# Preliminary Observations on Transformation of Soil Nitrogen under Coconuts

BY

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THE seat of soil nitrogen is organic matter and a study of the transformations of nitrogen in the soil under various systems of cropping and cultivation is of fundamental scientific and practical importance.

Bemmer (1) in a review of recent work on soil organic matter remarks: " Considering the importance of nitrogen from the standpoint of soil fertility and the fact that about 98% of the nitrogen in most soils is organic, the nitrogenous organic complexes of soil have received surprisingly little attention. Very little definite information has been obtained regarding either their nature or their transformation in soil. " The nature of humus substances are yet obscure and hardly any investigations have been carried out on humus forms of hot climates. (Vageler (11), p. 131). At the recent Commonwealth Conference on Tropical and Sub Tropical Soils, Crowther stated " that little was actually known about the nitrogen cycle in tropical or any other soils, although many mechanisms had been invoked to explain gains and losses of soil nitrogen " ( (3), p. 234).

It is generally accepted that the first stage of mineralisation of soil nitrogen is the production of ammonia from organic matter. The oxidation of ammonia in the soil takes place on the surface of the soil particles and it is only exchangeable ammonium ions that are oxidised. The next stage is the oxidation of the ammonia to nitrate and finally to nitrate.

It has also been assumed that in most arable crops absorption of nitrogen by the plant takes place in the form of nitrate.

" The nitrates are all dissolved in the soil solution, unless the soil dries out, but much of the ammonium is held on the exchange complex. The total quantity of mineral nitrogen in the soil is the difference between the rate it is being produced from the soil's store of organic matter by the soil population and the rate it is being removed by leaching, by growing crops and by other members of the soil population; and the proportion of nitrate to ammonia depends also on the rate of oxidation of ammonia to nitrates the uptake of nitrates by the plant and the loss of nitrates by leaching." (Russel (9), p. 292).



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Grasslands soils have the main proportion of their mineral nitrogen present as ammonia (Richardson (8): Theron (10), a point that should be kept in mind under conditions of coconut cultivation, where there is a *temporary* ley of grass under coconuts that is normally biennially ploughed in and occasionally disc-harrowed.

On the other hand arable soils have a fairly constant but low content of ammonium nitrogen, but a variable nitrogen content ranging from 2 to 20 ppm. of nitrogen, as nitrate for normal soils, but according to Griffiths and Manning (4) rising even up to 500 ppm. for some tropical soils such as those in Uganda. Under fallow conditions there is a considerable accumulation of nitrates during the dry season, which however gets leached during the rains. Preliminary studies on Top Soils (0-9″ depth) taken in 1947 from plots of the N.P.K. manurial experiment on Coconuts at Bandirippuwa Estate had indicated a surprisingly high content of $NH_4$-Nitrogen, as shown in Table I:

**TABLE I—(Date of Sampling, August 4, 1947)**

| *No. of Plot* | *Carbon Per cent.* | *Nitrogen Per cent.* | *C/N Ratio* | *$NH_4$—Nitrogen p.p.m.* |
|---|---|---|---|---|
| 1 | 0·65 | 0·053 | 12·26 | 16 |
| 2 | 0·49 | 0·042 | 11·67 | 22 |
| 3 | 0·56 | 0·060 | 9·33 | 11 |

The more detailed observations recorded in this paper were made on three series of soil samples taken from a single plot (Plot No. 42) of the same manurial experiment on coconuts which had been continuing since 1935 at Bandirippuwa Estate. Manures have been bienially applied since November 1935 in circular trenches 3 feet wide, 6 inches deep, cut at a distance of 3 ft. from the palm. Immediately following manuring the land was ploughed. The last manuring and ploughing preceding the first soil sampling was in November 1951. Since the commencement of the manurial experiment in 1935 the plots were not grazed by cattle so that any complications due to the dropping of urine and dung does not arise.

Three series of soil samples were taken on 3.4.52 ; 19.4.52 and 27.6.52. Samples were taken outside the manure circle in two sets, one along the Rows of Palms (R) and the other in the centre of the squares (S) at four depths: 0-9″ (Top), 9-18″ ($Sub_1$); $1\frac{1}{2}$-$2\frac{1}{2}$′ ($Sub_2$) and $2\frac{1}{2}$-$3\frac{1}{2}$′ ($Sub_3$).

Composite samples from five borings were taken, stored in a wide mouthed bottle with a few c.c. of toluene to arrest bacterial action and analysed without delay. 2 more samples were used for analysis.

The soil was a deep loam, well drained overlying a subsoil of lateritic gravel much below the depth sampled. The pH and exchangeable base contents of the soil are shown in Table II.

**TABLE II—Exchangeable Bases in Soil Samples from Plot 42**

| *Sample No.* | *Depth Horizon* | *pH Total Exchangeable bases ME/100 gms.* | *Exchangeable calcium ME/100 gms.* | *Exchangeable potash ME/100 gms.* |
|---|---|---|---|---|
| RT | 0– 9″ | 3·46 | 1·86 | 0·095 |
| $RS_1$ | 9 –18″ | 2·83 | 1·66 | 0·026 |
| $RS_2$ | 1½–2½′ | 2·75 | 1·82 | 0·056 |
| $RS_3$ | 2½–3½′ | 3·73 | 2·31 | 0·030 |
| ST | 0 – 9″ | 3·38 | 1·96 | 0·095 |
| $SS_1$ | 9 –18″ | 3·91 | 1·62 | 0·088 |
| $SS_2$ | 1½–2½′ | 4·26 | 2·35 | 0·015 |
| $SS_3$ | 2½–3½′ | 3·54 | 1·86 | 0·033 |

The rainfall data since the preceding manuring up to the last soil sampling are given below :—

| | *Inches* | *No. of rainy days* |
|---|---|---|
| December 1951 | 1·84 | 10 |
| January 1952 | 4·10 | 7 |
| February 1952 | 4·70 | 6 |
| March 1952 | ·23 | 1 |
| April 1952 | 3·71 | 12 |
| May 1952 | 11·54 | 19 |
| June 1952 | 7·40 | 16 |

On February 21, 1952, rainfall recorded was 3·16″.

## EXPERIMENTAL

Total Nitrogen was determined by the Kjeldahl method. $NH_4$-Nitrogen by the Maclean and Robinson method (7), Nitrate nitrogen by the phenol-disulphonic method according to Harper (5) and nitrite by the Griess method.

## DISCUSSION

The results are given in Table III and are of considerable interest. Contrary to the accepted views regarding the nitrogen distribution in arable soils, the following significant features will be noted: (*a*) the very high content of $NH_4$-Nitrogen, amounting to over 5% of the total nitrogen; (*b*) the high concentration of $NH_4$-Nitrogen in the subsoils, the amount in the 9″-18″ horizon being even higher than in the surface horizon, and the amounts at a depth of 2½ to 3½ ft. being quite appreciable ; (*c*) the very low concentration of Nitrate nitrogen except in the top soils of the series sampled on 3.4.52 ; (*d*) the consistent nature of the results in the three series of samples taken.

Bruce (2) in this studies on the periodicity of nitrification in a coconut area manured between rows of palms, found nitrates averaging 8.9 lb. per acre, but ranging from 1.0 lb. to 18.0 lb., the higher contents being present during the dry months. The basis of calculation of lbs. per acre is not stated; but on the usual basis of 2,000,000 lbs. of soils per acre the nitrate content averages 4.5 p.p.m. and ranges from 0.5 p.p.m. to 9.0 p.p.m. The total nitrogen of the manured area averaged on the same basis 221 p.p.m.

**TABLE III—Total Nitrogen, Ammonium, Nitrate and Nitrite Nitrogen in Coconut Soil**

*(Plot No. 42, Bandirippuwa Estate)*

| | *Series I—Collected 3.4.52* | | | *Series II—Collected 19.4.52* | | | | *Series III—Collected 27.6.52* | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | *Ammoniacal N PPM* | *Nitrate N PPM* | *Nitrite N PPM* | *Total N PPM* | *Ammonical N PPM* | *Nitrate N PPM* | *Nitrite N PPM* | *Total N PPM* | *Ammonical N PPM* | *Nitrate N PPM* | *Nitrite N PPM* |
| R Top | 19·5 | 8 | 0·40 | 280 | 18·1 | 2 | 0·30 | 338 | 16·3 | 2 | 0·02 |
| R Sub[1] | 30·8 | 1 | 0·10 | 307 | 23·3 | 1·5 | 0·04 | 376 | 18·4 | 1 | 0·10 |
| R Sub[2] | 17·1 | 3 | 0·50 | 224 | 17·1 | 1 | 0·01 | 266 | 14·6 | 1 | 0·08 |
| R Sub[3] | — | — | — | 270 | 6·9 | 1 | 0·04 | 231 | 9·3 | 2 | 0·05 |
| S Top | 12·0 | 10 | 0·30 | 400 | 16·3 | 3 | 0·10 | 369 | 22·6 | 3 | 0·10 |
| S Sub[1] | 19·5 | 3 | 0·10 | 280 | 11·3 | 1·5 | 0·02 | 307 | 12·0 | 1 | 0·04 |
| S Sub[2] | 14·5 | 4 | 0·20 | 250 | 6·9 | 1 | 0·01 | 320 | 5·6 | 3 | 0·04 |
| S Sub[3] | — | — | — | 210 | 2·6 | 1 | 0·06 | 310 | 9·9 | 1 | 0·04 |

Data for the distribution of soil nitrogen for tropical soils are rare except for the useful observations of Laudelout and du Bois (6) based on studies of a savannah soil overlying a lateritic crust in the Belgian Congo given in Table IV.

**TABLE IV—Nitrogen Distribution on a Savannah Soil (Laudelout and De Bois)**

| | *Depth* | *pH* | *Total N* *Per cent.* | $NH_4$*-N* * | $NO_3$*-N* * |
|---|---|---|---|---|---|
| Hill top | Surface | 5·1 | 0·151 | 0·38 | 3·83 |
| | 20 cm. | 5·2 | 0·100 | 1·82 | 1·82 |
| Valley | Surface | 5·1 | 0·108 | 4·54 | 9·40 |
| | 15–20 cm. | 5·2 | 0·078 | 1·03 | 1·71 |
| Lateritic crust | Surface | 5·2 | 0·400 | 0·82 | 1·65 |
| 3 m. from crust | Surface | 5·2 | 0·182 | 1·11 | 0·37 |
| | 10–30 cm. | 5·1 | 0·155 | 3·11 | 3·46 |
| 8 m. from crust | Surface | 5·1 | 0·157 | 1·08 | 3·24 |
| | 10–20 cm. | 5·2 | 0·127 | 2·71 | 1·02 |
| | 40–60 cm. | 5·1 | 0·110 | 0·34 | 22·63 |
| 38 m. from crust | Surface | 5·1 | 0·147 | 0·70 | 0·35 |
| 90 m. from crust | Surface | 5·1 | 0·147 | 2·59 | 0·74 |

* These are presumably p.p.m. though not specifically stated in the paper.

In this case however, except that the ammoniacal Nitrogen is always higher in the illuvial than in the surface horizon, its content is on the average low compared to the amounts of nitrate.

Similar studies based on samples taken from Kirimetiana Estate, Lunuwila, where the pasture had been heavily grazed by cattle, confirm the presence of high contents of amoniacal nitrogen in coconut soils. Nitrates in fact could not be detected in this case. The samples were however, taken to a depth of 18″ only.

**TABLE V—Ammoniacal and Nitrate Nitrogen of Soils**

*Kirimetiana Estate, Lunuwila*
(Sampled 20.8.52)

| | | $NH_4$ | *Nitrate N* |
|---|---|---|---|
| Row Top | 0– 9″ | 15·8 ppm. | nil. ppm. |
| Row Sub | 9–18″ | 18·6 | nil |
| Square Top | 0– 9″ | 19·3 | nil |
| Square Sub | 9–18″ | 20·1 | nil |

Until further work is done, it is difficult to offer an explanation for the high contents of $NH_4$-Nitrogen and its distribution in the profile, observed in the coconut soil. Although Laudelout and du Bois (6) state that there is no explanation for the observation that Ammoniacal-nitrogen is higher in the illuvial horizon than in the surface horizon it is possible that the exchangeable amonia gets hydrolysed and leached to the lower layers where it accumulates.

A recent paper by Theron (10) entitled " The influence of plants on the mineralisation of nitrogen and the maintenance of organic matter in the soil " is of particular interest in this discussion. Under tropical conditions, where no legumes take the place of clovers of the temperate humid areas, Theron concludes that grass depresses the mineralisation of soil nitrogen to nitrate. In a series of pot experiments with a perennial grass, no nitrates were found, but there was a tendency for ammonia to make its appearance in quantities larger than is normally found in cultivated soils. The nitrogen present as exchangeable ammonia was about 6 p.p.m. while nitrates rarely exceeded 1 p.p.m. According to him, the oxidation of the ammonia to nitrates is interfered by the grass, caused by bacteriostatic excretions by living roots which paralyse the autotrophic dehydrogen system of the nitrifying organisms without interfering with the process of ammonification. According to Theron " This hyphothesis offers an explanation for the rather unexpected presence of ammonia under grass and it leaves a channel open through which perennial crops can obtain nitrogen, namely, by way of ammonia produced in the normal course of ammonification. The view expressed by Richardson (8) that the grass herbage takes up most of its nitrogen as ammonia is of interest in this connection."

Is it possible to speculate that under the system of cultivation of coconuts, where a temporary two year ley of grass is maintained under the palms, and the accumulation of ammoniacal nitrogen as shown by our data occurs, the root system of the coconut palm absorbs a considerable amount of its nitrogen requirements in the form of ammonia and not as nitrate?(*)

A more detailed study following up the nitrogen transformations after ploughing in the grass would be necessary. The data recorded commence with the first sampling only four months after ploughing in of the ley. In a recent estimate based on quadrat samples obtained from different plots of this manurial experiment, it was calculated that on the average 1.6 tons air-dried material, containing 39 lb. nitrogen are turned into the soil per acre. The grass soon re-establishes itself, but how far the decomposition of this organic matter influences the distribution of the different forms of nitrogen in the soil and in the nutrition of the coconut palm remain to be investigated.

Similar studies should also be made on other soil types on which coconuts are cultivated.

Nitrogen happens to be the most expensive of the artificial manures used on coconut estates. Systematic studies of the nitrogen cycle under coconuts should be valuable in rationalising the nitrogen economy of the coconut palm.

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(*) Hutchinson, H. B. and Miller, N. H. J.—Direct assimilation of ammonium salts by plants. J. Agri. Sci. (1908-10), Vol. 3, 178-193.

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