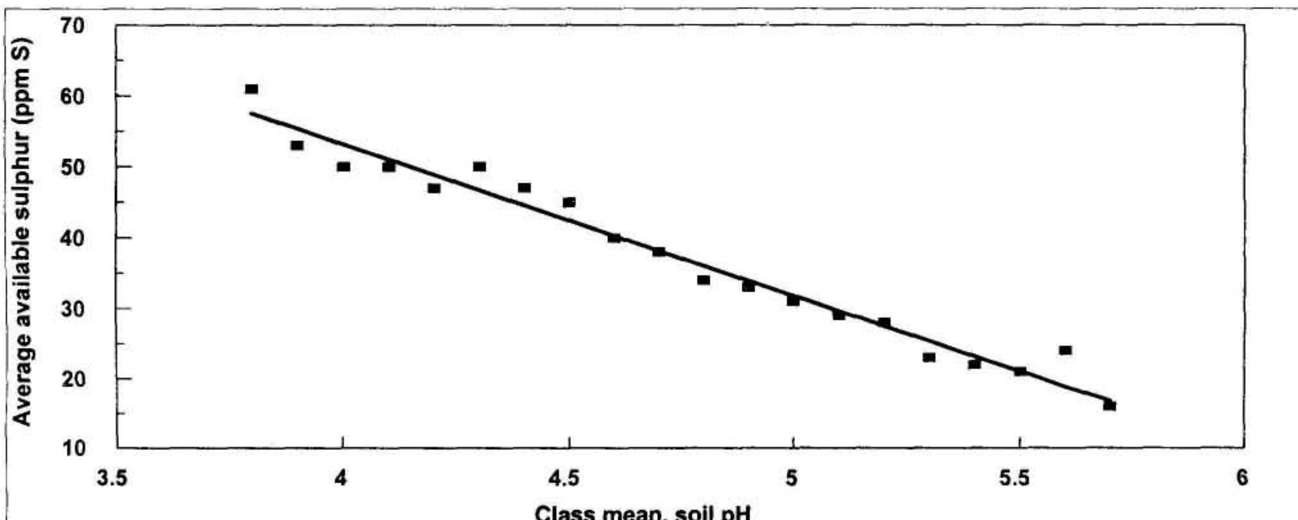

Fig. 4. pH and available sulphur in tea soils of Dooars

relationships derived for each sub-district between organic carbon and available sulphur status. The correlations are generally quadratic, with the exception of the Jainti sub-district, with the highest correlation being obtained in the Jainti and Nagrakata sub-districts. The Dam Dim and Kalchini sub-districts also show a similar high correlation, but the Chulsa, Binnaguri and Dalgaon sub-districts show relatively low correlation. This cannot be ascribed to soil type, geographical location, climate or even soil organic carbon status, so the reasons for the poor correlation in these sub-districts require further investigation. The relationships are graphically depicted in Fig. 3. This clearly shows the relatively lower available sulphur status of the three eastern sub-districts and the very high available sulphur status of the Nagrakata sub-district.

Table 8. Relationship between pH and organic carbon in the tea soils of subdistricts of Dooars

Subdistrict	pH range	Constant	Slope	Correlation
Damdim	4.15-5.74	3.02	-0.28	0.61
Chulsa	3.85-5.64	3.48	-0.32	0.65
Nagrakata	3.95-5.54	4.66	-0.59	0.84
Binnaguri	3.65-5.74	1.84	-0.02	0.10
Dalgaon	3.95-5.64	3.11	-0.40	0.74
Kalchini	4.15-5.54	2.24	-0.20	0.39
Jainti	4.45-5.44	1.64	0.03	0.002
All Dooars	**3.55-3.74**	**3.25**	**-0.34**	**0.94**

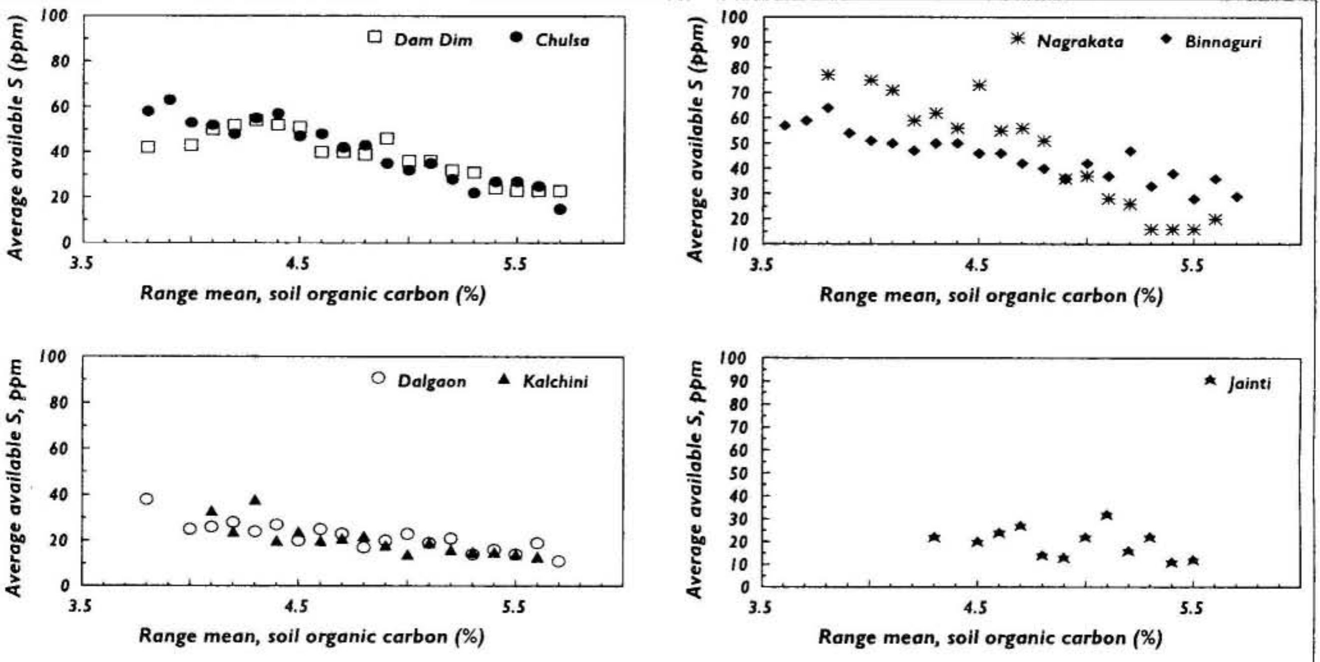

Fig. 5. Relationship between pH and available sulphur in the tea soils of Dooars sub-districts

The increase in available sulphur with increase in organic carbon status of soils is not surprising. Increased organic carbon normally results in increased microbial activity, resulting in increased mineralization (Stevenson, 1986). However, the reason for the differences in response between the western and eastern sub-districts, even in the same organic carbon ranges is not clear at present. Earlier work from Tocklai (Phukan *et al.*, 1994) has shown that there are

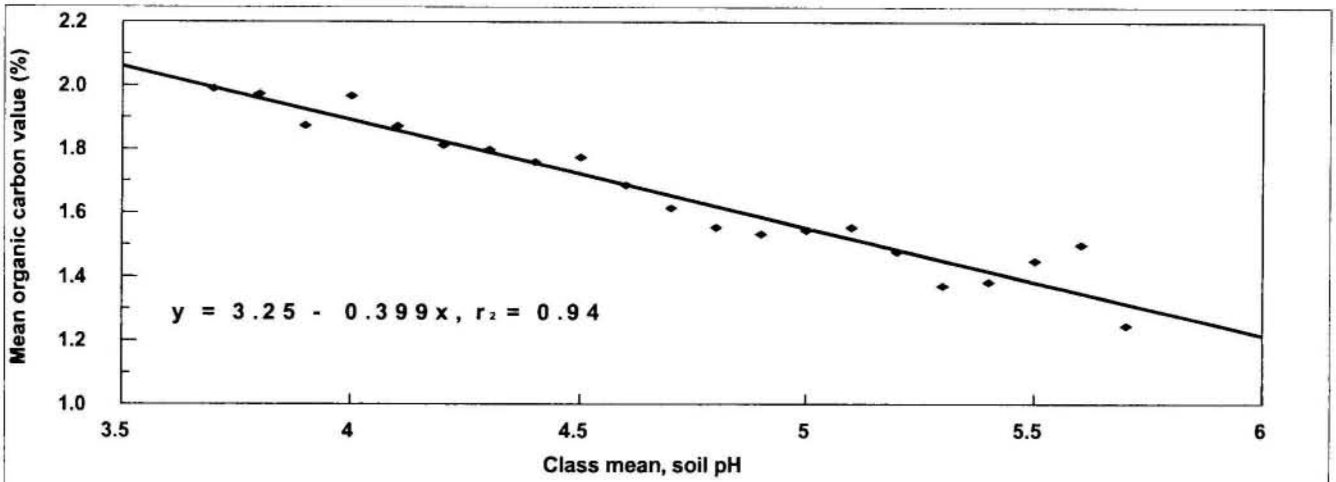

Fig. 6. pH and organic carbon in tea soils of Dooars

qualitative differences in organic matter composition between the various tea growing soils of Assam. Fractionation of organic matter in Dooars soils may throw some light on factors affecting sulphur mineralization in these soils.

A correlation was also observed between low soil pH and high available sulphur status of soils in this study. This is summarised in table 5. As pH increases, the frequency of soils with low available sulphur (<20 ppm S) increases, while those with available sulphur >40 ppm S decreases. Approximately 25 % of soils in each pH range has available S in the range
of 20-40 ppm S.

When the relationship between pH and mean available S at 0.1 pH intervals (e. g. pH 4.15-4.24) was determined, a strongly negative linear relationship with the equation y = -21.28x + 138.17 and correlation r^2 = 0.97 was obtained. This is shown in Fig. 4. This is contrary to the hypothesis formulated by Adams and Pearson (1967) based on the increased adsorption of sulphate by at lower pH values (Ensminger 1954, Nelson 1964). This observation is also surprising in light of the results of Acosta-Martinez and Tabatabai (2002) who have shown that activity of arylsulphatase, an enzyme involved in organic sulphur mineralization (Tabatabai, 1982), clearly increases with increasing pH from pH 4 to pH 7 in soils limed to different extents.

Table 6 shows that the negative relationship between pH and available sulphur is valid for all sub-districts of Dooars, though the slope is higher in the four western sub-districts than in the three eastern ones. The correlation also decreases from west to east, starting with the Binnaguri sub-district. The correlation is very poor in the Jainti sub-district, possibly a reflection on the relatively low number of samples from this area. These relationships are shown graphically in Fig. 5.

In the course of investigating the relationship between soil parameters and yield, George and Barpujari (2005) have observed that there is a negative relationship between soil pH and organic carbon status in 1734 soils of Dooars. This relationship also holds true for the present database, as shown in table 7, where it can be seen that there is a increasing frequency of soil with low (<1%)

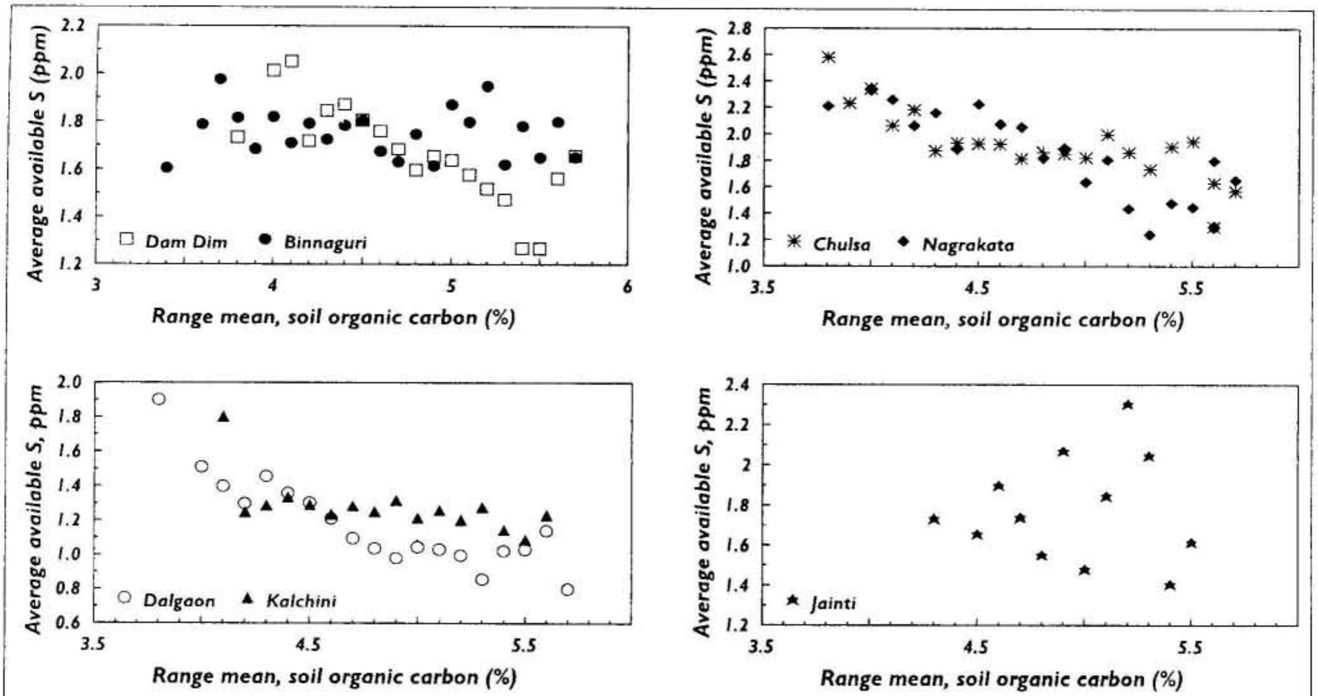

Fig. 7. Relationship between pH and organic carbon status in the tea soils of Dooars sub-districts

organic carbon as the soil pH range increases and a concomitant decrease in sections with higher soil organic carbon. Fig. 6 clearly shows the negative linear correlation between pH and organic for all 5077 soils of Dooars. While this relationship can be explained by the reduced microbial activity in highly acid soils, this does not explain the reason for high levels of available sulphur in these soils.

When the relationship between soil pH and organic carbon was determined for the various sub-districts of Dooars, it was observed that the negative linear relationship did not hold good for all subdistricts. Specifically, there was no impact of pH on the soils of Binnaguri sub-district, there was poor correlation between these two parameters in the Kalchini sub-district and the data from the Jainti sub-district was random (Table 8). This is also shown graphically in Fig. 7.

In summary:

1. Approximately 43% of the tea soils of Dooars have available sulphur status higher than 40 ppm, the crticial limit established for tea (Chakravartee and Gohain, 1994).

2. The four sub-districts in western Dooars had a higher frequency of high sulphur soils than the three sub-districts of eastern Dooars, suggesting a geographical basis for this trend.

3. There is a positive quadratic relationship between organic carbon status of soil and available sulphur as expected (Chakravartee and Gohain, 1994, Stevenson, 1986).

4. However, a negative correlation was observed between pH and available sulphur which is contrary to that

hypothesized in the literature (Adams and Pearson, 1967).

5. The observed negative correlation between soil pH and organic carbon may have some role in the above observation.

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