NITROGEN STATUS OF INDIAN SOILS.

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The nitrogen content of most Indian soils varies from 0·03 to 0·07 per cent as against 0·10 to 0·17 per cent of European and American soils. This low level of nitrogen reflects itself in the yield of our staple crops. The nitrogen in the soil exists almost entirely in a combined form and the problem of nitrogen is therefore intimately connected with the organic matter of the soil. The study of the problem divides itself into three main divisions: (1) Increasing the store of nitrogen by a system of rotation of crops, by the addition of nitrogenous fertilisers or by fixation; (2) the prevention of loss of nitrogen, and (3) utilisation of nitrogen by the crops. In fact, any system of land husbandry that has not as its aim these three objects in view is bound to fail.

1. *Increasing the store of nitrogen.*—A leguminous crop fixes the atmospheric nitrogen in addition to the supply of organic matter to the soil. Where this cannot be done, the land is usually fallowed, but this system has only a limited value because there is no addition of organic matter but only a small increase of nitrogen. Where neither of these processes are adopted the land is likely to deteriorate in its fertility unless heavily manured from time to time. Under irrigated condition the intensity of cropping can be as high as 80%, thus allowing no time for fallow. In such systems green manuring is an absolute necessity, especially when the supply of F.Y.M. is limited.

It is now generally accepted that for Indian soils at least the addition of inorganic nitrogenous fertilisers alone is not desirable, even though such treatment of the soil may immediately show an increased crop return. Continued application of artificial fertilisers has a deleterious effect on the soil and, as has been more recently shown, on the quality of the crops. The Department of Agriculture in Bihar, as I expect in many other parts of India, does not recommend artificials, except in combination with organic manures. When there is sufficient carbon, especially in the form of easily decomposing substances, the organisms thriving on their energy materials utilise all the nitrogen they get from the soil and fix some from the atmosphere. The utility of the organic fertilisers is therefore enhanced by the fact that they serve as a means to obtain nitrogen from the atmosphere. One instance of this may be mentioned here. Molasses, which is a waste product of the sugar industry, contains 0·3–0·5 per cent nitrogen and over 20% carbon. The sugar content is 45–60 per cent. When quantities varying from 250 mds. to 1,000 mds. per acre are added to the soil under laboratory conditions, there is found to be an increase in the total nitrogen content of the soil,

which is more than the nitrogen supplied by the molasses. Table 1 illustrates this.

TABLE 1.

Nitrogen in milligrammes per 100 grammes of soil.

	Original.	One month incubation.	Two months incubation.	Three months incubation.	Four months incubation.
Soil alone	72·8	73·7	66·4	62·0	56·3
,, plus 1% molasses ..	77·2	77·6	83·5	66·0	64·8
,, ,, 3% ,, ..	86·0	85·7	90·0	70·0	66·3
,, ,, 4% ,, ..	90·4	92·6	99·4	82·0	69·1
,, ,, 5% ,, ..	94·8	94·2	94·2	85·1	71·9

NOTE.—1% molasses corresponds to 250 mds. per acre and an increase of 1 mgm. per 100 gms. of soil equals 20 lbs. of nitrogen per acre.

Though the increase of 4–9 mgms. per 100 gms. of soil is definite in two months, the subsequent loss should be noted and an attempt made to prevent it. The reason for this loss is not far to seek. Experiments at Sabour have shown that on incubation, the oxidation of carbon in the molasses amounts to nearly 60% of carbon, which escapes as carbon dioxide in 30 days. As soon as the carbon is lost, there is nothing to hold the nitrogen back. But if the crops were growing on the land, the nitrogen will be utilised and not lost. Great care is therefore necessary to arrive at an optimum period when the molasses should be incorporated in the soil, prior to putting the land to crop. If the period is too short, a state of nitrogen starvation would be experienced by the growing plant as all the available nitrogen would be locked up by the soil micro-organisms ; on the other hand, if the period is too long, the danger of nitrogen loss exists. A period of 4–8 weeks appears to be the optimum period. It may happen that the period recommended may offer, in some instances, practical difficulties in farming, in which case it may be worthwhile ploughing in, after about one month, a less easily decomposing material such as straw to hold the nitrogen back. The nature and amount of this material must depend upon the period that the molasses has to remain in the soil, before the crop is put in. Experiments on this point are being carried out by me at Sabour.

What is true of molasses holds equally true for other organic manures. Another very useful manure is the habitation manure. In trying out the Indore process of compost making in some of our trials, we composted sugar-cane trash and other farm residues with soil and got a perfectly good manure, giving a nitrogen content of 0·9 to 1·8%, depending upon the nature of the starting material, the highest nitrogen content having been obtained when sugar-cane trash alone was used. The crop tests on wheat and maize in the pots showed that this manure can be used with advantage. Table 2 illustrates this.

TABLE 2.

Yield of grain and straw in gms. per pot.

	Wheat.		*Maize.*	
	Grain.	Straw.	Grain.	Straw.
Control	43·69	56·7	18·0	23·0
F.Y.M. (40 lbs. N. per acre) ..	42·70	42·4	31·81	28·4
Habitation manure (40 lbs. N. per acre)	51·01	61·0	27·47	29·9

The residual value of this manure after the wheat crop is being investigated. This offers a cheap and good substitute for organic manures as it is only the waste products that are utilised in the preparation of this manure.

Oil cakes are also useful but their utility is limited by the fact that they leave very little humus in the soil.

2. *Prevention of loss of nitrogen.*—Nitrogen can either be lost as free nitrogen from the soil, as a result of denitrification, or as soluble nitrogen compounds in drainage. There is also a possibility of nitrogen loss as ammonia. The first and last processes are experienced only under few or specialised conditions and the loss is usually not considerable. There is, however, a large amount of nitrogen lost by drainage, if care is not taken in the methods of farming. One of the main causes of the loss is that the nitrogen gets too easily nitrified in the season when the crop on the land cannot utilise it fully, and it may be completely lost in drainage water. In one experiment, I found that the yield of the wheat crop was lower in the green manured plot than in the unmanured one. It looked paradoxical but subsequent investigation showed that the green crop (vetches) decomposed far too quickly, with the inevitable loss of nitrogen as nitrates. The extent of loss was measured and successful experiments done to prevent loss of nitrogen, by incorporating a cellulosic material like wheat straw to hold the nitrogen back. The results are shown below :—

TABLE 3.

	Nitrogen (milligrammes) per pot removed by leaching.
Soil alone	71·6
„ plus green manure	89·8
„ „ „ „ plus straw	46·4

It is desirable therefore to study in detail the nature of the manure that is applied to the soil. In the case of green crop, the age and season have a great deal to do with the rate of decomposition, the younger plants decomposing much quicker than older ones and the whole thing being greatly influenced by the moisture and aeration in the soil. The same thing holds for other types of organic matter.

3. *Utilisation of nitrogen.*—The final arbitrator of the value of the nitrogen is the plant and our present knowledge is that it takes up nitrates

most easily and ammonia in certain cases. It has also been suggested that the plant utilises simple forms of amino compounds, but the experimental evidence is by no means conclusive. The question of availability of nitrogen needs to be kept in the forefront, in considering the nitrogen status of Indian soils.

The decomposition of organic matter is the necessary preliminary to the release of plant nutrients in the soil, particularly nitrogen. It is now possible to give a quantitative measure of the effect of varying C : N ratio of organic manures on the course of their decomposition. The narrower the ratio, the quicker would be the decomposition. In many of my experiments a close relationship existed between the rate of decomposition and the C : N ratio of the decomposing material and it was possible to regulate the course of decomposition by artificially altering the C : N ratio of the substance. Two instances are quoted below. Activated sludge having C : N of 12 was used as a manure in pots and in the laboratory to study the rate of nitrification. To this was added varying quantities of cellulosic material to slow down its decomposition. The nitrogen level of the individual substance as well as the mixtures was kept the same, i.e. 5 mgms. of nitrogen per 100 gms. of soil. On the other hand, mustard plant, having a C : N of 26 and therefore very slow to decompose, was treated with small quantities of dried blood, keeping the nitrogen level the same, i.e. only altering the carbon level. The results are shown in the following table.

TABLE 4.

Ammonia and nitrate nitrogen in mgms. per 100 gms. of soil.

A.	2 weeks.	4 weeks.	7 weeks.	9 weeks.	14 weeks.
1. Soil alone ..	1·14	1·73	0·93	1·36	1·30
2. „ plus sludge	2·26	2·00	2·43	2·40	3·08
3. Soil plus sludge plus 5% N. as straw ..	0·70	0·86	0·11	0·70	1·09
4. Soil plus sludge plus 20% N. as straw ..	0·44	0·17	0·11	0·11	0·12

B.	1 week.	3 weeks.	8 weeks.	18 weeks.	26 weeks.	34 weeks.
1. Soil alone ..	1·89	2·34	2·49	3·61	4·00	3·52
2. „ plus mustard	1·02	0·99	2·07	2·98	4·67	4·88
3. „ „ „ plus dried blood	1·34	2·18	3·63	4·70	6·27	7·33

In the case of sludge, the nitrogen is almost completely rendered unavailable when 20% of its nitrogen is replaced by straw giving the same quantity of nitrogen. In the case of mustard the quickening of the decomposition is evident from the data. Another interesting thing that emerges from the figures is that after nearly six months the nitrogen of the mustard is higher than that of the control, an observation which lends support to the view that the nitrogen, locked up by the soil micro-organisms, is released when the carbon and nitrogen have reached an equilibrium. After this there

would be a constant supply of available nitrogen for the plant. This was confirmed by the pot experiments.

Similar results were obtained when F.Y.M. was treated with straw and with dried blood to widen and narrow down respectively its C : N ratio.

The availability of nitrogen from organic manure is dependent upon the level of carbon existing along with it. It is necessary to stress this point, so that the value of the organic matter as a source of nitrogen should be assessed in its proper perspective. It is admittedly true, and my experiments have confirmed it, that the form in which carbon exists has a great deal to do with its power of regulating the nitrogen availability from a manure, but total carbon gives an approximate measure, in many instances a correct measure, of its effect on the decomposition of the organic matter.

A passing reference may be made to the importance of the time when nitrogen is available for the growing plant. From the manures having a wide C : N, the nitrogen would be available rather late and this would explain the failure of certain organic manures to give increased yields. If the availability is long delayed, the crop would not derive any benefit from such organic manure, in fact a state of nitrogen deficiency would be set up ; but the nitrogen made available about the flowering time of cereal crops goes to increase the protein content of the grain. Regulated nitrification thus provides a means of either increasing the yield or improving the quality of grain crops. This has been found to be correct in some of my experiments. Further work is in progress.

Summary.—The nitrogen level of Indian soils is low and it is essential to conserve, increase and profitably utilise the nitrogen of the soil. Addition of green manures, organic manures and the proper understanding of the mechanism of the decomposition of the organic matter to prevent losses and to utilise the nitrogen to best advantage, i.e. improving the yield and quality of crops are suggested so that further deterioration may not take place in the level of soil fertility.