RESEARCHES ON UTILISATION OF CANE MOLASSES.

Part V. Nitrogen fixation by the solid-lime compound in the soil and its bearing on plant growth.

by

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Attention has already been drawn to the application of the solid-lime compound obtained from cane molasses as a source of supplying nitrogen to soil (*vide* Parts III and IV). Laboratory studies have shown that the product undergoes rapid decomposition in presence of soil flora and leads to fixation of considerable quantities of atmospheric nitrogen. But the pot and plot experiments carried out (*vide* Part IV) with the object of establishing the practical significance of the above finding would suggest that, under field conditions, the fixed nitrogen, at any rate the major part of it, is somehow rendered unavailable for plant nutrition. It is not clear, however, as to the manner in which the fixed nitrogen is not available in the soil system—whether it takes an altogether different course in the soil so that it does not become available when the plant wants it, or is it so rapidly lost from the soil system that it is of no use to the plant. The present paper relates to these and allied aspects of the problem.

EXPERIMENTAL.

Materials and Methods.—The sample of solid-lime compound used in the present studies was the same as that described in Part III of this series. The soil used for these experiments was the red loam originally obtained from an adjoining uncultivated area, and which had been well dried and powdered in the usual manner. It was further sieved through 100 mesh so that uniform sampling might be ensured. This sample of soil contained 0.53 per cent. carbon and 0.052 per cent.

nitrogen. The straw used for the experiment was ragi (*Eleusine coracana*) straw which was well dried and powdered to yield a uniform sample.

Estimations of carbon and nitrogen were carried out according to Bhaskaran *et al.*, (*Jour. Ind. Inst. Sci.*, 1936, **19A**, 45). Total ammonia was estimated according to Olsen (*Compt. Rend. Trans. Lab.* Carlsberg, 1929, **17**, No. 15). The method for the determination of ammonia volatilised was the same as described by Subrahmanyan (*Nature*, 1937, **39**, 884).

Decomposition of the product in the soil and fixation of nitrogen.—The soil (20 g.) was weighed into a number of flat glass basins (capacity 200 c.c.) and treated with 0.4 g. of the solid product and 40 c.c. of distilled water. Another set of such dishes containing only soil and water were maintained under similar conditions as controls. All the dishes were kept in an incubator maintained at 30°C.

At periodic intervals, samples were taken and analysed for their carbon and nitrogen contents. The results obtained are presented in Fig. I.

It may be seen from the foregoing results that the product decomposes readily in the soil and enables fixation of useful quantities of nitrogen. It may also be observed that nitrogen fixation reaches its maximum between eight and twelve days and after this period, the nitrogen content goes down steadily. Thus, within the following fortnight more than 50 per cent. of the fixed nitrogen is lost from the system, and at this stage, only very little of the added carbon is found to remain in the soil.

The rapid decrease in the nitrogen present in the experimental sample would suggest that although a part of the fixed nitrogen is useful to the crop, the rest would be lost from the soil. This would constitute a serious loss and should be prevented either by altering the conditions relating to the application of the fertilizer or by adding certain materials that would hold the nitrogen in the system.

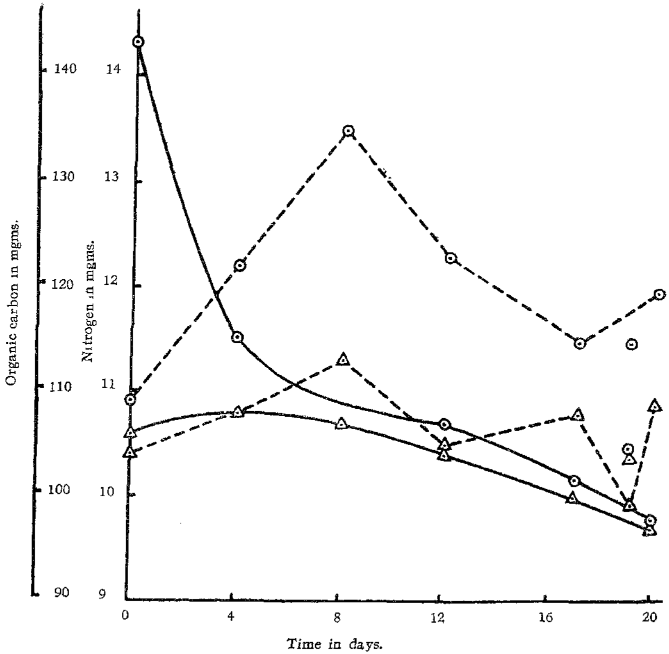

FIG. 1.

Organic carbon (Experimental)
,, ,, (Control)
Total nitrogen (Experimental)
,, ,, (Control)

For devising an effective method of preventing this wasteful loss of organic nitrogen, it was necessary to find out the exact nature of the nitrogen as it is present in the system and as it escapes. It may be expected that the fixed nitrogen in the soil is ammonified and, in presence of large amounts of calcium carbonate which are formed as a result of decomposition of the lime compound, the ammonia is volatilised ;

for it is well known that ammonia gets readily volatilised in an alkaline medium. To elucidate this probable reaction that may go on in the system a further set of experiments were carried out.

Estimation of ammonia in the medium.—The soil (50 g.) was weighed into a number of shallow glass dishes (capacity 200 c.c.) and treated with 1 g. of solid product and 100 c.c. of distilled water. A parallel set of dishes containing only soil and water were maintained as controls. The fermentation was allowed to proceed in the usual way and, at stated intervals during the period of 53 days, the nitrogen fixed and the ammonia formed were estimated. The results obtained are recorded in Table I and Fig. II.

TABLE I.

Time in days	Nitrogen fixed in mgms.	Total ammonia in mgms.	
		Experimental	Control
0	Nil	0.95	1.20
4	4.10	...	...
8	5.00	0.98	1.06
10	4.00	0.84	1.13
14	3.50	0.53	1.11
20	3.50	0.81	1.09
30	2.50	...	...
36	1.00	...	...
53	Nil	...	...

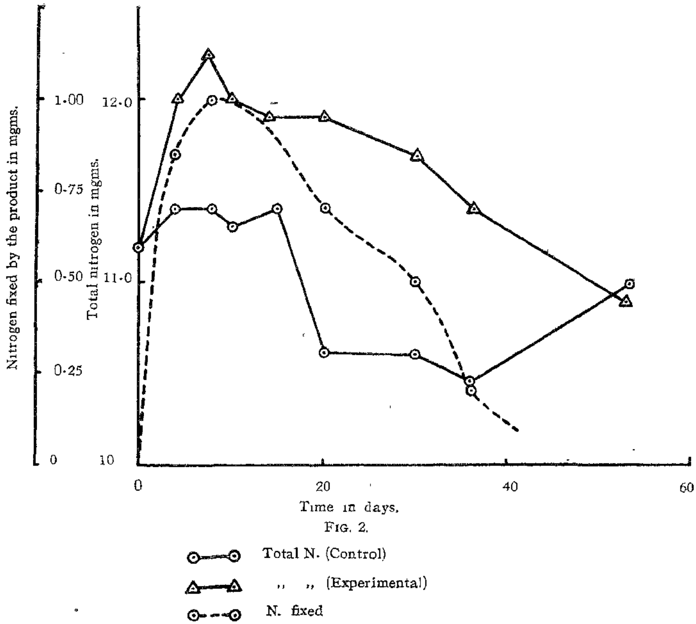

FIG. 2.

As has already been observed in Fig. I, the maximum amount of nitrogen is fixed in about ten days and then the fixed nitrogen is lost at a fast rate, and this loss of nitrogen, as may be seen from Table I becomes complete in about five weeks.

There was, however, no perceptible difference between the amount of ammonia present in the experimental series and that in the controls. Possibly, the fixed nitrogen in the experimental dishes might have volatilised, and more readily so, in presence of large amounts of calcium carbonate in the system. Attention was therefore directed to study the nature and extent of volatilisation of ammonia from the system.

Volatilisation of ammonia.—The previous set of experiments were repeated with this modification—the shallow dishes were covered with suitable petri dish tops in which filter papers previously soaked with known amounts of standard acid (according to the technique developed by Subrahmanyan, *loc. cit.*) were attached so as to absorb all the volatilised ammonia. The results obtained during the period of 36 days are recorded in Table II.

TABLE II.

Ammonia volatilised in mgm. of nitrogen from 50 g. of soil (average of 4 samples)

Time in days ...	2	5	7	11	14	18	25	30	36
Experimental ...	Nil	...	0.084	...	...	0.084	0.112	0.084	0.112
Control ...	Nil	...	0.028	...	...	...	...	...	...

From the foregoing results it would appear that there is no volatilisation of ammonia to any appreciable extent. Although the quantities that are handled in these studies are small, the observed figures for ammonia in the experimental samples are too low to point to the volatilisation of ammonia. Thus it was difficult to say as to what happens to the fixed nitrogen under the conditions.

It was then considered whether some alteration in regard to the conditions of application of the fertilizer or addition of some suitable material to it would ultimately throw some light on the fate of the fixed nitrogen. It is well known that addition of cellulosic materials to soil exerts a marked influence on the mobilisation of nitrogen in the soil. In view of this, it was thought useful to study the effect of straw powder on the fermentation of the solid product and the consequent nitrogen changes.

Influence of powdered straw on the mobilisation of fixed nitrogen.—The soil (10 g.) was weighed into a number of flat bottomed dishes (capacity same as that of the previous set) and treated with appropriate quantities of the molasses-lime compound, straw powder and distilled water, so that two sets of experimental samples might result, one set giving the final (after maximum nitrogen fixation) C: N ratio of 20:1 and the other 30:1. The third set with water and soil alone were maintained as controls. The fermentation was allowed to proceed as usual. Samples were taken at 2-day intervals during the early stages and at 4 and 6-day intervals during the later stages, and analysed for their carbon and nitrogen contents. The results are given in Table III and Fig. 3.

TABLE III.

Time in days	In mgms. A. Control without straw			B. Straw 0.115 g. added (C : N : : 20 :1)			C. Straw 0.230 g. added (C : N : : 30 : 1)			Nitrogen fixed by 0.200 g. of straw
	Organic C	Total N	Nitrogen fixed	Organic C	Total N	Nitrogen fixed	Organic C	Total N	Nitrogen fixed	
0	87.4	5.20	Nil	140.4	6.16	Nil	193.7	7.54	Nil	Nil
2	84.8	5.32	0.12	101.3	...	...	124.5	8.58	1.04	...
4	78.0	5.84	0.64	109.2	6.60	0.44	117.4	8.99	1.45	...
8	80.3	5.98	0.78	110.8	6.98	0.82	127.5	9.13	1.59	0.05
12	59.9	6.13	0.93	94.9	7.75	1.49	121.9	10.11	2.57	0.10
16	59.5	5.94	0.74	102.7	7.91	1.75	126.0	10.27	2.73	0.22
22	59.5	5.96	0.76	84.1	8.04	1.88	113.5	10.24	2.70	0.25
28	55.8	5.66	0.46	82.8	8.74	2.58	91.8	...	...	0.33

It may be observed from the foregoing table that in presence of straw the decomposition of solid product proceeded in the usual way as also the fixation of nitrogen and further, a large part of the fixed nitrogen was retained in the system. Straw by itself fixed only very little nitrogen but its presence in the medium enabled the retention of the major part of the fixed nitrogen. The quantitative relationship, if any, between the amount of straw present and the nitrogen retained cannot however be determined from the foregoing results.

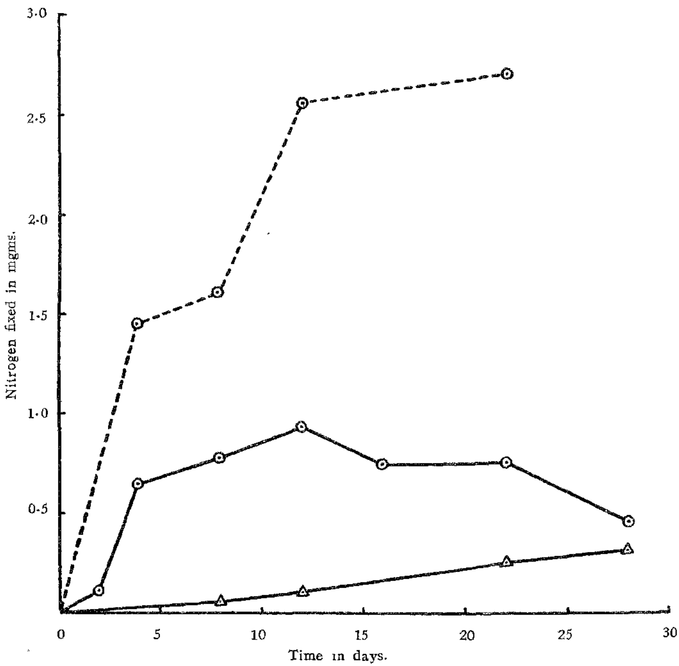

FIG. 3.

Solid-lime compound + straw
Solid-lime compound alone
Straw alone

A more interesting aspect relating to the fixation of nitrogen under these conditions, as would be revealed by the results recorded in Table III and Fig. 3, is that the process of fixation of nitrogen is immediately followed by its loss, the rate of fixation being faster than the loss during the earlier stages till about the 12th day. It would appear therefore that the figure for the nitrogen fixed, as is generally obtained, does not represent the total nitrogen actually fixed in the system but only that resulting from the two processes, the fixation and loss, taking place almost simultaneously.

The exact manner in which the nitrogen is held by the straw and the related aspects are being studied and will be included in later communications.

DISCUSSION.

The results of the present enquiry would show that the solid-lime compound is eminently suited as a fertilizer for the supply of organic nitrogen to the soil. The mixed calcium salts of organic acids produced as the result of the decomposition of this product in the soil serves as an efficient medium for fixation of large quantities of atmospheric nitrogen. The return of nitrogen for carbon utilised (being under 1:30) is highly favourable from the practical point of view.

There is, however, an important factor relating to the quantitative availability of the fixed nitrogen in the soil system. It has been observed as a result of extensive experiments on the field that the major part of the fixed nitrogen is wastefully lost. The laboratory studies relating to this problem have shown that the fixation of nitrogen under these conditions is almost immediately followed by the loss, so that both the processes proceed simultaneously for about 12 days, till the period of maximum fixation is reached, and during this period the rate of fixation is obviously greater. The loss continues steadily even after the 12th day so that more than 50 per cent. of the fixed nitrogen disappears within the following fortnight and the remaining part in the course of the next three weeks. Thus, in about five weeks the fixed nitrogen is entirely lost from the soil. This combined with the fact that a period of rest is necessary between fertilizer application and sowing or transplanting would indeed show that the plants cannot fully utilise the nitrogen fixed by this product.

Probably, this loss of biologically fixed nitrogen is of a general character in the soil even under natural conditions, more especially in tropical climes, and this same loss, which is going on universally to a lesser extent to which natural fixation is also taking place, may have been magnified under the experimental conditions. This important aspect, which has been so far ignored in nitrogen fixation studies, may account to a large extent the failure of the fixation method in actual field practice.

The question, however, resolves into (a) in what form does the fixed nitrogen escape and (b) how can it be effectively retained there for the full benefit of the crop. A systematic study of these would lead to finding out methods of preventing the loss of biologically fixed nitrogen.

The influence of cellulosic materials like straw on the mobilisation of nitrogen would suggest that the loss of fixed nitrogen can be prevented to an appreciable extent by admixture of the product with powdered straw before application to the field. A fuller understanding of the part played by the straw powder in the conservation of the fixed nitrogen in the soil would lead to not only a knowledge of the exact nature of its loss but also to the evolution of more efficient methods of preventing the loss.

SUMMARY.

1. The solid-lime compound is rapidly decomposed in the soil, resulting in the fixation of considerable amounts of nitrogen. The maximum amount of nitrogen is fixed between 8—12 days.

2. The fixed nitrogen is rapidly lost from the soil. More than half of it disappears within a fortnight following the period of maximum fixation.

3. There is no adequate evidence to show that the fixed nitrogen is lost in the form of ammonia.

4. In presence of straw, larger amounts of nitrogen are found to be fixed in the medium, while straw alone fixes negligible amounts.

5. The loss of nitrogen from the medium can be prevented to an appreciable extent by the addition of cellulosic materials like straw.

6. Fixation of nitrogen, as is measured, is the result of two counteracting processes—fixation and loss—which are taking place simultaneously in the system.

7. The practical significance of the foregoing results has been discussed.

The authors wish to thank Mr. B. N. Banerjee for his kind interest in the progress of the work.

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[Received 5-9-1939.]

Printed at the Hosali Power Press, Ulsoor, Bangalore, by D. N. Hosali, Proprietor.