THE VICISSITUDES OF NITROGEN IN THE SOIL SYSTEM.

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Several workers on soils in different parts of the world have observed loss of nitrogen from the soil in ways other than through drainage. There is a general concensus of opinion that nitrogen undergoes loss in gaseous form to a greater or less extent under field conditions.

Loss of nitrogen is usually explained in terms of carbon-nitrogen ratios, which concept originated from studies on ammonification and nitrification under a variety of conditions. The causes leading to the loss of total nitrogen in the soil do not, however, appear to have been clearly understood. Large quantities of nitrogenous fertilisers are bought and applied to the soil. If nitrogen is to be bought and put into the soil only to be lost into the air, it is bad business. It is one thing if the readily soluble and available nitrogen added to the soil is converted from current account into capital or fixed deposit account, as it were, and it is another thing to lose it as a result of exchange fluctuations.

In the course of investigations by the writer on the nitrification of cattle manure, green manure and ammonium sulphate under field conditions in Coimbatore soils, data were obtained which are difficult of explanation in terms of the usually accepted views. The rate of nitrification and accumulation of nitrates was, as would be expected, greatest with ammonium sulphate, least with cattle manure and intermediate with green manure. Taking 100 for the nitrification value of ammonium sulphate under field conditions, the relative rates for green manure were 50 and 25 respectively in the first foot layer of the soil. From fortnightly examinations extending over a period of three years, it was evident that there was a periodical loss of total nitrogen in the soil under all the manurial treatments but that it was greatest with ammonium sulphate. Similar fluctuations were noticed in unmanured plots also but to a lesser degree. It was ascertained that there was no movement of nitrogen into the deeper layers and there was no moisture saturation leading to denitrification. The following statement shows periodical increase or decrease of nitrogen over the corresponding unmanured plot.

TABLE I.

Periodical increase or decrease of nitrogen over the corresponding unmanured plot.

(In parts per million of dry soil.)

Date of sampling	Green manure		Cattle manure		Ammonium sulphate	
	Nitric nitrogen	Total nitrogen	Nitric nitrogen	Total nitrogen	Nitric nitrogen	Total nitrogen
	Season 1930-31.					
31st October, 1930 ..	+3·6	+27·7	+3·7	+26·4	+4·7	−48·1
13th November, 1930 ..	−0·6	+20·7	−2·4	−16·1	−0·3	−0·7
8th December, 1930 ..	+1·8	+19·4	−0·1	+37·5	−0·2	+14·2
27th January, 1931 ..	+3·7	+44·1	+1·9	+29·5	+3·0	+0·0
13th February, 1931 ..	+6·5	+52·7	+4·8	+65·2	−0·6	+4·2
2nd March, 1931 ..	+3·5	−50·5	+1·0	−58·4	+0·2	−71·5
13th March, 1931 ..	+7·8	+6·5	+3·4	+34·5	+1·8	−7·2
20th April, 1931 ..	+6·1	−51·0	−6·1	−22·0	−3·5	−34·0
	+32·4	+69·6	+6·2	+96·6	+5·1	−143·1
	Season 1929-30.					
3rd October, 1929 ..	−4·1	−15·0	−1·6	−28·0	+20·1	−47·0
21st October, 1929 ..	+7·8	+6·0	+12·3	−2·0	+8·1	−28·0
9th November, 1929 ..	+5·6	+101·1	+0·4	+47·0	+2·4	+23·0
25th November, 1929 ..	+6·4	−10·0	+6·6	−26·0	+12·6	−38·0
6th December, 1929 ..	+8·2	−1·0	+2·9	+7·0	+32·5	+15·0
24th January, 1930 ..	+6·6	+12·0	+0·1	−1·0	+6·1	−20·0
8th February, 1930 ..	+9·2	+35·0	−4·4	−16·0	−4·9	−30·0
24th February, 1930 ..	+7·2	+1·0	+1·6	+33·0	+21·1	+29·0
21st March, 1930 ..	−4·3	−10·0	+1·0	−13·0	−4·9	+8·0
	+42·6	+119·1	+18·9	+1·0	+93·1	−88·0

The usual explanation for nitrogen fluctuations is that, when easily decomposable organic matter is added to the soil, biological processes begin to operate immediately the requisite nitrogen for the development of the organisms is obtained from the soil if present in sufficient amount, or from the atmosphere in case of insufficient supplies in the soil. On this basis, the loss in total nitrogen is rather difficult to explain. The nitrogen loss followed the peak values for nitrate accumulation. The influence of carbon-nitrogen ratio might have been felt in the early stages of the decomposition of the materials added, but it is not clear how the loss of nitrogen, which appears to have occurred chiefly in the end product stage, can be connected with the carbon-nitrogen ratio.

In order that this relationship, if there is any, may be intelligible, the mutual effects of soluble and readily available carbonaceous and nitrogenous substances have been investigated. Cane sugar and sodium nitrate have been used in different proportions to give varying carbon-nitrogen ratios ranging from 20C : 0N to 0C : 1N. The ratios were obtained by keeping the amount of nitrogen constant and adding the requisite amount of cane sugar to make up the different ratios. The results are given in the statement below.

TABLE II.

Changes in nitric nitrogen under different carbon nitrogen ratios.

Percentage of nitric nitrogen on soil dried at 105°C. to 110°C.

A period	Control	20 : 0	20 : 1	15 : 1	10 : 1	5 : 1	1 : 1	0 : 1
At start ..	*nil*	*nil*	0·101	0·102	0·103	0·104	0·105	0·106
After 10 days ..	,,	,,	0·022	0·049	0·048	0·059	0·099	0·106
,, 20 ,, ..	,,	,,	0·029	0·042	0·050	0·060	0·098	0·103
,, 30 ,, ..	,,	,,	0·025	0·042	0·061	0·070	0·099	0·107
,, 40 ,, ..	,,	,,	0·035	0·050	0·065	0·066	0·097	0·104
,, 50 ,, ..	,,	,,	0·043	0·045	0·064	0·085	0·097	0·106
Total nitrogen content at different periods.								
At start ..	0·075	0·073	0·171	0·181	0·176	0·177	0·176	0·180
After 10 days ..	0·078	0·104	0·161	0·148	0·159	0·164	0·159	0·160
,, 20 ,, ..	0·077	0·108	0·153	0·168	0·166	0·170	0·177	0·159
,, 30 ,, ..	0·085	0·111	0·154	0·164	0·165	0·161	0·170	0·168
,, 40 ,, ..	0·079	0·111	0·156	0·143	0·164	0·165	0·171	0·171
,, 50 ,, ..	0·080	0·111	..	..	..	..	..	..
Percentage change control versus the rest	+6·7	+49·3	−6·9	−13·1	−7·4	−6·8	−4·1	−8·3

As the substances added were cane sugar and sodium nitrate, both of which are readily attacked by micro-organisms in the soil, the maximum change in total nitrogen occurred in ten days from the start of the experiment.

A gain in total nitrogen occurred in the absence of added nitrogen to the extent of about 50 per cent, evidently due to fixation of atmospheric nitrogen. In all other cases, there were varying degrees of losses. With nitrate only and no organic matter, there was little change. In the presence of both nitrate and sugar definite loss in total nitrogen occurred, the amount of loss generally increasing as the ratio was narrowed.

In regard to nitric nitrogen, its fluctuation appears to have been regulated by the carbon-nitrogen ratio. The wider the ratio, the greater was the loss. It should be noted that loss in nitrate need not mean loss in total nitrogen. With the 20C : 1N ratio, the loss was about 78% and as only 10 per cent of the total nitrogen is lost, the balance should be assumed to have been absorbed by the micro-organisms. At the other extreme in 0C : 1N ratio the added nitrate nitrogen stood stationary throughout. This evidently could not be utilised by the micro-organisms. It is, therefore, difficult to explain the loss of 8·3 per cent in this case.

Organic carbon was estimated periodically as was done in the case of nitrogen. The position at the end of 50 days showed varying degrees of loss as is seen in the statement below.

TABLE III.

Treatment	Maximum loss of carbon	
	% on total	% on added
Control	5·4	....
20C : 0N	51·9	74·5
20C : 1N	50·6	74·2
15C : 1N	47·9	77·9
10C : 1N	39·8	77·6
0C : 1N	8·4	....

Loss of carbon had taken place in all the series and the greatest loss occurred during the first ten days. The loss during the subsequent period was correspondingly small.

When the loss of carbon is calculated as a percentage of the total carbon content in the soil the loss appears to be a function of the C : N ratio. But when it is worked out as a percentage of the amount of the organic matter actually added a totally different state of affairs is revealed. It will be seen that, regardless of the C : N ratio or of the amount of carbon added, the amount of carbon lost is fairly constant, about 70 to 80 per cent of the added carbon. It should, however, be noted that the carbon-nitrogen ratio ultimately assumes a ratio round about 10 irrespective of the initial magnitude.

TABLE IV.

	C : N on total C and N.		C : N on organic C & N	
	Initial	Final	Initial	Final
Control	12·8 : 1	11·1 : 1	10·9 : 1	9·9 : 1
20C : 0N	39·0 : 1	12·5 : 1	37·5 : 1	11·5 : 1
20C : 1N	16·8 : 1	9·5 : 1	39·4 : 1	11·1 : 1
15C : 1N	13·2 : 1	8·9 : 1	29·1 : 1	12·2 : 1
10C : 1N	10·6 : 1	6·8 : 1	24·1 : 1	9·9 : 1
0C : 1N	5·3 : 1	5·1 : 1	11·4 : 1	11·3 : 1

For a clearer understanding of the processes involved, the soil cultures may be conveniently classified into the following three groups, viz.,

(1) soil cultures containing sugar only and no nitrate ;

(2) cultures containing sugar and nitrate in different proportions ;

(3) cultures containing only nitrate.

Considering the first group, it will be seen that loss of carbon has been associated with a gain in nitrogen, the latter being obviously obtained from the atmosphere to maintain the ratio at about 10 : 1. Now the question arises whether this fixation of atmospheric nitrogen could again be started by the addition of more organic carbon and how far this process could go.

As regards the second group, the introduction of nitrate into the soil along with sugar has resulted in a loss of nitrogen. The biological agencies seem to be entirely different. Nitrogen fixing organisms of the *Azotobacter* type have either changed their functional characteristics or entirely new kinds of organisms have come to the front under the new environment.

The loss of nitrogen is rather difficult to explain since the two essential conditions for denitrification, viz. absence of oxygen and presence of easily oxidisable organic matter are not satisfied in the laboratory experiments. Photo-chemical decomposition can explain fixed losses but there must be some other factor operating in the case of the laboratory experiments.

It would be interesting to find what would happen if the C : N ratio is altered by keeping the carbon constant and changing the nitrate content. It might be expected that since the amount of carbon decomposed is constant, the amount of nitrate converted into organic form will also be constant, irrespective of the ratios. If, however, the ratio is altered with organic nitrogen, mineralisation of organic nitrogen may be the result. These require experimental investigation.

The third group comprises cultures containing only nitrate but no sugar. In this case, the changes in carbon and nitrogen are too small to be detected by the methods of analysis employed. The bacterial activity was probably at a minimum. Where, however, ammonium sulphate was substituted for sodium nitrate, there was a loss of about 10% in total nitrogen while the rest had been converted into nitrate nitrogen. Fixation of carbon might be expected in this case and by the addition of sugar nitrification might be impeded.

Under field conditions, there would be slow decomposition of nitrate in the presence of sunlight first into nitrite and then at an accelerated rate into the gaseous form. This process would be considerably accentuated in the presence of moisture approaching the saturation capacity of the soil.