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TRANSFORMATIONS OF NITROGEN IN THE SWAMP SOIL.

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Mineralisation of the organic soil nitrogen is essentially a biological process, consisting of two well defined stages—ammonification and nitrification. The quantity of mineralised nitrogen may be inferred from the amounts of ammonia and nitrates that are formed. In dry soils, ammonification proceeds much slower than nitrification, so that the greater part of the mineralised nitrogen is found in the form of nitrates. The rate of nitrification will thus serve as a means of measuring the comparative rate of organic nitrogen transformation. Such, however, is not the case with the swamp soil. A number of investigators have shown that under such conditions nitrates are not formed and, even if present, are quickly converted into nitrites and are finally lost or denitrified (Warington, 1892, 1897 ; Nagaoka, 1903, 1904, 1906 ; Daikuhara and Imasaki, 1907 ; Kelley, 1911 ; Oelsner, 1918 ; Janssen and Metzger, 1928 ; Bartholomew, 1929 ; Joachim and Kandiah, 1929 ; Mukerji and Vishnoi, 1936 ; and others). According to Harrison and Iyer (1912–16), bulky organic manures yield ammonia under the conditions of the rice soil, there being no nitrification, although the major part of the nitrogen is lost in the elementary state. Subrahmanyan (1927, 1929) observed that in the absence of freshly decomposing organic materials, water-logging results in slight diminution in nitric nitrogen and a distinct increase in free and saline ammonia ; the formation of ammonia has been shown to be enzymic in origin. In presence of fermenting organic matter, even added nitrates are completely lost.

It is not clear whether all the nitrogen thus rendered available in the form of ammonia is utilised by the plant. The amount of available nitrogen in the soil is a balance between the nitrogen liberated from the decomposition of the organic matter and that absorbed by the micro-organisms which decompose the non-nitrogenous and nitrogenous constituents. In dry cultivated soils there have been a number of studies relating to the importance of the composition of organic materials in determining the availability of their nitrogen in the soil (Thomas and Harper, 1926 ; Blair and Prince, 1928 ; Waksman, 1926 ; Waksman and Tenney, 1928 ; Jensen, 1929 ; Martin, 1930 ; Lemmermann, Jensen and Engel, 1930 ; Sievers, 1930 ; Smith and Humfeld, 1930 ; Salter, 1931 ; and others.) The supply of easily available nitrogen is also known to be an important factor in determining the rate of organic matter decomposition

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TABLE I.

Changes in ammonia production and in total nitrogen.

Material used	C-N ratio of material	Days											
		0		8		29		57		78		170	
		NH_3-N	Total N	NH_3-N	Total N	NH_3-N	Total N	NH_3-N	Total N	NH_3-N	Total N	NH_3-N	Total N
		Nitrogen as parts per million											
Dried blood ..	3·3	..	530	48·0	500	79·8	440	100·7	400	100·0	360	66·9	320
Urea ..	0·4	..	530	95·1	520	186·9	400	126·2	330	121·5	300	42·2	280
Hongay leaf ..	13·8	..	530	20·0	520	54·1	480	66·8	450	67·3	420	43·6	390
Farmyard manure	9·8	..	530	4·6	530	10·2	520	7·0	490	2·8	460	1·9	380
Lantana ..	22·6	..	530	2·3	530	2·8	530	1·9	520	0·5	520	0·9	460
Straw ..	120·3	..	530	..	..	0·5	530	0·9	530	..	520	..	500
Untreated soil (control) ..	(10·0)	1·2	230	1·2	230	2·3	230	..	..	..	220	1·4	210

(Meakle, 1918 ; Starkey, 1924 ; Waksman and Starkey, 1924 ; Barthel and Bengtsson, 1924 ; Anderson, 1926 ; Waksman, 1927 ; and others). The position in regard to the swamp soil is not, however, so well defined although a few workers (Itano and Arakawa, 1927 ; Osugi, Yoshie and Komatsubara, 1931) have studied the decomposition of organic materials under such conditions.

The present investigation relates to the transformations in the swamp soil of organic nitrogen from widely different sources, the nature of the losses of nitrogen taking place under such conditions and the means whereby it can be either prevented or, at any rate, reduced to a minimum.

Experimental.

The soil (100 g. lots) was treated with different organic materials in quantities corresponding to 30 mg. of nitrogen. The substances employed were urea, dried blood, hongay leaf, farmyard manure, lantana and rice straw respectively. The mixtures were then swamped and allowed to decompose at 30° and the changes in the different forms of nitrogen (ammoniacal, nitrate, and total) followed in samples taken from time to time.

It was observed that, in general, ammonification proceeded faster with substances with narrow C-N ratios than with the others. With substances of very wide C-N ratios, there was practically no ammonification. The quantities of ammonia formed in the medium tended to increase during the first 8 to 10 weeks after which there was a steady decrease. Nitrification was observed only in the case of substances with narrow C-N ratios and the production of nitrate generally commenced only after about a month when the vigour of the initial fermentation had subsided and fairly large quantities of ammonia had accumulated in the system. There was progressive loss of nitrogen in almost all the cases and, as may be seen from Table I, although the production of ammonia or the loss of nitrogen varied widely for the different substances, there was a close relationship between the two. Thus, substances like dried blood and urea, which ammonify rapidly, also lose their nitrogen at a fast rate, while substances like hongay leaf which ammonify at a somewhat moderate rate do not lose their nitrogen so rapidly. On the other hand, there is very little loss of nitrogen with substances like lantana and straw which also exhibit very little ammonification.

Addition of increasing quantities of fermenting organic matter (10, 20, 30 and 40 mg. respectively of nitrogen added as dried blood to 100 g. lots of soil) resulted in corresponding increase in the production of ammonia and in greater losses of nitrogen (Table II).

The results of experiments carried out with mixtures of organic materials in such proportions as would give a C-N ratio of about 15 to 1 and in quantities corresponding to 30 mg. of nitrogen per 100 g. of soil (Table III) would, however, show that the extent of mineralisation and the loss of nitrogen can be adequately controlled by adjusting the ratio of carbon to nitrogen.

TABLE II.

Changes in total and ammonia nitrogen in presence of increasing quantities of dried blood.

Mg. nitrogen added as dried blood	Days 0		8		29		57		78	
	NH_3-N	Total N	NH_3-N	Total N	NH_3-N	Total N	NH_3-N	Total N	NH_3-N	Total N
	Nitrogen in parts per million									
10	..	330	16	310	28	290	19	290	7	280
20	..	430	23	400	73	390	58	370	33	350
30	..	530	48	500	80	440	101	400	100	360
40	..	630	43	590	132	500	130	440	..	400

TABLE III.

Changes in ammonia and in total nitrogen in presence of mixtures of materials adjusted to C-N ratio, 15 : 1.

Materials mixed	Days 0		8		29		57		78	
	NH_3-N	Total N	NH_3-N	Total N	NH_3-N	Total N	NH_3-N	Total N	NH_3-N	Total N
	Nitrogen expressed as parts per million									
Lantana+Dried blood ..	..	530	1·2	490	6·2	480	16	480	28	480
Urea+Glucose	..	530	10·4	470	163	470	144	440	160	420
Urea alone .. (control)	..	530	95·1	520	187	400	126	330	122	300

From Table III can be seen that the production of ammonia from urea was not appreciably checked by the presence of glucose ; in a like manner dried blood also would seem to ammonify independently of the presence of lantana. The amounts of ammonia were, however, small in this case because of the small quantity (less than 0·1 gm.) of dried blood itself present in the medium. On the other hand, it may be noted that the loss of nitrogen from urea or from dried blood (*cf.* Table I) has been greatly retarded by the presence of their respective components. The mechanism of the retention of nitrogen is still obscure. The steady increase in the ammonia content of the medium would suggest that ammonification was not retarded by the presence of the added components. The non-volatilisation of the ammonia thus formed would, on the other hand, point to its being in some combined form, probably as a salt.

Attention has already been drawn to the fact that pure carbohydrates, as also substances with wide C-N ratios, undergo fermentation in the soil yielding organic acids. If we assume that the ammonification of the added nitrogenous material and the acid fermentation of the carbohydrate or cellulosic material proceeded side by side, then the ammonia resulting from the former would combine with the acids produced by the latter. In this manner, volatilisation of ammonia and consequent loss of nitrogen would be largely prevented.

The observations that nitrogen loss was greatest with substances which underwent the most rapid ammonification suggested that a part at least of the loss might have been due to volatilisation as ammonia. Experiments conducted with soil treated with urea and dried blood respectively (50 mg. N for 100 g. of soil) indeed showed that ammonia was the chief nitrogenous product among the gases evolved and accounted for the major part of the

TABLE IV.

Loss of nitrogen and volatilisation of ammonia.

Treatment		Days					
		8	15	22	29	57	78
UREA (Swamped) ..	Loss of total nitrogen (mgs.)	0·6	2·8	4·8	16·2	19·2	..
	Loss as ammonia (mgs.)	0·5	2·3	4·6	..	15·8	19·0
DRIED BLOOD (Swamped) ..	Loss of total nitrogen (mgs.)	1·6	5·3	10·4	14·1	20·7	24·1
	Loss as ammonia (mgs.)	1·6	4·1	8·8	12·3	17·6	20·8
DRIED BLOOD (maintained at 60% saturation).	Loss of total nitrogen (mgs.)	0·6	3·0	4·1	5·3	7·1	10·4
	Loss as ammonia (mgs.)	0·2	1·4	2·3	3·2	4·3	6·2

Nitrogen originally added = 50 mg.

nitrogen lost from the soil system (Table IV). Similar experiments carried out with soil treated with dried blood but maintained at 60 per cent saturation also showed that the major part of the loss was by volatilisation as ammonia.

DISCUSSION.

Under the conditions of the swamp soil ammonification proceeds at a much faster rate than nitrification. There would therefore be an accumulation of ammonia in the soil system and consequent loss by volatilisation. However, as may be seen from the above studies, there is very little loss of nitrogen during the early stages of fermentation when the dissolved oxygen content of the medium is low and when the soil reaction is fairly acid and contains useful amounts of free organic acids (chiefly lactic and acetic). It is only after the first few weeks, when more or less aerobic conditions are restored and nitrification sets in, that the loss of nitrogen from the soil system is most pronounced. Although it has been suggested that the losses of nitrogen occurring under the 'anaerobic' conditions of the swamp soil may be due to denitrification, the results of the present enquiry would suggest that volatilisation of ammonia proceeds under conditions which are the very reverse of those favouring denitrification.

The nitrogen losses observed in the present studies are rather considerable, but these will be much less in the presence of the growing plant. Still, among the conditions which determine the rapidity of decomposition of organic materials added to the soil temperature is of the greatest importance, and in tropical regions the temperature prevailing in the rice soils is bound to be high and the decomposition may proceed at a fast rate. The organic matter resulting from such decomposition will have a narrower C-N ratio and the losses of nitrogen may thus be enormous, due both to the greater decomposition and to the fact that less of organic matter will be synthesised by the micro-organisms concerned. Such losses may, as would appear from this study, be profitably reduced by adding the substances in small lots at a time or in presence of immobilisers which would retain the surplus nitrogen in combined forms.

SUMMARY.

Decomposition of organic materials (such as urea, dried blood, farmyard manure, green manure and seed cake) in the swamp soil results in the production of ammonia. The extent of such production is determined by the C-N ratio of the materials applied, being more with substances of narrow ratios than with those of wide ones.

Addition of increasing quantities of organic materials results in proportionately greater production of ammonia followed by correspondingly heavier loss of nitrogen. The loss is most pronounced in the case of substances with narrow C-N ratios.

An enquiry into the mechanism of the loss of nitrogen has shown that this occurs largely through volatilisation of ammonia from the soil system. It has been found that, under the swamp soil conditions, ammonification proceeds much faster than nitrification, so that there is accumulation of ammonia in the medium. The volatilisation of ammonia is favoured by the high temperature prevalent under tropical conditions.

Addition of carbonaceous materials calculated to widen the C-N ratio to 15 : 1 or more is effective in reducing the loss of nitrogen.

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