

THE CONDITION OF CEYLON TEA SOILS

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Quite obviously, if the tea industry is to give serious consideration to replanting, it is essential to know something of the general level of fertility of the soils which are to be replanted. During the past year we have been carrying out a soil survey designed to gain information about the general level of fertility of soils which have been under continuous tea cultivation using, where possible, undisturbed jungle and patna soils as indication of the original natural state.

It is by no means uncommon to hear sweeping statements to the effect that all the top soil in tea areas has been washed away, references to played out or exhausted soils and to the need for building up humus levels. Expressions of fear that high crop levels will rapidly exhaust our soils are also to be heard from time to time.

Few popular ideas about tea ever seem to stand up to examination, but in any case replanting is too expensive a project to be entered into without some information about the way in which Ceylon tea soils have stood up to continuous cultivation and cropping.

At the outset it is essential to stress the fact that there is no infallible means of testing or analysing soil which will give a simple index of its fertility or, more especially, its capacity for sustained fertility under good management. Working with a single perennial crop under a comparatively narrow range of climatic and geological conditions does, however, simplify the problem to some extent.

The fact of the matter is that soil is a most complex mixture, or system, of minerals, organic matter, and micro-organisms, the study of which is still in its infancy. However, nothing is achieved by the contemplation of difficulties and problems can only be solved by systematic investigation.

We decided first to carry out a broad survey of simpler characteristics, which task was allotted to the Agricultural Chemistry Department. At the same time we commenced a detailed study of the biochemistry of St. Coombs soil starting with the nitrogen cycle. This task was obviously given to the Biochemistry Department.

In my talk I intend to explain some of the findings of the broad survey and later in the day I will give you some more detailed explanation of the chemical and biochemical processes with which we are at present concerned.

It will not surprise you to learn that one of the simple characters examined in the survey was the total content of organic matter. In Ceylon tea soils the type of clay is such that organic matter is probably more important than it is in other soils with different types of clay. We actually measured the total carbon content and for our present purpose we can say that the carbon content multiplied by two gives a close approximation of the content of organic matter.

Another simple character which we could measure easily was the total nitrogen content. Nitrogen content alone gives perhaps less useful information than the total carbon content alone. The ratio of carbon to nitrogen is, however, expected to conform to a certain pattern.

If, in addition to nitrogen, the nitrogen present as ammonia and the nitrogen present as nitrate are both measured, some assessment of the biological activity is possible. Moisture content, and acidity or pH measurements, completed the examination of each individual sample.

For the purpose of this survey we preferred to dig pits down to 6 feet depth where possible, and to sample the soil from the sides of the pit in six inch slices down to two feet depth, and in larger slices at the lower levels. The slices were thoroughly mixed so that the analyses indicated the contents of layers of soil of definite thickness. Deep pits give a better idea of the general nature of the soil than shallow samples and abrupt changes from surface to sub-soil are more easily seen. The general picture presented by the sides of such a pit is generally referred to as a soil profile.

The results of the survey were, on the whole, remarkably consistent, and I will show you the figures for some typical profiles.

Naturally, we started work at St. Coombs. (Tables 1 to 5).

Table 1—*St. Coombs field No. 1. in course of replanting.*
Progress of plants in area so far replanted satisfactory.
Pits dug in area not uprooted

Depth	moisture %	pH	TOTAL ON DRY WEIGHT			
			Carbon %	Nitrogen %	Ammonia (Parts per million)	Nitrate
0-6"	20.33	4.0	2.72	0.27	8	6
6-12"	23.57	4.1	2.67	0.27	8	6
12-18"	25.35	4.2	2.11	0.23	8	14
18-24"	25.00	4.4	1.59	0.18	7	5
24-36"	26.06	4.3	1.28	0.14	7	4
36-60"	27.41	4.3	1.04	0.11	8	3
60-84"	29.28	4.9	0.88	0.09	7	5

Average 1.75

Table 2—*St. Coombs jungle. Relatively undisturbed jungle in same field.*

Depth	Moisture %	pH	TOTAL ON DRY WEIGHT			
			Carbon %	Nitrogen %	Ammonia (Parts per million)	Nitrate
0-6"	25.84	4.2	4.81	0.46	8	12
6-12"	23.37	4.3	2.45	0.28	3	6
12-18"	21.74	4.3	1.68	0.20	7	4
18-24"	19.17	4.3	1.55	0.16	8	3
24-36"	20.05	4.4	1.33	0.13	7	2
36-60"	20.59	4.7	0.81	0.08	5	2
60-84"	14.93	5.1	0.40	0.02	3	2
	16.50	4.6	0.34	0.02	2	2

Average 1.91

The pH figures shown are low because they are measured in a special way. In terms of figures given to estates they would be about 0.5 of a pH unit higher than those shown in the tables.

Table 3—*St. Coombs cultivated field compared to jungle*

Depth	Carbon		Nitrogen		Ammonia		Nitrate	
	Jungle	C. Field.	Jungle	C. Field	Jungle	C. Field	Jungle	C. Field
0-6"	4.81	2.72	0.46	0.27	8	8	12	6
6-12"	2.45	2.67	0.28	0.27	3	8	6	6
12-18"	1.68	2.11	0.20	0.23	7	8	4	14
18-24"	1.55	1.59	0.16	0.18	8	7	3	5
24-36"	1.33	1.28	0.13	0.14	7	7	2	4
36-60"	0.81	1.04	0.08	0.11	5	8	2	3
60-84"	0.40	0.88	0.02	0.09	3	7	2	5
Average	1.91	1.75	0.19	0.18	6	7	4	6

The top six inch samples include the jungle mulch which partly accounts for the richness of the jungle sample. Cultivation has incorporated some of this mulch in the cultivated soil which in the 6-12" and 12-18" layers shew more organic matter than the jungle soil. Some of the jungle mulch will decompose rapidly in the early years after clearing.

Although the jungle mulch is biologically active and shows both high ammonia and nitrate in the top six inches the cultivated and manured soil compares favourably with it. The nitrate contents of soil vary very rapidly over quite wide ranges but where they are in excess of the crop requirements—be it jungle or tea—they may wash down to lower horizons.

The nitrate figures must be considered in conjunction with the demand made by the plants growing in the soil. It is also important to realise that the nitrates are not necessarily formed in the layer in which they are found, as, not being held by the soil like ammonia, they tend to wash down.

The really remarkable thing about the jungle soils I have examined is the very superficial root system of the jungle flora. Very few roots are found below 6 inches or one foot. The top six inches of soil is very dark and there is an abrupt change at 6 inches to the familiar red or yellowish red soil.

Virgin patna soils may be even richer than jungle soils where they have been left undisturbed and not burnt off every year. The grasses appear to root deeper than the jungle.

St. Coombs patna soil is very dark down to 2 feet depth. From 2 to 3 feet the soil is still dark and changes from brown to red below 3 feet. This change of colour corresponds very roughly to the root system. One of the apparently richest soils we have examined came from undisturbed patna land on St. Coombs. (Table 4).

Table 4—*St. Coombs patna.*

Depth	Moisture %	pH	TOTAL ON DRY WEIGHT			
			Carbon %	Nitrogen %	Ammonia ^a (Parts per million)	Nitrate
0-6"	25.8	4.6	11.64	0.75	11	1
6-12"	27.1	4.7	5.68	0.40	9	1
12-18"	18.3	4.6	2.82	0.18	—	—
18-24"	12.6	4.6	1.75	0.12	—	—
24-36"	10.2	4.7	0.90	0.07	7	2
36-60"	13.3	5.0	0.51	0.02	—	—
60-84"	11.2	4.7	0.50	0.01	—	—

You will note that the top soil has something over 20 per cent. of organic matter in it. From the practical farming point of view it is really an acid heath soil and contains an excessive accumulation of organic matter. The nitrogen content is fantastic amounting to 15,000 pounds in the top acre six inches, equivalent to 75,000 pounds of sulphate of ammonia. The nitrogen is only very slowly available, the nitrate production rate being apparently very low. The growth of the patna flora, mainly grasses, did not suggest a very high nitrate supply. Tea clearings on such soils tend to make slow progress at first, but eventually may give very high yields.

Examination of fields, which have been opened up from patna land, indicates that the organic matter level falls considerably under cultivation when the original content is excessive. Patna soils require a good deal of detailed investigation for many are potentially good soils and some fine areas of tea have been opened up from them. My impression is that patna clearings are generally found to be 'slow starters' and this difficulty may possibly be overcome.

Before passing on to other areas it may interest you to see figures relating to a highly fertile soil from my garden which was opened from patna. (Table 5).

Table 5—Garden soil, St. Coombs. Dark brown layer 0-18", 18" and below red soil.

Depth	Moisture %	pH	TOTAL ON DRY WEIGHT			
			Carbon %	Nitrogen %	Ammonia (Parts per million)	Nitrate
0-6"	24.85	5.5	3.48	0.301	5	16
6-12"	26.60	5.5	3.48	0.211	6	15
12-18"	27.50	5.3	3.32	0.304	5	12

A great deal of lime has been added to raise the pH to 5.5 and, although much cattle bulk and compost have been dug in during the past 20 years, the organic matter content is below 7 per cent. The rate of nitrate production is very high. There is little doubt that liming greatly accelerates the rate of breakdown of organic matter and the content of 7 per cent. in the garden soil has only been maintained by heavy manuring with cattle bulk.

Where the pH of soil is naturally high, due to the presence of limestone, the organic matter in the soil is very low. Table 6 gives figures obtained from a tea field in Welimada district where there is an outcrop of limestone.

Table 6—High pH area—Welimada.

Depth	Moisture %	pH		TOTAL ON DRY WEIGHT			
		H ₂ O	KCl	Carbon %	Nitrogen %	Ammonia (Parts per million)	Nitrate
0-6"	16.95	6.3	5.6	0.78	0.082	5	16
6-12"	18.75	5.9	5.2	0.61	0.062	5	4
12-18"	20.05	5.9	5.3	0.53	0.057	4	3
18-36"	22.95	5.7	5.2	0.47	0.061	4	5
36-60"	24.40	5.5	5.3	0.44	0.047	5	10
Below 60"	16.15	5.8	5.3	0.13	0.013	6	4

You will note two columns of pH figures, the first of which gives values with which you are familiar. The second column corresponds to previous tables. Nearly

all our published figures are for values measured in water and correspond to the first column.

The total carbon and total nitrogen figures are very low and nitrate production is very high, although the high figures may be partly due to drought conditions and dry soil. In spite of the high nitrate production tea does not thrive in soils of such high pH. Just why tea dislikes soil of high pH value we do not know, but Mr. Tolhurst suspects that it may possibly be due to the fact that manganese or aluminium, for both of which tea apparently has a very high demand, become unavailable in neutral or very slightly acid soils.

More will be said about lime in my next paper and Mr. Tolhurst will refer to the tea bushes' need for lime or calcium, but I ask you to engrave upon your memory here and now the effects of any considerable quantity of lime upon tea soils.

We will now examine figures obtained for highly fertile low-country soils. (Table 7).

Table 7—*Low-country high yielding area—30 years old.*
 8-18" Dark layer.
 18-24" Lighter layer.
 24" and below yellow clay with red mottling.

Depth	Moisture %	pH	TOTAL ON DRY WEIGHT			
			Carbon %	Nitrogen %	Ammonia (Parts per million)	Nitrate
0-6"	23.50	4.4	2.50	0.207	14	5
6-12"	22.50	4.3	1.94	0.145	11	5
12-18"	21.15	4.4	1.47	0.117	12	4
18-36"	22.80	4.5	0.76	0.072	11	30
36-60"	25.60	4.7	0.37	0.036	11	57
Below 60"	25.15	4.8	0.24	0.022	9	39

At the higher soil temperatures breakdown of organic matter is rapid and there is not the same tendency for accumulation of peaty matter as noted at the higher elevations. Nevertheless the content of 5 per cent. organic matter in the top layers is quite high and is maintained under good management.

Biological activity is intense and the production of nitrates is far in excess of even the requirements of a complete cover of high yielding tea and vigorous green manure and shade trees. Considerable quantities of nitrate are washed down to a depth of 60 inches and over. The yield of the area in question is approximately 1,400 pounds per acre.

Table 8—*Low-country jungle close to above area.*
 0-12" Dark layer.
 12" and below yellow clay and red mottling.

Depth	Moisture %	pH	TOTAL ON DRY WEIGHT			
			Carbon %	Nitrogen %	Ammonia (Parts per million)	Nitrate
0-6"	25.10	4.8	2.76	0.226	13	0
6-12"	25.00	5.0	2.24	0.172	12	0
12-18"	25.80	5.1	1.28	0.114	10	0
18-36"	27.80	5.2	0.68	0.065	7	0
36-60"	28.65	5.2	0.36	0.036	8	0
Below 60"	27.50	5.2	0.31	0.028	8	0

} Less than one

Table 8 shows figures obtained from nearby jungle soil and from these it is evident that thirty years of high yields under good management have had little effect on the carbon and nitrogen status of the soil. The low nitrate in these jungle soils, which has been recorded on more than one instance, is probably due to the vigorous jungle growth which snaps up nitrates as soon as they are formed. The jungle in question is a secondary growth and is a tangled mass of vegetation. Figures for primary jungle comparable to the up-country figures given earlier are not so far available.

Now we will go to the other extreme and examine figures obtained from poor thin tea fields in the low-country at 350 feet elevation (Table 9) and up-country at 5,000 feet (Table 10).

Table 9—*Low-country. No marked horizons. Poor thin tea yielding 400 lbs. per acre.*

Depth	Moisture %	pH	TOTAL ON DRY WEIGHT			
			Carbon %	Nitrogen %	Ammonia (Parts per million)	Nitrate
0-6"	7.8	4.3	1.06	0.091	11	3
6-12"	9.0	4.3	1.12	0.077	11	2
12-18"	7.1	4.3	0.83	0.050	9	1
18-24"	7.3	4.3	0.67	0.032	8	1
24-36"	7.2	4.3	0.47	0.023	8	1
36-60"	3.7	4.5	0.38	0.010	8	1
60-84"	8.6	4.5	0.60	0.029	11	1

In the low-country the organic layers have either eroded or oxidised away and have not been replaced by leaf-fall, mulch and root activity. The soil ammonia is still high, but nitrate production is very low, especially in view of the poor growth.

Table 10—*Up-country. 0-12" Dark layer. 12" and below yellowish clay. Poor thin tea yielding under 300 lbs. per acre.*

Depth	Moisture %	pH	TOTAL ON DRY WEIGHT			
			Carbon %	Nitrogen %	Ammonia (Parts per million)	Nitrate
0-6"	16.9	5.2	3.32	0.233	19	2
6-12"	17.3	4.6	2.34	0.124	14	1
12-18"	22.2	4.5	1.18	0.097	10	1
18-36"	16.5	4.7	0.67	0.059	8	1
36-48"	13.0	4.8	0.64	0.029	7	0
48-66"	15.2	4.8	0.58	0.024	8	0

In the up-country soils the organic matter has persisted and is in fact rather higher than in nearby jungle. Ammonia is especially high, very much higher than in the jungle. Nitrate production is, however, very low in spite of low demand from the tea which yields under 300 lbs. per acre.

The low-country soil has deteriorated without doubt, and will require rejuvenation, probably by a period under a grass such as Guatemala grass. The up-country soil has all the appearance of having grown lazy and after studying the area for some time I have come to the conclusion that some hard working tea bushes would

put it right. The area in question is rather exposed to wind and heavy rain which is too much for the present debilitated tea bushes. Replanting such an area is problematical, but an experiment in the area will be most interesting. My impression is that vigorous clones under a good stand of shade trees with carefully sited wind-breaks will do well in the area. Since I wrote this talk, however, Mr. Tolhurst has found some evidence of a possible shortage of magnesium and I think you will find his lecture this afternoon to be of considerable interest. Up-country soils show remarkably little evidence of deterioration under the most adverse conditions. Below about 3,000 feet there is apparently a tendency for soils to deteriorate more rapidly unless they are kept under a good cover of tea. Declines at lower elevations are of a vicious type because poor tea may beget poor soil.

Finally some figures from a Gampola small holding are of very great interest. (Table 11).

Table 11—*A Gampola small holding.*

Depth	Moisture %	pH	TOTAL ON DRY WEIGHT			
			Carbon %	Nitrogen %	Ammonia (Parts per million)	Nitrate
0-6"	11.4	4.6	0.82	0.073	4	3
6-12"	12.6	4.6	0.49	0.051	3	14
12-18"	13.4	4.7	0.26	0.031	3	19
18-36"	13.7	4.8	0.10	0.017	4	24
36-60"	10.55	4.9	0.09	0.011	3	13
Below 60"	12.7	4.9	0.02	0.009	3	10

The tea is alleged to be 80 years old and there are about 700 bushes per acre growing on bare scraped soil. There is of course no horizon to be seen as the top soil has undoubtedly been scraped and eroded away.

I can only describe it as a noble soil putting up a gallant struggle.

Soil temperature conditions, especially under full exposure to the sun, will be high and the organic matter is rapidly oxidising away. The nitrate production is remarkably high but there are so few plants to use it up that it washes down to the lower horizons. Even after such criminal abuse it would probably improve quite rapidly under reasonable management.

Table 12—*Abandoned tea and mana grass.*

Depth	Moisture %	pH	TOTAL ON DRY WEIGHT			
			Carbon %	Nitrogen %	Ammonia (Parts per million)	Nitrates
0-6"	9.7	4.5	0.50	0.040	3	1
6-12"	11.2	4.6	0.23	0.022	3	2
12-18"	11.5	4.7	0.12	0.011	2	2
18-36"	11.4	4.7	0.13	0.012	4	2
36-60"	18.7	4.9	0.13	0.014	4	2
Below 60"	23.9	5.0	0.07	0.014	4	2

Table 12 shows a more advanced case of deterioration in the same area where the carbon content is down to 0.5 per cent., *i.e.* about 1 per cent. organic matter. Mana grass has become established for the past 20 years but is of course burned off at frequent intervals. Erosion continues between the grass clumps especially after burning. Nevertheless the grass is taking up the nitrate and would return it to the soil, and build up the organic matter if it were not burnt.

The soils from the north east monsoon area gave very much the same picture as the soils I have described. None of the patnas were anything like so rich as the St. Coombs patna described earlier, but in every case there was a history of burning or disturbance for food production and we could not describe them as virgin patna.

The survey of carbon, nitrogen, ammonia and nitrate contents has, I think, given very useful results and enables us to draw some general conclusions. I hope the survey will be continued and that many other characteristics will be measured, especially the general nutrient status and the total capacity for storing nutrients. It is, however, a long and tedious task and to have attempted too much in the preliminary survey would have confined our efforts during the year to St. Coombs or the up-country south west zone at the outside.

Later in the Conference other aspects of replanting besides the planting material and the soil will be considered. Eelworm, root diseases, and shot-hole borer all have to be taken into account, but from the Agricultural Chemist's point of view I think it can be fairly said that we are blessed with remarkably good, stable and tolerant tea soils. After a very long period of monoculture there are few signs of deterioration, at least at higher elevations under the estate system of management, and there are no apparent reasons why replanting with selected material should not be a great success.

Below 3,500 feet it is particularly important to maintain a cover over the soil, but where the history of management has been a good one this supports rather than opposes the case for replanting with vigorous, spreading types of bushes.