

DENITRIFICATION IN SUNLIGHT AND ITS RETARDATION

PART IV.

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Experiments show that when ammonium sulphate in solution is mixed with substances like titanium oxide, zinc oxide, silica, sterile or unsterile soil, there is appreciable nitrification and loss of nitrogen even in the dark, under completely sterile conditions. The nitrification and nitrogen lost increase in light. Before the formation of nitrate there is always the production and decomposition of ammonium nitrite in the process of nitrification. In all cases the actual amount of nitrate present is small in comparison with the loss of nitrogen. Hence, the amount of nitrate actually present in a soil after the addition of nitrogenous manure is not a true measure of nitrification which has to be determined by the difference in the total nitrogen before and after the process rather than on the actual amount of nitrate present.

Very little ammonia is lost from the soil as free ammonia although considerable amount of nitrogen loss takes place from soils.

Very little loss of nitrogen is observed when a nitrate is mixed with glucose and exposed to sun light.

Under field conditions on the addition of blood, urea and gelatin there is more loss in light than in dark. Molasses readily conserve the total nitrogen in the soil, and that is why organic substances are useful in preserving and increasing the soil nitrogen.

In recent years (*J. Indian Chem. Soc.*, 1935, 12, 77, 756; 1936, 13, 555) we have shown that when ammonium salts or other nitrogenous compounds undergo nitrification in the soil or in solutions there is a considerable loss of nitrogen in the gaseous state due to the formation and decomposition of ammonium nitrate, specially when the dose of nitrogen added is high. This loss is intimately connected with the process of nitrification and appears to be unavoidable in the soil under normal conditions. Field trials with different manures at Rothamsted and at other places reveal as high a loss as 70% of the added nitrogenous manure.

We have carried on further experiments on this type of nitrogen loss under aerobic conditions with ammonium salts in contact with soil and surfaces like TiO_2 , ZnO , SiO_2 etc. under completely sterile conditions. The dark experiments were carried on in flasks completely covered with black cloth. The following are the experimental results. The garden soil used in some of these experiments contained $\text{NH}_3\text{-N} = 0.7$ mg.%, $\text{NO}_3\text{-N} = 1.1$ mg.% and Total N = 33 mg.%.

The p_n of the original soil was 7.6. Most of the experiments described in this paper have been repeated several times.

TABLE I.

Started on 14-9-37 and stopped on 27-12-37. Exposure to sunlight for 604 hours. Max. temp. = 40°. Min. temp. = 23° in 500 c.c. conical Jena flask plugged with cotton wool.

Added		Light.		Left	
		NH ₃ -N. %	NO ₃ -N. %	Total N. %	% Loss. p _n .
5 g. TiO ₂	+ 0.0175 g. NH ₃ -N + 100 c.c. water	0.0112 g.	0.002 g.	0.0118 g.	21.1 6.7
5 g. SiO ₂	+ " " + "	0.0056	Nil	0.0058	66.8 6.6
5 g. ZnO	+ " " + "	0.0003	0.0035	0.004	77 7.2
5 g. Sterile soil	+ " " + "	0.0012	Nil	0.0074	57 7.4
5 g. Unsterile soil	+ " " + "	0.0008	"	0.0056	67 7.4

Dark.

5 g. TiO ₂	+ 0.0175 g. NH ₃ -N + 100 c.c. water	0.014 g.	"	0.0144 g.	19 6.9
5 g. SiO ₂	+ " " + "	0.014	"	0.0144	19 6.8
5 g. ZnO	+ " " + "	0.010	"	0.0124	28 7.2
5 g. Sterile soil	+ " " + "	0.007	"	0.0098	50.8 7.4
5 g. Unsterile soil	+ " " + "	0.0014	0.0093	0.0067	8.5 6.8

Started on 14-9-37 and stopped on 28-12-37. Exposure to sunlight for 618 hours. Max. temp. = 40°. Min. temp. = 23° in 500 c.c. conical Jena flask plugged with cotton wool.

Light.

5 g. TiO ₂	+ 0.035 g. NH ₃ -N + 100 c.c. water	0.0282 g.	0.0046 g.	0.028 g.	7 6.7
5 g. SiO ₂	+ " " + "	0.0112	Nil	0.0121	65 6.2
5 g. ZnO	+ " " + "	0.0093	0.0038	0.0098	61 7.6
5 g. Sterile soil	+ " " + "	0.0056	Nil	0.0172	50 6.7

Dark.

5 g. TiO ₂	+ 0.035 g. NH ₃ -N + 100 c.c. water	0.0318 g.	Nil	0.0321 g.	8.3 6.8
5 g. SiO ₂	+ " " + "	0.0188	"	0.0298	14.8 6.0
5 g. ZnO	+ " " + "	0.0112	"	0.0148	57.7 7.6
5 g. Sterile soil	+ " " + "	0.014	"	0.028	20.0 6.6

TABLE I (contd.).

Started on 14-9-37 and stopped on 3-1-38. Exposure to sunlight for 646 hours. Max. temp. = 40°. Min. temp. = 23° in 500 c.c. conical Jena flask plugged with cotton wool.

		<i>Light.</i>			<i>Left</i>		
Added		NH ₃ -N. %	NO ₂ -N. %	Total N. %	% Loss.	p _n .	
5 g. TiO ₂	+ 0.07g. NH ₃ -N + 100 c.c. water	0.0467 g.	0.0062 g.	0.0534 g.	18.8	6.0	
5 g. SiO ₂	+ " " + " "	0.035	Nil	0.0362	48.2	6.0	
5 g. ZnO	+ " " + " "	0.014	0.0046	0.0192	64.5	—	
5 g. Sterile soil	+ " " + " "	0.0254	Nil	0.0314	55.1	6.4	
5 g. Unsterile soil	+ " " + " "	0.0164	Nil	0.0366	47.6	6.2	
<i>Dark.</i>							
5 g. TiO ₂	+ 0.07 g. NH ₃ -N + 100 c.c. water	0.0638 g.	Nil	0.0642	8.3	6.0	
5 g. SiO ₂	+ " " + " "	0.0508	"	0.0512	26.8	6.0	
5 g. ZnO	+ " " + " "	0.0221	"	0.0292	57.4	—	
5 g. Sterile soil	+ " " + " "	0.0468	"	0.0564	19.4	6.2	
5 g. Unsterile soil	+ " " + " "	0.0508	0.0014	0.0588	16.0	6.2	

Started on 14-9-37 and stopped on 6-1-38. Exposure to sunlight for 667 hours. Max. temp. = 40°. Min. temp. = 23° in 500 c.c. conical Jena flask plugged with cotton wool.

		<i>Light.</i>				
		NH ₃ -N. %	NO ₂ -N. %	Total N. %	% Loss.	p _n .
5 g. TiO ₂	+ 0.14 g. NH ₃ -N + 100 c.c. water	0.11 g.	0.007 g.	0.112 g.	15.0	5.6
5 g. SiO ₂	+ " " + " "	0.084	0.0009	0.0862	37.8	5.8
5 g. ZnO	+ " " + " "	0.030	0.0049	0.0312	74.0	7.2
5 g. Sterile soil	+ " " + " "	0.062	0.0007	0.0668	30.8	5.6
5 g. Unsterile soil	+ " " + " "	0.051	0.0007	0.1041	25.4	5.8

TABLE I (contd.).

Dark.

Added	Left				
	NH ₃ -N. %	NO ₃ -N. %	Total N. %	% Loss.	p ₂ .
5 g. TiO ₂ + 0.14 g. NH ₃ -N+100 c.c. water	0.128 g.	Nil	0.131	6.5	5.6
5 g. SiO ₂ + " " + " "	0.112	"	0.119	15.0	5.8
5 g. ZnO + " " + " "	0.0904	"	0.0928	33.8	7.0
5 g. Sterile soil + " " + " "	0.123	"	0.131	6.5	5.8
5 g. Unsterile soil + " " + " "	0.117	0.0005	0.131	6.5	5.8

Started on 14-9-37 and stopped on 10-1-38. Exposure to sunlight for 675 hours. Max. temp.=40°. Min. temp. = 23° in quartz boiling tube. Sterile and plugged with cotton wool

Light.

5 g. TiO ₂ + 0.14 g. NH ₃ N+100 c.c. water	0.0934 g.	0.0031 g.	0.0944 g.	30.3	5.6
5 g. SiO ₂ + " " + " "	0.052	0.0011	0.052	62.0	5.8
5 g. ZnO + " " + " "	0.0467	0.0011	0.0472	66.4	7.0
5 g. Sterile soil + " " + " "	0.0519	0.0008	0.056	59.4	6.2

Started on 28-1-38 and stopped on 17-5-38. Exposure—daily 8 hours in 1000 watt bulb light in 500 c.c. Jena flask plugged with cotton wool.

5 g. TiO ₂ +0.14 g. NH ₃ -N+100 c.c. water	0.1286 g.	0.0184 g.	0.1214 g.	0.14	5.6
5 g. ZnO ₂ + " " + " "	0.0896	0.0386	0.0984	2.15	7.0
5 g. TiO ₂ +0.07 g. " + " "	0.0584	0.0110	0.0512	1.11	6.0
5 g. ZnO+0.07 g. " + " "	0.0229	0.0268	0.0321	15.7	7.2

The experiments recorded above show that even in the dark there is appreciable nitrification and loss of nitrogen when ammonium salts in solutions are mixed with surfaces and kept under sterile conditions. The nitrification and nitrogen loss are always greater in light than in the dark. Moreover, the large number of experimental results recorded in this paper show conclusively that nitrification and nitrogen loss are possible

even in the absence of bacteria both in light and in the dark. It appears, therefore, that ammonium salts can undergo slow oxidation on different surfaces with the formation of nitrites and nitrates even in the absence of nitrite or nitrate formers (bacteria). The oxidation, however, is greater if the mixture of the ammonium salts and surface contains bacteria or is exposed to light. It must be emphasised that under normal conditions in the soil or in solutions there is more loss of nitrogen due to the formation and decomposition of ammonium nitrite than the formation of nitrate. It is well known that under normal conditions, soil contains small quantities of nitrate and traces of nitrite, although the nitrogen content may be fairly high.

The marked influence of zinc oxide in helping nitrogen loss in light cannot be ascribed to the reaction of ammonium salts with zinc oxide, because this action should be more or less identical in both light and in the dark, as the temperature of the vessels in light and dark was almost the same.

When the nitrogenous matter undergoes oxidation on the soil surface, the first product in the case of proteins is ammonia, which on nitrification produces nitrites and nitrates. In the case of ammonium salts, by nitrification, nitrites and nitrates are produced. It appears, therefore, that before the formation of nitrate, there is always the possibility of the loss of nitrite by the formation and decomposition of ammonium nitrite as an intermediate product. Hence in all cases the actual formation of nitrate may be small in comparison with the loss of nitrogen by the process of the decomposition of ammonium nitrite. Our experimental results are in agreement with these views, because in most cases the amount of nitrate present after the process of nitrification is small in comparison with the nitrogen lost. It is clear, therefore, that the amount of nitrate actually present in a soil or a solution on the addition of nitrogenous manure is not a true measure of nitrification, which causes more loss of nitrogen in the gaseous state than the amount of the nitrate formation. Hence the amount of nitrification under aerobic conditions has to be judged by the difference in the total nitrogen before and after the process, rather than on the actual quantity of nitrate present. Hence in order to estimate the amount of nitrification under ordinary conditions in a system it is necessary to estimate the total nitrogen before and after the process. The recent experiments of Waksman and Madhok (*Soil Sci.*, 1937, **44**, 361) are not at all convincing as the total nitrogen of the soil before and after the experiments has not been determined. Unless the difference of total nitrogen before and after the experiments is known, it is impossible to conclude definitely about the amount of nitrification.

We have repeatedly observed that hardly any ammonia escapes under aerobic conditions in the soil, because in our experiments no ammonia was obtained in flasks containing sulphuric acid, although large amounts of nitrogen gas was collected in the nitrometer.

Amount of gas collected when water was put into the nitrometer. Temperature = 30°. Time = 37 days.

200 G. soil + 0.28 g. nitrogen + 50 c.c. water = 99.5 c.c. gas
 ,, + 50 c.c. water only = 21 c.c. gas

Amount of gas collected by the displacement of 20% caustic potash in the nitrometer. Temperature = 32-33°. Time = 52 days.

200 G. soil + 0.28 g. nitrogen + 50 c.c. water = 11.3 c.c.
 ,, + 50 c.c. water = 1.8 c.c.

It may be stated that the nitrogen may be lost as ammonia gas from the soil, but this seems improbable in the soils of temperate climates, because they are acidic in nature. In order to test this point with our soils the following experiments have been performed.

Three 250 c.c. conical flasks containing concentrated sulphuric acid, ferrous sulphate and sulphuric acid and distilled water respectively were joined in series to a quartz flask of 250 c.c. capacity. To the other end of the quartz flask, three flasks containing dilute sulphuric acid were attached to absorb the ammonia evolved from the reaction vessel. A mixture of sterile soil and ammonium sulphate was put in the reaction vessel and was sterilised and plugged with cotton wool. Air from a gas cylinder of 30 litres capacity was bubbled through these flasks. After the exposure, the contents of the quartz flask as well as of the catches were analysed. The following are the experimental results.

TABLE II.

Started on 13-1-37 and stopped on 8-2-37. Exposure—150 hours to sunlight in quartz flask (250 c.c.). Aeration—30 litres for each 7 hours of exposure.

Initial concentration.	Final concentration.
$\text{NH}_3\text{-N} = 0.0483\%$	0.02084%
$\text{NO}_2\text{-N} = 0.0022$	0.0025
Total N = 0.0505	0.0233
	3.7% lost as calculated from ammonia
	Ammonia in the catches placed next to the reaction vessel = 0.0033 g.
	Loss in total nitrogen = 0.027 g. or 14.4%

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The experimental results recorded above show that the loss of nitrogen cannot be accounted for on the viewpoint, that gaseous ammonia is chiefly lost because the loss of total nitrogen is much greater than that of ammonia.

Once the nitrate is formed, it can be lost by leaching and not by denitrification of the type discussed in this paper as is evident from the following results.

TABLE III.

Started on 8-9-36 and stopped on 6-10-36. Exposure to sunlight for 100 hours.

Added	Left		
	NH ₃ -N.	NO ₃ -N.	Total N.
1 g. Fe ₂ O ₃ + 1.4 g. NO ₃ -N + 100 c.c. water	0.002 g.	1.381 g.	1.383 g.
" + 0.7 " + "	0.002	0.648	0.650
" + 0.14 " + "	0.002	0.1236	0.1256
" + 0.07 " + "	0.0019	0.0618	0.0634
" + 0.035 " + "	0.0010	0.0124	0.0139
" + 0.0028 " + "	0.0007	0.0020	0.0028
" + 0.014 " + "	0.001	0.0124	0.0134

Started on 27-10-36 and stopped on 9-12-36. Exposure to sunlight for 200 hours.

1 g. Fe ₂ O ₃ + 1.4 g. NO ₃ -N + 100 c.c. water	0.0007 g.	1.388 g.	1.4 g.
" + 0.7 " + "	0.0003	0.6982	0.7
" + 0.14 " + "	0.0001	0.139	0.1389
" + 0.07 " + "	0.0012	0.0688	0.07
" + 0.035 " + "	0.0016	0.0298	0.0348
" + 0.014 " + "	0.0015	0.0132	0.014
" + 0.0028 " + "	0.0004	0.0020	0.0028

Started on 8-9-36. Stopped on 6-10-36. Exposure to sunlight for 100 hours.

1 g. Fe ₂ O ₃ + 1 g. glucose + 1.4 g. NO ₃ -N + 100 c.c. water	0.0056 g.	0.948 g.	1.3 g.
" + " " + 0.7 + "	0.0056	0.586	0.644
" + " " + 0.14 + "	0.0046	0.112	0.113
" + " " + 0.07 + "	0.004	0.0467	0.066
" + " " + 0.035 + "	0.0028	0.0200	0.0222
" + " " + 0.014 + "	0.0012	0.00406	0.00416
" + " " + 0.0028 + "	0.0008	0.0004	0.0008

TABLE III (contd.).

Started on 27-10-36. Stopped on 9-12-36. Exposure to sunlight for 200 hours.

				NH ₃ -N.	NO ₃ -N.	Total N.
1 g. Fe ₂ O ₃ +1 g. glucose + 1.4 g. NO ₃ -N+100 c.c. water				0.007 g.	0.9324 g.	1.4 g.
" + " "	+ 0.7	+	"	0.0062	0.5724	0.7
" + " "	+ 0.14	+	"	0.0058	0.0998	0.1398
" + " "	+ 0.07	+	"	0.0052	0.0456	0.07
" + " "	+ 0.035	+	"	0.0031	0.0192	0.0348
" + " "	+ 0.014	+	"	0.0021	0.0038	0.014
" + " "	+ 0.0028	+	"	0.0009	0.0001	0.0039

It is generally believed that denitrification is frequently observed when a nitrate is mixed with organic matter but in our experiments the beakers containing nitrates alone do not show appreciable nitrogen loss or a change of nitric nitrogen. The beakers containing glucose and nitrate in some cases show a decrease in nitrate, but not in the total nitrogen, and at the lowest concentration when the carbon-nitrogen ratio is above 20, nitrogen fixation takes place.

Blood, urea, and gelatin were added to small plots in fields. The ammoniacal, nitric, total nitrogen and total carbon were determined from time to time. Some of the fields have been treated with molasses and some are covered with wooden planks to determine the effect of sunlight and carbonaceous substances upon nitrification and nitrogen loss from soils. The following results show that our conclusions regarding the phenomenon of nitrogen loss are also being borne out by field experiments. The first estimation shows the condition of the field just after mixing the above substances.

TABLE IV.

Blood.

Plot 6 sq. ft. Started on 27-11-36.

<i>Light.</i>					
NH ₃ -N.	NO ₃ -N.	Total N.	Total C.	Date of sampling.	
%	%	%	%		
0.001 g.	0.0028 g.	0.07 g.	0.5424 g.	27-11-36	
0.0012	0.0031	0.07	0.5133	7-12-36	
0.0025	0.0037	0.07	0.4569	25-12-36	
0.0026	0.0042	0.07	0.4562	25-1-37	
0.0009	0.008	0.0636	0.4421	25-2-37	
0.0011	0.0112	0.05	0.4412	22-3-37	
0.0011	0.0116	0.0482	0.4421	3-5-37	
<i>Covered.</i>					
0.0010 g.	0.0032	0.0823	0.5569	27-11-36	
0.0012	0.0034	0.0823	0.5234	7-12-36	
0.0022	0.0036	0.0799	0.4932	25-12-36	
0.0022	0.0038	0.0799	0.4824	25-1-37	
0.0014	0.0073	0.0636	0.4646	25-2-37	
0.0014	0.008	0.0584	0.4622	22-3-37	
0.0014	0.0082	0.0578	0.4612	3-5-37	

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TABLE V.

Blood + molasses.

Plot 6 sq. ft. Started on 30-11-36.

Light

NH ₃ -N. %	NO ₃ -N. %	Total N. %	Total C. %	Date of sampling.
0.0031 g	0.0032 g.	0.0034 g.	2.829 g.	30-11-36
0.0029	0.0031	0.0031	2.539	7-12-36
0.0037	0.0032	0.0034	2.182	25-12-36
0.0043	0.0035	0.0041	1.7214	25-1-37
0.0031	0.0021	0.0031	0.8624	28-2-37
0.0028	0.0035	0.0078	0.8452	24-3-37
0.0028	0.0036	0.0072	0.8314	3-5-37

Covered,

0.0028	0.0022	0.00875	2.781	30-11-36
0.0020	0.0025	0.00875	2.631	7-12-36
0.0056	0.0022	0.00874	2.010	25-12-36
0.0056	0.0018	0.00872	0.9921	25-1-37
0.0018	0.0014	0.00824	0.7212	25-2-37
0.0029	0.0031	0.00824	0.7224	22-3-37
0.0029	0.0031	0.00823	0.7112	3-5-37

TABLE VI.

Urea.

Plot 6 sq. ft. Started on 7-12-36.

Light

0.0031 g.	0.0022 g.	0.14 g.	0.385 g.	7-12-36
0.0200	0.0031	0.14	0.388	25-12-36
0.02	0.0050	0.1272	0.3892	25-1-37
0.015	0.0086	0.1178	0.3892	25-2-37
0.0035	0.028	0.0875	0.3921	22-3-37
0.0036	0.0318	0.0710	0.3921	3-5-37

Covered

0.0040	0.0023	0.175	0.385	7-12-36
0.0146	0.0025	0.175	0.3886	25-12-36
0.0155	0.0039	0.1654	0.3892	25-1-37
0.0017	0.0079	0.1524	0.3892	25-2-37
0.0014	0.0250	0.1004	0.3892	22-3-37
0.0016	0.027	0.0998	0.3892	8-5-37

TABLE VII.

Urea + molasses.

Plot 6 sq. ft. Started on 7-12-36.

NH ₃ -N.	NO ₃ -N.	Total N.	Total C.	Date of sampling.
0.0050 g. %	0.0023 %	0.200 %	2.553 %	7-12-36
0.0056	0.0020	0.1986	2.079	25-12-36
0.0062	0.0043	0.1925	0.9794	25-1-37
0.0031	0.0044	0.1612	0.8132	25-2-37
0.0031	0.0056	0.1277	0.8043	22-3-37
0.0037	0.0062	0.1182	0.8112	3-5-37

Covered.

0.0049	0.0034	0.220	3.431	7-12-36
0.0043	0.0028	0.1892	1.5831	25-12-36
0.0061	0.0037	0.1874	0.8454	25-1-37
0.0043	0.0039	0.1721	0.7944	25-2-37
0.0037	0.0040	0.1346	0.7934	22-3-37
0.0037	0.0054	0.1212	0.7118	3-5-37

TABLE VIII.

Gelatin.

Plot 6 sq. ft. Started on 25-12-36.

Light.

0.02 g %	0.0056 %	0.200 %	0.7198	25-12-36
0.04	0.0062	0.200	0.7112	25-1-37
0.046	0.0074	0.1752	0.7086	25-2-37
0.035	0.007	0.1556	0.6012	22-3-37
0.014	0.0102	0.1042	0.6102	3-5-37

Covered.

0.02 g %	0.0056	0.212	0.7198	25-12-36
0.037	0.0058	0.200	0.7154	25-1-37
0.038	0.0063	0.1823	0.7092	25-2-37
0.0174	0.0075	0.1667	0.6124	25-3-37
0.0178	0.0079	0.1508	0.6124	3-5-37

TABLE IX.

Gelatin + molasses.

Plot 6 sq. ft. Started on 25-12-36.

Light.

$\text{NH}_4\text{-N.}$	$\text{NO}_3\text{-N.}$	Total N.	Total C.	Date of sampling.
	%	%	%	
0'020 g.-%	0'0062 g.	0'200	1'838	25-12-36
0'0056	0'0066	0'200	0'9842	25-1-37
0'0181	0'0047	0'1924	0'8278	25-2-37
0'0056	0'008	0'175	0'8138	22-3-37
0'0062	0'0084	0'1731	0'8034	3-5-37

Covered.

0'020	0'008	0'200	1'838	25-12-36
0'007	0'0057	0'200	0'9672	25-1-37
0'0106	0'0039	0'1864	0'8122	25-2-37
0'005	0'028	0'175	0'8122	22-3-37
0'0056	0'030	0'1734	0'8122	3-5-37

The experiments carried on in flasks show that although the dark vessels had slightly a higher temperature than the vessels kept in sunlight, the loss in total nitrogen due to nitrification is always greater in vessels receiving sunshine than in those kept in the dark when ammonium sulphate at various concentrations were mixed with surface like titanium oxide, silica, zinc oxide and sterile or unsterile garden soil. It appears, therefore, that sunlight, which increases the velocity of nitrification, also increases nitrogen loss.

The field trials carried on with different nitrogenous substances like blood, urea and gelatin show that even in the field trials there is more marked nitrogen loss from the fields exposed to sunlight than in those covered with wooden planks. Another highly significant result has been obtained in these experiments, that when molasses is mixed with these nitrogenous substances and added to the field, the nitrogen loss in the fields

both in light and in the dark is much smaller than in those plots where nitrogenous substances were added to the soil alone. It is clear; therefore, that the carbonaceous substances present in molasses retard the process of nitrification and the loss of nitrogen. Hence in tropical soils, at any rate, a mixture of nitrogenous substances with carbonaceous substances like molasses, hay, leaves, etc, are more useful as a nitrogenous store than the nitrogenous substance alone.

For the first time in the study of the problem of organic manures, light has been thrown by our researches on the value of organic nitrogenous manure. The carbonaceous substances added with the organic manure not only protect nitrogen and retard loss, but also in many cases when the proportion of carbonaceous substances is large, fixation of nitrogen takes place as in the case of cowdung and other substances.

It has been frequently mentioned that the loss of nitrogen observed after the addition of nitrogenous substances to the soil is due to the escape of ammonia, but from the experiments described in these papers, it appears that the amount of ammonia that escapes from the soil mixed with ammonium sulphate is very small although a good deal of nitrogen is lost from soil due to the formation and decomposition of ammonium nitrite found as an intermediate product during nitrification. Hence the nitrogen loss under aerobic condition cannot be explained from the viewpoint of escape of ammonia.

It is of interest to note that in our field trials in light with the nitrogenous substances mixed with molasses, sometimes in the beginning of the experiments, the loss in nitrogen may be slightly less than that in the dark. This is noticeable with blood and gelatine mixed with molasses. We are of opinion that this behaviour may be due to a certain amount of nitrogen fixation in light in the molassed fields containing nitrogenous compounds.

We have also investigated the influence of temperature on nitrification of ammonium sulphate mixed with soil. The following results have been obtained.

TABLE X.

200 G. soil + 0.28 g. of N as ammonium sulphate. Original $\text{NH}_3\text{-N} = 0.00084$ g.%. $\text{NO}_3\text{-N} = 0.0036$ g.% and total N = 0.0387 g.%.

At 20°.

$\text{NH}_3\text{-N}$.	$\text{NO}_3\text{-N}$.	Total N.	Date of sampling
%	%	%	original soil.
0.1408 g.	0.0036 g.	0.1787 g.	15-9-37

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TABLE X (contd).

NH ₃ -N. %	NO _x -N. %	Total N. %	Date of sampling original soil.
0.08 g.	0.0048 g.	0.1167 g.	30-9-36
0.04	0.0064	0.1012	15-10-37
0.022	0.0188	0.0964	30-10-37
At 25°.			
0.1408	0.0036	0.1787	Original soil 15-9-37
0.074	0.0052	0.1129	30-9-37
0.035	0.0162	0.0934	15-10-37
0.0198	0.0268	0.0912	30-10-37
At 30°.			
0.1408	0.0036	0.1787	Original soil 15-9-37
0.046	0.0080	0.1129	30-9-37
0.0062	0.0372	0.070	15-10-37
0.0042	0.0384	0.0668	30-10-37
At 35°.			
0.1408	0.0036	0.1787	Original soil 15-9-37
0.050	0.0072	0.1078	30-9-37
0.008	0.028	0.0636	15-10-37
0.0042	0.0302	0.0612	30-10-37
At 40°.			
0.1408	0.0036	0.1787	15-9-37
0.027	0.0058	0.0875	30-9-37
0.0086	0.0224	0.0603	15-10-37
0.0042	0.0242	0.0575	30-10-37
At 45°.			
0.1408	0.0036	0.1787	Original soil 15-9-37

TABLE X (contd).

NH ₃ -N. % 0·024 g.	NO ₃ -N. % 0·0048 g.	Total N. % 0·0700 g.	Date of sampling.
0·0092	0·0063	0·0583	15-10-37
0·0042	0·0064	0·0512	30-10-39
At 50°.			
0·1408	0·0036	0·1787	15-9-37
0·016	0·004	0·0626	30-9-37
0·0092	0·0042	0·0538	15-10-37
0·0036	0·0042	0·0487	30-10-37
At 60°.			
0·1408	0·0036	0·1787	15-9-37
0·0092	0·0036	0·0612	30-9-39
0·0092	0·0037	0·0538	15-10-37
0·0032	0·0036	0·0488	30-10-37
Exposed to sunlight daily for 8 hours (temperature 35°).			
0·1408	0·0036	0·1787	15-9-37
0·0186	0·0037	0·0612	30-9-37
0·0092	0·0042	0·056	15-10-37
0·0042	0·0042	0·0492	30-10-37

TABLE XI.

200 G. soil + 8 g. cane sugar + 0·28 g. nitrogen as ammonium sulphate. The soil contained NH₃-N = 0·0004 g.%, NO₃-N = 0·002 g.% and total N = 0·0368 g.%. Started on 3-11-37.

At 10-13°.				
NH ₃ -N. %	NO ₃ -N. %	Total N. %	Total C. %	Date
0·1404 g.	0·002 g	0·1768 g.	2·004 g.	3-11-37
0·116	0·0021	0·1676	1·2136	18-11-37

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TABLE XI (contd.).

NH ₃ -N.	NO ₂ -N ₂	Total N.	Total C.	Date.
%	%	%	%	
0.0624 g.	0.0022 g.	0.1489 g.	0.7770 g.	3-2-37 ^I
0.053	0.0031	0.1273	0.7112	18-12-37
		At 25°.		
0.1404	0.002	0.1768	2.004	3-11-37
0.070	0.0036	0.1676	0.9877	18-11-37
0.0572	0.0050	0.1278	0.556	3-12-37
0.028	0.0062	0.1167	0.5022	18-12-37
		At 30°		
0.1404	0.002	0.1768	2.004	3-11-37
0.043	0.0045	0.14	0.8956	18-11-37
0.0224	0.008	0.1167	0.5524	3-12-37
0.02	0.0104	0.100	0.4986	18-12-37
		At 35°		
0.1404	0.002	0.1768	2.004	3-11-37
0.040	0.008	0.1165	0.5273	18-11-37
0.020	0.0196	0.1016	0.5376	3-12-37
0.0104	0.025	0.0934	0.4195	18-12-37
		At 40°.		
0.1404	0.002	0.1768	2.004	3-11-37
0.031	0.0032	0.1128	0.4205	18-11-37
0.017	0.0042	0.1000	0.4205	3-12-37
0.0085	0.0071	0.0875	0.4205	18-12-37
		At 45°		
0.1404	0.002	0.1768	2.004	3-11-37
0.0155	0.0032	0.1000	0.4205	18-11-37
0.0106	0.0036	0.0934	0.4205	3-12-37
0.0074	0.0043	0.0814	0.4205	18-12-37

TABLE XI (contd.).

NH ₃ N.	NO ₃ N.	At 50°.		Date of sampling.
		Total N.	Total C.	
%	%	%		
0·1404 g.	0·002 g.	0·1768 g.	2·004 g.	3-11-37
0·0132	0·0028	0·1000	0·6914	18-11-37
0·0104	0·0018	0·0934	0·5199	3-12-37
0·0062	0·0030	0·0778	0·5022	18-12-37
		At 60°.		
0·1404	0·002	0·1768	2·004	3-11-37
0·0096	0·002	0·1000	0·5312	18-11-37
0·0093	0·002	0·0885	0·5244	3-12-37
0·0015	0·002	0·0778	0·5187	18-12-37
		Exposed to sunlight. (Temperature 35°)		
0·1404	0·002	0·1768	2·004	3-11-37
0·02	0·003	0·1183	0·5273	18-12-37
0·016	0·0033	0·100	0·5010	3-12-37
0·007	0·0034	0·100	0·4986	18-12-37

The foregoing results show that the higher the temperature, the greater the loss of nitrogen. In sunlight, however, the loss in nitrogen is much greater than in the dark at the same temperature.

Canesugar markedly retards the loss of nitrogen when it is added to ammonium sulphate which is undergoing nitrification.