BIOCHEMICAL STUDIES ON THE ORGANIC MATTER IN CEYLON TEA SOILS

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This paper deals with investigations of a preliminary nature carried out during the years 1953—1957 on the biochemical aspects of organic matter in Ceylon tea soils. The investigations were generally confined to cultivated soil from St Coombs Estate (elevation 4,500′ AMSL), but the results of experiments on tea soils from other elevations, when they relate to the subject of this article, have also been included.

Studies on the organic-matter status of Ceylon tea soils have so far been mostly confined to the assessment of the total carbon and total nitrogen contents; the results, though useful in many respects, do not indicate the *nature* of the nitrogen in the soil, particularly that fraction of the nitrogen which is mineralised to ammonia, nitrites and nitrates by the soil microbes and is thus made available as plant food. For example, up-country tea soils are very rich in organic nitrogen, but a large part of it appears to be resistant to mineralisation by soil microbes and therefore unavailable as food; the total nitrogen content of these soils does not indicate the immediate fertility of the soil.

The rate and degree of mineralisation by the soil microbes can be studied under controlled laboratory conditions. The results of such experiments may not truly represent the changes that occur under natural conditions in the field, but they do indicate to some extent the fraction of the organic nitrogen susceptible to mineralisation.

It has been shown (Tolhurst, 1956) that organic matter in tea soils in both the low country and the up country is high though variable, whilst it is uniformly low in the mid-country. It is possible that the rate of mineralisation of organic nitrogen in the mid-country soils is equal to if not more rapid than the build up of organic nitrogen from prunings and old leaves from tea and shade trees, etc. On the other hand, in the up-country tea soils there appears to be a highly resistant nitrogen fraction which is difficult to mineralise. In Part I of this article, preliminary studies on the fractionation of organic matter in an up-country tea soil (St Coombs estate), and the susceptibility of these fractions to mineralisation when incorporated into the soil, are reported. In Part II, experiments conducted to evaluate the proportion of the organic nitrogen susceptible to mineralisation in tea and jungle soils from districts at different elevations and with differing climatic conditions are described; studies on the rate and degree of mineralisation of organic nitrogen in up-country tea soils are also included.

PART I.—SOIL ORGANIC MATTER

In the study of the organic matter in Ceylon tea soils, attention has mainly been directed towards the determination of the total carbon content. Even though the amount of soil organic matter can be calculated roughly from the carbon content, the factor used for this purpose has been disputed, since the composition of the organic matter varies widely in different soils. A fractionation study, on the other hand, is likely to be more useful, because it could throw some light on the nature of the resistant and susceptible fractions present in tea soils.

Before attempting the fractionation of the soil organic matter, a method of extraction which will cause the minimum possible changes in its physico-chemical properties must be used; since classical methods involve the use of strong alkali, a study of the milder and neutral reagents was made by Bremner & Lees (1949). A similar approach was made to the extraction of the organic matter from tea soils using both alkaline and neutral reagents. The effect of various regeants on the solubility of the organic nitrogenous compounds in tea soil under two different experimental conditions is given in the following tables (Tables 1 & 2).

TABLE 1.—*Effect of various reagents on the solubility of the organic nitrogen in tea soil*

(St Coombs, Field No. 10, 0–6" layer) (Results expressed as % total organic nitrogen extracted)

Reagents	Strength of the reagent (M)	Four consecutive washings of 24 hrs duration in a separating funnel		Occasional shaking of the soil with the reagent for 24 hrs Single extraction (Soil sample 1)
		Soil sample 1	Soil sample 2	
potassium dihydrogen orthophosphate (KH_2PO_4)	0.1	5	—	—
di-potassium hydrogen orthophosphate (K_2HPO_4)	0.1	8	—	—
tri-potassium orthophosphate ($K_3PO_4.H_2O$) ...	0.1	28	32	11
potassium pyrophosphate ($K_4P_2O_7$)	0.1	28	50	30
potassium pyrophosphate neutralised with hydrochloric acid	0.1	—	41	21
tri-potassium orthophosphate neutralised with hydrochloric acid	0.1	—	16	5
potassium fluoride ($KF.2H_2O$)	0.5	23	61	23
potassium oxalate ($(COOK)_2.H_2O$)	0.2	14	—	-
potassium citrate ($K_3C_6H_5O_7.H_2O$) ...	0.2	16	—	—
sodium DL-tartrate ($(CH(OH).COONa)_2H_2O$)	0.2	11	—	—
potassium hydroxide (KOH)	0.5	24	39	51

TABLE 2.—*Effect of various reagents on the solubility of the organic nitrogen in a tea soil profile*

(St Coombs, Field No. 9). (Results expressed as % total organic nitrogen extracted)

Reagents	Strength of the reagent (M)	Soil profile	
		0—2"	2—6"
potassium pyrophosphate, neutralised with hydrochloric acid	0.1	29	31
potassium fluoride	0.5	50	45
potassium hydroxide	0.5	32	29

Of the various reagents tried, potassium fluoride was found to be the best; apart from being a neutral reagent, the percentage of extraction of organic nitrogen was found to be comparable to, or even greater than, that of potassium hydroxide.

An experiment was next carried out to determine the optimum strength of the potassium fluoride reagent for the maximum extraction of the organic nitrogen. Typical results for one soil sample are presented in Figure 1.

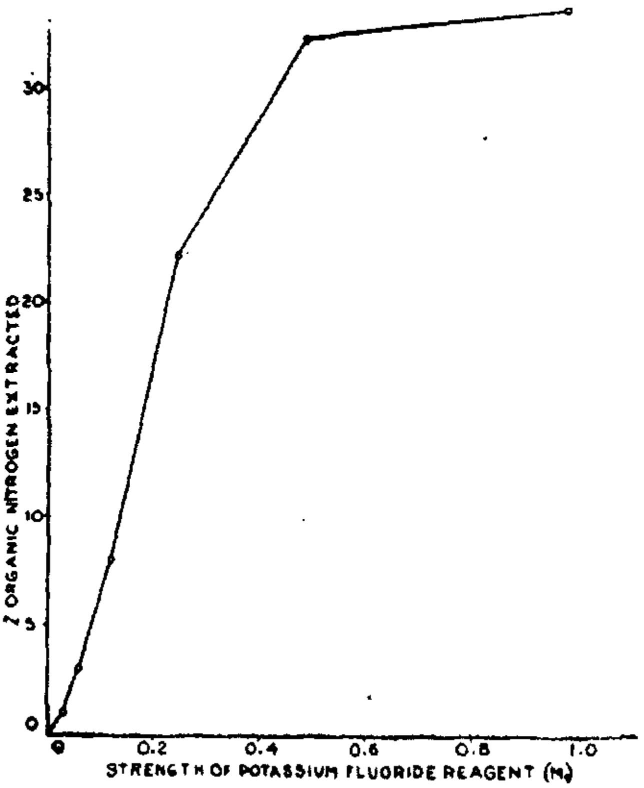

Fig. 1—Extraction of soil organic nitrogen by potassium fluoride reagent.

The optimum strength was found to be about 0.5 M.

The organic matter extracted with the potassium fluoride reagent was next dialysed against distilled water, to remove the inorganic constituents, and it was found that part of the organic nitrogen was also dialysed. The dialysable fraction of the nitrogen represented ammonia, nitrites, nitrates, probably also with amino-acids. Between 8 and 16 per cent of the toal organic nitrogen was found to dialyse. The results are shown in Table 3.

TABLE 3.—*Dialysable fraction of organic nitrogen*

St Coombs Field No.	Profile	Total organic nitrogen		Dialysable organic nitrogen as % total organic nitrogen
		Before dialysis mgs	After dialysis mgs	
8	0—2"	40.0	35.5	11.2
10	0—2"	20.4	17.2	15.7
	2—6"	16.9	15.0	11.2
2	0—2"	16.0	14.8	7.5
	2—6"	12.2	11.2	8.2

The organic matter extract after dialysis was fractionated into humic and fulvic acid fractions by treatment with dilute sulphuric acid to pH·3.0.

The susceptibility to mineralisation of the humic and fulvic acid fractions of the organic matter from St Coombs cultivated soil (Field No. 9, 0—2" layer) when incorporated with the same soil and incubated at 30° C for 4 weeks (moisture 33%) was estimated. For purposes of comparison similar fractions obtained by the initial extraction of the soil with alkali were also incubated with the soil. The results are shown in Table 4.

TABLE 4.—*Percentage mineralisation of nitrogen in organic matter fractions when incorporated into tea soil.*

(Results expressed as % mineralisation of organic nitrogen).

Organic matter fraction	Organic matter extracted by	
	Potassium hydroxide 0.5M	Potassium fluoride 0.5M
Humic acid	10.7	1.7
Fulvic acid	27.8	62.4

The humic acid fraction obtained by treatment with alkali appeared to be less resistant to mineralisation than that obtained from potassium fluoride. The fulvic acid fraction obtained from alkali treatment, on the other hand, was found to be more resistant to mineralisation than that obtained from potassium fluoride. The large differences found are probably due to changes in the physico-chemical properties of the organic matter caused by treatment with alkali, as suggested by Bremner & Lees (1949). It is likely that metallic cations are more easily removed from the organic complexes, with less effect on their physico-chemical properties, by potassium fluoride reagent (which is neutral in reaction) and thus render the fulvic acid fraction more labile for mineralisation by the soil microbes.

The fractionation of the organic matter in poor and in rich cultivated tea soils was next carried out. For this purpose, tea yield figures from the various fields at St Coombs estate for a consecutive period of five years (1950 to 1955) were obtained by courtesy of the Superintendent, Mr E. S. Rose. It was found that field No. 10 gave an average yield of 1161 lb. made tea per acre per annum, the highest for this estate at that time, while field No. 2 gave 746 lb. made tea per acre per annum, the lowest figure. It was expected that the organic matter fractions in the soil from these two fields would show large differences. The results are shown in Table 5.

TABLE 5.—*Organic matter fractions of soil from high and low yielding fields at St Coombs estate*

Analysis for:	High-yielding field		Low-yielding field	
	Profile		Profile	
	0—2"	2—6"	0—2"	2—6"
Total organic nitrogen (% of soil) ...	0.363	0.315	0.305	0.254
Organic nitrogen extracted by potassium fluoride reagent (% of soil) ...	0.102	0.085	0.080	0.061
Dialysable fraction of extracted organic nitrogen (% of soil)	0.016	0.010	0.006	0.005
Organic nitrogen in humic acid fraction (% of soil)	0.043	0.035	0.026	0.015
Organic nitrogen in fulvic acid fraction (% of soil)	0.041	0.038	0.037	0.035
Percentage absorption of light of potassium fluoride extract (5 mm. cell) ...	88	84	53	27

The total organic nitrogen as well as the various nitrogenous fractions, other than the fulvic acid fraction, appear to be higher in the high-yielding field than in the low-yielding area. The large differences in the percentage absorption of light by the organic matter extract indicate the presence of a large amount of dark-coloured organic complexes in the high-yielding field. The low-yielding field (No. 2) is adjacent to field No. 1 and more or less similarly situated. It has been shown earlier (Tolhurst 1956a; Elias 1960) that the difference in behaviour to replanting between Field No. 10 and Field No. 1 is probably due to the following: (1) Field No. 10 was brought into cultivation from a rich patna area, whilst field No. 1 was formerly a jungle area; (2) Field No. 10 was planted in 1931 whilst Field No. 1 has been under cultivation since the 1880's; (3) there appears to be a slight difference in the annual rainfall in the two areas; (4) Field No. 1 has a steeper terrain than Field No. 10; and (5) the direction of the slope in the two areas is different. Similar differences exist between Fields Nos. 10 and 2 (which is similar to No. 1) and have probably been responsible for the differences in the organic matter status of the two fields.

Summary

1. Results of preliminary investigations on the fractionation of the soil organic matter in up-country tea soils (St Coombs estate) and the susceptibility to mineralisation of these fractions when incorporated into the tea soil are reported.

2. Potassium fluoride (0.5M) appears to be a better reagent for the extraction of organic matter in up-country tea soils than other neutral and alkaline reagents tried. The different reagents give about the same degree of extraction, but potassium fluoride, being neutral, is likely to cause the minimum changes in the physico-chemical properties of the organic matter.

3. The degree of mineralisation of the fulvic acid fraction of the organic matter extracted by potassium fluoride reagent (and incorporated into the soil), was found to be more than twice as much as the same fraction obtained from potassium hydroxide.

4. A comparative study of the organic matter fractions from the high-yielding and low-yielding fields at St Coombs showed that the high-yielding field was superior to the low-yielding field in its total organic nitrogen content as well as in available nitrogen.

PART II. MINERALISATION OF SOIL ORGANIC NITROGEN UNDER CONTROLLED LABORATORY CONDITIONS

The soil organic matter consists of humified and unhumified material from dead plants and animals, in different stages of decomposition, which is caused predominantly by soil micro-organisms including fungi. The mineralisation of organic nitrogen probably takes place through the following stages (Russell, 1950):

Organic nitrogen —> ammonia —> nitrites —> nitrates

These changes occurring in the field may be studied in the laboratory by incubating the soils under standard conditions. The rate of mineralisation found under these conditions is probably not exactly the same as the rate of similar change occurring under cultivated field conditions; however, the amount of decomposable organic nitrogen and the nature of the mineralised product can be assessed. The results of various experiments carried out in this connection on Ceylon tea soils are briefly described in this section. The determination of the ammonia and the nitrate was carried out according to a modified method (Ramaswamy, in press).

1. Fraction susceptible to mineralisation of organic nitrogen in tea soils from different elevations

It has been found that the soil micro-organisms become active only in the presence of sufficient water. For example, dry soils may be preserved for very long periods without any change in their mineral nitrogen content; but by subjecting the soils to a process of alternating moist and dry conditions, it appears to be possible alternately to activate and inactivate the life processes of these soil microbes. By this process, the susceptible fraction of the organic nitrogen is mineralised gradually. The following experiment was conducted to determine the number of such alternate wetting and drying processes required to give the maximum possible degree of mineralisation of organic nitrogen.

Tea soils from St Coombs and four other estates at different elevations were air-dried and spread to about a quarter-inch thickness on porcelain plates. The soils were wetted with a fine jet of distilled water to just below the saturation point (pre-determined) and allowed to air-dry in the laboratory (temperature variation 20–25°C). Depending upon the weather conditions, the soils took between 2 and 10 days to dry. The soils were wetted and dried again; the process of wetting and drying was continued several times. The mineralised nitrogen was determined at intervals. It was found that the organic nitrogen mineralised easily to ammonia, but subsequent conversion to nitrites and nitrates was negligible during the whole period. The rates of mineralisation of the organic nitrogen in various soils are shown in Fig. 2.

It may be seen from Fig. 2, that there was a rapid mineralisation of organic nitrogen up to the 36th wetting and drying treatment, after which the increase was small. The percentage mineralisation at this stage may, therefore, be taken to represent approximately the susceptible fraction.

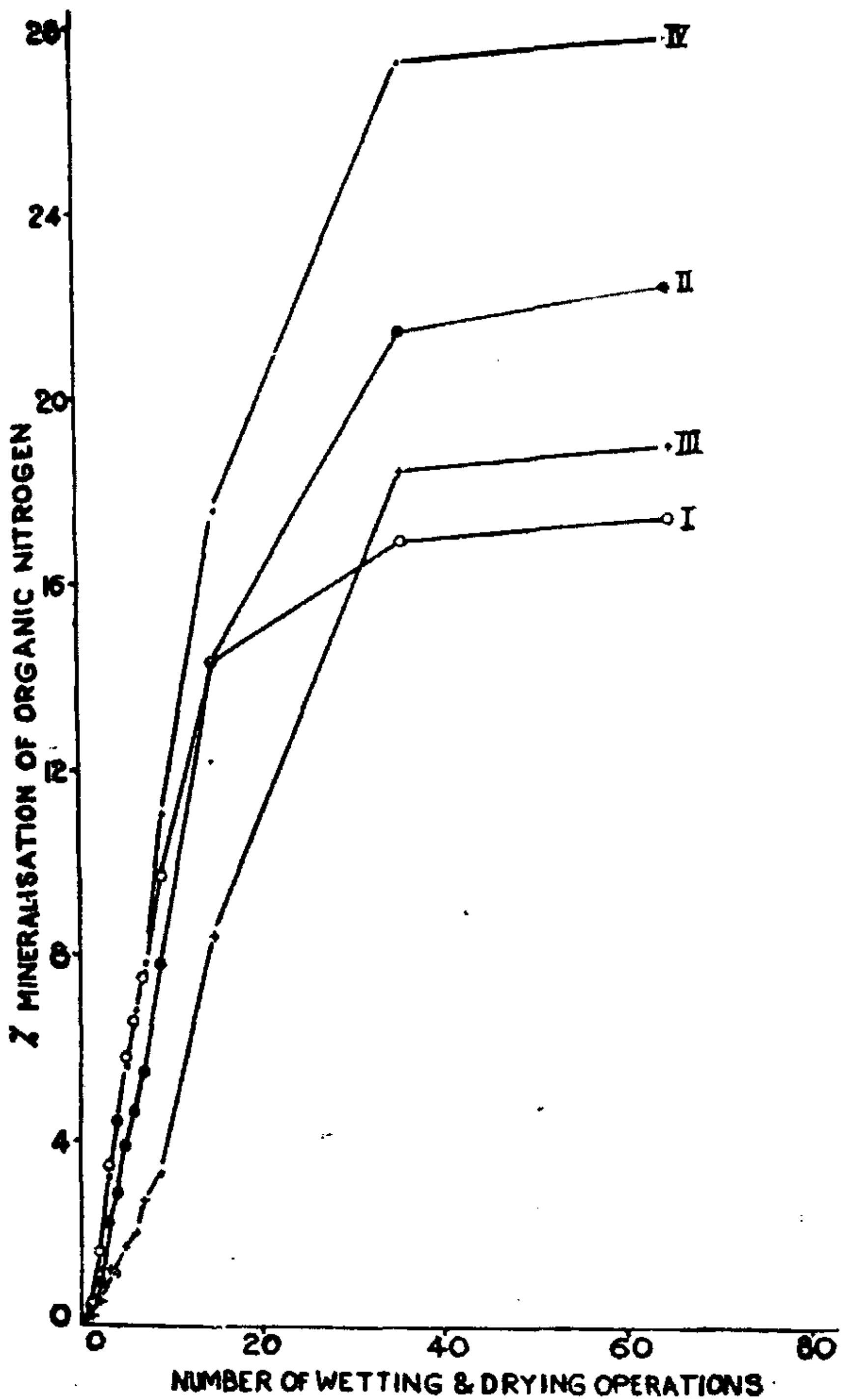

Fig. 2 Susceptibility to mineralisation of organic nitrogen from tea soils at different elevations (by alternate wetting and drying method).

I. St Coombs, 0-2" soil (elevation 4500' AMSL); II. St Coombs, 2-6" soil; III. Endane, 0-6" soil (elevation 1300' AMSL); IV. Sapumalkande, 0-6" soil (elevation 600' AMSL).

It may also be seen from Fig. 2, that the organic nitrogen in the 2–6" layer of the soil (St Coombs) was found to contain a higher percentage susceptible to mineralisation than that in the top 2" of the soil.

The changes in the pH of the soils during the period of test were also determined. All the soils showed a steady increase in pH and this was found to vary between 30 and 50 times the initial hydrogen ion concentration.

A sample of the soil from one other district (Dartry, elevation 2,400′ AMSL, 0–6" layer) was also treated along with the above set, but this soil was found to contain initially a large amount of exchangeable ammonia (967 ppm as nitrogen on dry soil). This high figure could not have been due to manuring since the field from which the soil was sampled was manured two months prior to sampling and there had been a rainfall of about 19 inches during this interval. (It was found on No. 8 field, St Coombs that the amount of exchangeable ammonia, after manuring with TRI-500 mixture, dropped to normal levels of 3 to 8 ppm nitrogen within 4 to 7 weeks during which there had been a rainfall of only 1.44 to 9.35 inches). The mineral nitrogen contents of this Dartry soil dropped steadily (to 736 ppm nitrogen on dry soil) during the period of test. This soil also showed an increase in pH, but to a lesser extent (only five-fold) than the other soils studied. Because of the peculiarity of the soil, and since apparently no organic matter appeared to have been mineralised, the results for this soil are not shown in Fig. 2.

A number of tea and jungle soils (0–6" layer) from districts at different elevations and with different climatic conditions were next examined by the wetting and drying method. In this experiment also, no appreciable amounts of nitrites and nitrates were formed; ammonia was found to occur predominantly. The results are represented in Figures 3 & 5 while the total organic nitrogen content are shown for purposes of comparison in Figures 4 & 6.

The results indicated that the susceptible fraction of the organic nitrogen was generally higher in the tea soils than the jungle soils; it was also found to be higher in the mid-country soils than in the up-country soils in both the S.W. and the N.E. monsoon zones. Sufficient information about the low-country tea soils could not be obtained as only one sample from districts below 1,000 ft elevation was available. From these results, it is possible to speculate about the nature of changes that occur in the organic nitrogen in the mid-country districts. It would appear that in this region, particularly under the prevailing climatic conditions (frequently alternating wet and dry conditions) the rate of mineralisation of the organic nitrogen may be expected to be equal to if not higher than any building-up processes.

The susceptible fraction of the organic nitrogen in soils from different elevations (both in S.W. and N.E. monsoon zones) was found to decrease as the elevation increased while the total organic nitrogen increased as the elevation increased. The statistical significance of these results is shown in Table 6.

TABLE 6.—*Correlation coefficients on the relationship between elevation and the susceptible and total organic nitrogen in soils*

	Susceptible fraction of organic nitrogen, and elevation		Total organic nitrogen, and elevation	
	Tea Soils	Jungle Soils	Tea Soils	Jungle Soils
Correlation coefficient	—0.702	—0.839	+0.796	+0.783
t (calculated)	3.425	4.086	4.570	3.334
t (tabulated) @ 1% probability ...	3.055	3.499	3.055	—
t (tabulated) @ 2% probability ...	—	—	—	2.998

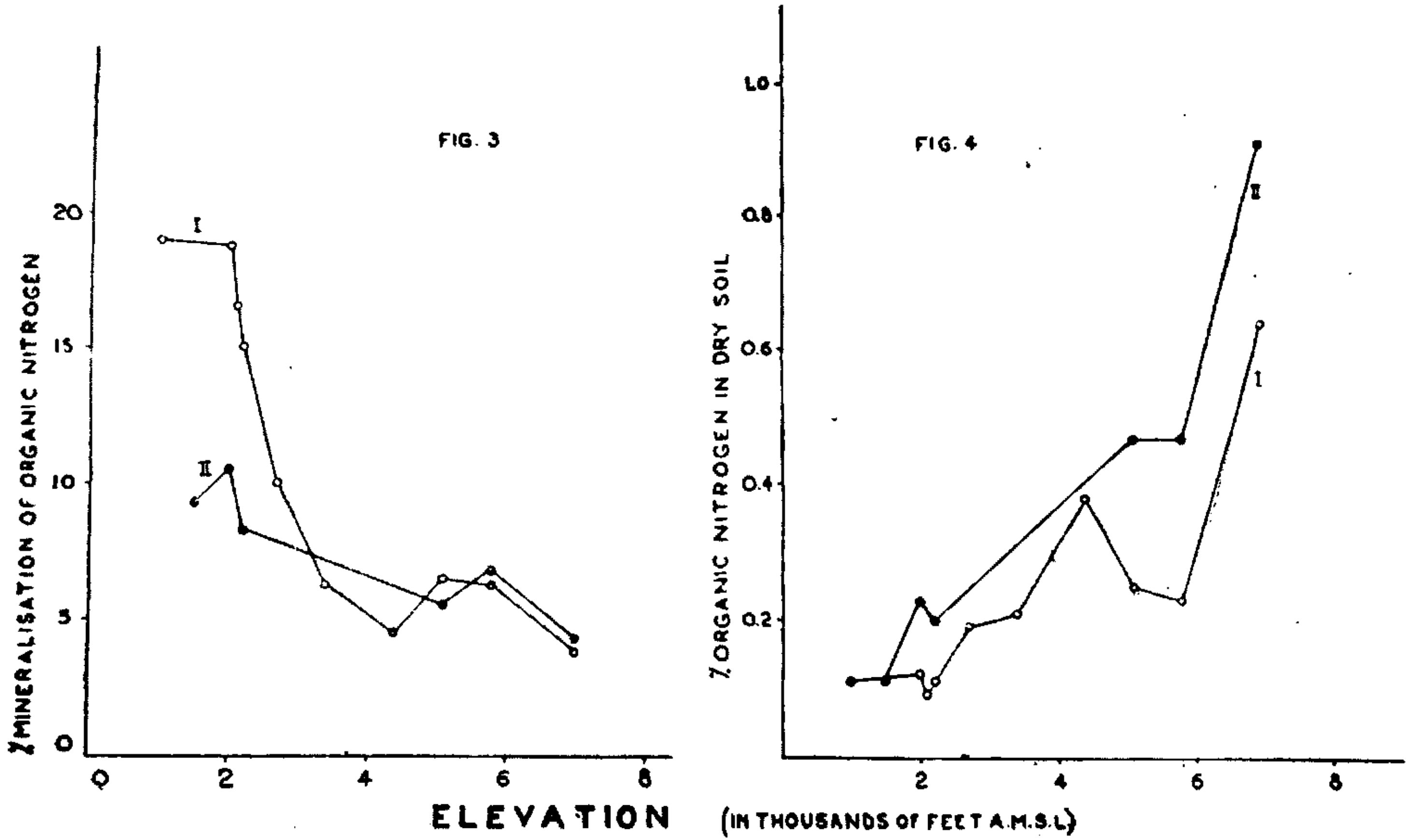

Fig. 3—Percentage mineralisation of organic nitrogen in the tea (I) soils and the jungle (II) soils from districts at different elevations in the S.W. Monsoon zone.

Fig. 4—Organic nitrogen content of the tea (I) soils and the jungle (II) soils from districts at different elevations in the S.W Monsoon zone.

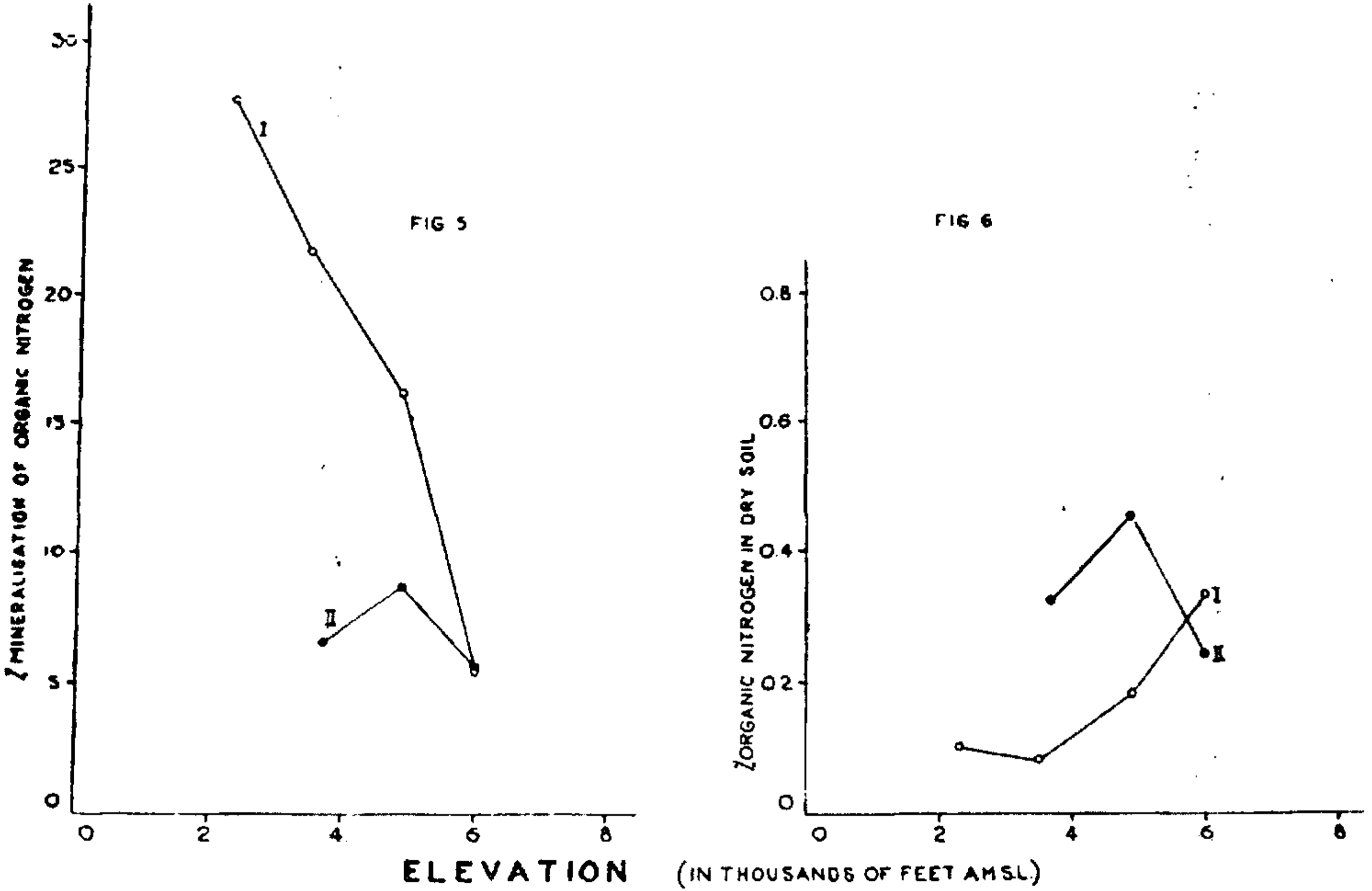

Fig. 5—Percentage mineralisation of organic nitrogen in the tea (I) soils and the jungle (II) soils from districts at different elevations in the N.E. Monsoon zone.

Fig. 6—Organic nitrogen content of the tea (I) soils and the jungle (II) soils from districts at different elevations in the N.E. Monsoon zone.

Table 7.—*Mineralisable organic nitrogen in different soils, expressed as tons of ammonium sulphate per acre*

S.W. Monsoon Zone						N.E. Monsoon Zone					
Tea Soils			Jungle Soils			Tea Soils			Jungle Soils		
Estate No.	Elevation ft	Tons of $(NH_4)_2SO_4$ per acre	Estate No.	Elevation ft	Tons of $(NH_4)_2SO_4$ per acre	Estate No.	Elevation ft	Tons of $(NH_4)_2SO_4$ per acre	Estate No.	Elevation ft	Tons of $(NH_4)_2SO_4$ per acre
1	100	12.8	1	1,500	5.8	1	2,300	12.0	1	3,700	11.2
2	1,000	10.4	2	2,000	13.6	2	3,500	8.4	2	4,900	17.5
3	2,000	9.9	3	2,200	8.3	3	4,000	8.0	3	6,000	14.1
4	2,100	7.3	4	5,100	17.5	4	6,000	11.2			
5	2,200	7.6	5	5,800	17.3						
6	2,700	9.2	6	7,000	28.0						
7	3,400	7.3									
8	4,400	9.6									
9	5,100	8.9									
10	5,800	7.6									
11	7,000	16.8									

Laboratory incubation studies showed that most of the mineralised ammonia in these experiments was available (under conditions suitable for nitrification) for conversion to nitrites and nitrates by the nitrifying organisms.

As a matter of general theoretical interest, the amount of mineralised nitrogen in all the soils investigated was expressed as tons of ammonium sulphate per acre (assuming two million pounds of soil per acre, 6" deep), and the data are given in Table 7.

These figures give a rather surprising picture of the available organic nitrogen in Ceylon tea soils. Moreover, the data are in no way exhaustive; only the top six inches have been considered and the mineralisable fraction of the total organic nitrogen may in fact be much higher. The organic matter returned to the soil in the form of prunings, and dead leaves of tea and shade trees, which is known to be very substantial (Visser, 1960), has not been considered here. Nevertheless, it is of course known from practical experience, that regular additions of inorganic manures are necessary to maintain high yields. The minimum rate advised for this is 8 lb. of nitrogen to 100 lb. made tea and a 10 lb. rate is commonly used ; thus a yield of 1,000 lb. per acre requires approximately 0.21 tons of ammonium sulphate per annum. Yet, looking at the figures of Table 7, the available nitrogen is the 'equivalent' of this supply for 35–80 years of cultivation. The explanation of this must be that in natural conditions, mineralisation does not occur fast enough or to such an extent as was produced in the laboratory in these experiments.

Further it is quite essential to *maintain* a high level of organic matter in soils, to sustain the soil microbes and to maintain the soil structure and moisture-retaining capacity. Liberal applications of nitrogenous fertilisers must be made, particularly when estates are likely to produce higher yields following replanting with high-yielding clonal material. Special attention should be paid in the mid-country districts to increasing the total organic matter content of the soil.

2. Incubation studies

(a) Mineralisation of organic nitrogen in incubated soil

St Coombs cultivated tea soil was taken from field No. 10 at different depths and air-dried. The soil was crushed, and incubated in a continuously humid atmosphere at 30°C. The mineralised nitrogen was determined at intervals. The results are shown in Table 8.

TABLE 8.—*Rate of mineralisation of soil organic nitrogen*

(Results expressed as % conversion of organic nitrogen to ammonia)

Soil profile	Days of incubation				
	7	14	21	28	35
0—6"	— 0.4	0.1	1.2	1.0	1.5
6—12"	0.6	0.2	1.6	1.3	1.9
12—24"	1.7	0.8	2.0	0.8	1.9
24—36"	1.5	2.1	0.4	1.3	0.4
36—60"	6.9	10.9	5.6	— 2.4	3.4
60—84"	13.4	11.0	10.3	12.2	8.4

The degree of mineralisation of organic nitrogen to ammonia was found to be higher in samples from below 36" than in those from above this level; evidently the organic nitrogen in sub-soils is more susceptible to mineralisation than that present in top soils. The results for nitrification have not been shown in Table 8, since this was found to occur very little, probably because the soils were incubated at very low moisture levels (4-6%).

(b) Effect of added potassium nitrate on the formation of ammonia and the activity of the soil fungi under different conditions.

In order to study this, use was made of lysimeter tubs, previously described by Lamb (1954). These are essentially steel tubs, in which tea bushes are grown in soil, with piped drainage so that the soil drainage water can be collected, measured and analyzed.

A set of lysimeter experiments was initiated during August 1953, mainly for the purpose of determining the rate of percolation of rain water through the same tea soil (St Coombs No. 10 field) and also the loss of inorganic nutrients in the drainage water. Results obtained from September 1953 to August 1954, particularly after treatment with potassium nitrate are of interest in relation to the formation of ammonia, the loss of added nitrate and the growth of soil fungi. Addition of potassium nitrate appeared to increase the ammonia content of the drainage water, particularly during a spell of rainy weather. The results are summarised in Table 9.

TABLE 9.—*Increase in the ammonia content of drainage water during wet weather in lysimeters treated with potassium nitrate*

Weather conditions and date	Potassium nitrate added to each lysimeter (g)	Ammonia as nitrogen in the drainage water (average of two sets)			
		Lysimeter without tea bush		Lysimeter with tea bush	
		ppm	Total (mgs)	ppm	Total (mgs)
1. Fairly dry season, 16th September, 1953 to 1st December, 1953 ...	Nil	0.42	24	0.50	25
2. Fairly dry season, 2nd March, 1954 to 25th May, 1954	20.93	0.41	19	0.15	8
3. Wet season, 26th May, 1954 to 18th August, 1954	5.27	9.32	1158	1.70	262

It may be seen from the results in Table 9, that the lysimeter (with or without the tea bush), after a treatment with potassium nitrate, showed a very high loss of ammonia in the drainage water during the wet season as compared with losses during the dry seasons. It is therefore reasonable to assume that, during the wet weather conditions, addition of potassium nitrate had either greatly stimulated the mineralisation of soil organic nitrogen to ammonia, or the nitrates were reduced to nitrites and ammonia.

Laboratory incubation studies on St Coombs cultivated soil confirmed the findings of the lysimeter studies. Loss of nitrate nitrogen was found in top soil (0–24") at high moisture levels and particularly under anaerobic conditions (Table 10). Addition of potassium nitrate stimulated the formation of ammonia, probably by mineralisation of the soil organic nitrogen (Table 12); but the loss of nitrate nitrogen could not be explained by this (Table 11).

The soils, however, particularly those showing heavy losses of nitrates, were found to contain an abundance of soil fungi (particularly of the *Penicillium* group).

The experimental results are shown in Table 10–12.

Table 10.—***Loss of added nitrate nitrogen under different experimental conditions***

(Results expressed as % loss or gain of nitrate nitrogen compared to the initial content)

(*a*) St Coombs cultivated soil, 0–6" layer from field No. 10, incubated when one-third saturated with water at 30°C, under anaerobic conditions (continuous flow of humid carbon-dioxide gas over the soil).

Days of incubation ...	12	18	27	34	42
% Loss or gain ...	—20	—14	13	—12	—15

(*b*) St Coombs cultivated soil, profile from field No. 10, incubated at slightly below the saturation point of water at 30°C, under anaerobic conditions (continuous flow of humid carbon dioxide gas over the soil).

Soil profile	Days of incubation				
	3	7	11	13	18
0—6"	—38	—90	—87	—92	—100
6—12"	—51	—24	—21	—87	—100
12—24"	+ 1	—10	— 5	— 2	— 14
24—36"	—19	+11	+22	+11	+ 6
36—60"	+10	+ 2	+ 2	— 1	— 1
60—84"	+ 9	+ 2	+16	+17	+ 12

(*c*) St Coombs cultivated soil, 0–6" layer from field No. 10, incubated at slightly below saturation point of water at 30°C, under aerobic conditions (continuous flow of humid air over the soil).

Days of incubation ...	10	20	27
% Loss or gain ...	—31	— 9	— 6

Table 11.—*Loss of mineral nitrogen (ammonia + nitrate) under different experimental conditions.*

(Nitrite was found to be in traces only)

St Coombs cultivated soil, 0–6″ layer from field No. 10, incubated at 30°C under aerobic conditions. (Mineral nitrogen added=200 ppm of the soil).

(Results expressed as % increase over the initial content)

Experimental details	Days of incubation			
	7	14	42	56
Moisture level at 25%				
(*a*) Soil only (Control) ...	75	85	92	92
(*b*) Soil + Potassium nitrate ...	0	−3	3	−16
Moisture level at 35%				
(*a*) Soil only (Control) ...	62	100	100	131
(*b*) Soil + Potassium nitrate ...	6	−11	1	−25

Table 12. –*Formation of ammonia in the presence of added potassium nitrate (200 ppm of the soil).*

St Coombs cultivated soil, 0–6″ layer from field No. 10, incubated at 30°C, under aerobic conditions.

(Results expressed as % increase over the initial content)

Experimental details	Days of incubation			
	7	14	42	56
Moisture level at 25%				
(*a*) Soil only (Control)	25	8	0	—17
(*b*) Soil + Potassium nitrate ...	195	242	431	550
Moisture level at 35%				
(*a*) Soil only (Control)	0	8	—17	8
(*b*) Soil + Potassium nitrate ...	180	260	407	520

In the set of lysimeter experiments described earlier in this paper, it was also found that nearly 50 per cent of the added nitrate (in the lysimeters without the tea bushes) could not be accounted for, either in the drainage water or in the soil itself. The soil was found to contain abundant fungi, especially those of the *Penicillium* group. It is probable, therefore, that the 'missing' nitrate was utilised by the soil fungi and possibly by other micro-organisms. In tea areas with heavy and continuous rainfall, nitrate losses due to leaching are probably not as high as one might expect; for under such conditions, the nitrate is probably utilised by the vigorously growing soil fungi. After death, the soil fungi are probably decomposed by the soil bacteria, which then gradually release the mineralised form of nitrogen. If this is correct—and further studies are needed to confirm it—it means that there is a natural safeguard against excessive loss of soil nitrate due to leaching, in areas with prolonged heavy rainfall.

Summary

1. Experiments on some Ceylon tea and jungle soils to evaluate the fraction of the total organic nitrogen that is susceptible to mineralisation are reported. Samples of soils from districts at various elevations in the S.W. and N.E. monsoon zones were examined.

2. Repeated wetting and drying of the soils was used in the laboratory to cause mineralisation of the susceptible nitrogen fraction. In all the soils examined, little mineralisation to ammonia occurred after about 36 wet and dry treatments; the percentage mineralisation at this stage was taken to represent the susceptible fraction.

3. The total organic nitrogen, and the susceptible fraction, differed considerably in the various samples, and significant correlations were found to exist between the elevation (from which the sample was taken) and total organic nitrogen (positive correlation), and between elevation and the susceptible fraction (negative correlation). Thus, with increasing elevation, total organic nitrogen contents were generally higher, but the fractions of these which were susceptible to mineralisation were less. This was true for soils from both the S.W. and the N.E. monsoon zones. Only one sample from below 1,000 feet was examined.

4. Nevertheless, mineralisable organic nitrogen appeared to be fairly abundant in all the tea soils studied, and the amount available (as distinct from the fraction) had no definite correlation with elevation.

5. Lysimeter studies showed an increase in the ammonia content of the drainage water under wet weather conditions when potassium nitrate was added. They also showed that part of the added nitrate nitrogen could not be accounted for either by its presence in the soil or by removal in the drainage water. The soil contained an abundance of soil fungi, particularly of the *Penicillium* group; the nitrate was probably utilised by the rapidly-growing fungi.

6. Laboratory incubation studies confirmed the results of the lysimeter experiments.

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