NITROGEN BALANCE STUDIES FOR SALT AFFECTED SOILS CROPPED WITH COTTON*

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The nitrogen balance for five different soils cropped with cotton (*Gossypium barbadense var. monoufy*) and fertilized with either ammonium sulphate or calcium nitrate was studied in pot experiments. The soils used were sandy loam, calcareous sandy loam, alkaline sandy loam, saline-alkaline sandy loam and saline sandy loam. Nitrogen added as seeds, fertilizers, irrigation water and insecticides, nitrogen removed by the plants and nitrogen contents of the soils before sowing and after the harvest were determined.

The obtained results showed nitrogen loss from the soil-plant system. The deficit in nitrogen ranged between 32.6 and 118.7 kg/feddan or from 10.6 % to 31.4 % of the nitrogen added and found in the soils. It was highest from the alkaline and least from the saline soils. Also, the unaccounted for nitrogen (not recovered) was higher with ammonium sulphate than with calcium nitrate fertilizer.

It was also found that nitrogen content of all tested soils decreased due to growing cotton plants. The soils lost from 5.2 % to 31.9% of its nitrogen depending upon soil type and kind of applied nitrogen fertilizer.

The main conclusion of the reported balance sheets is that certain nitrogen losses occured and were porbably due to volatilization of ammonia and denitrification.

INTRODUCTION

Many attempts have been made to draw up nitrogen balance sheets for cropped soils (Allison 1955, 1965 and Jansson 1963). In general, these attempts showed that the income and outgo seldom balance. Usually, all of the nitrogen that went into the soil-plant system was not recovered. According to Allison (1965), recoveries in harvested crops of nitrogen released from soil or added as fertilizers were commonly less than 50%. Nitrogen might be lost from soils in drainage water and as gasses in the forms of ammonia, elemental nitrogen, oxides of nitrogen and from plants as organic compounds (Allison 1965, Broadent and Clark 1965, Martin and Chapman 1951, Martin and Skyring 1962 and Wahhab *et al* 1957). Fundamental informations are needed on how much nitrogen is lost through the various channels and under variety of soil conditions. Such informations are required as a basis for practical recommendations that lead to more efficient use of nitrogen in crop production.

The simplest type of nitrogen balance experiments is that conducted in pots. In such experiments, all sources of nitrogen losses and gains are chemically determined and any deficit is attributed to gasseous losses (Allison 1965). The present work illustrates an attempt to draw nitrogen balance sheets for calcareous, alkaline and saline soils cropped with cotton using ammonium and nitrate fertilizers.

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MATERIALS AND METHODS

Soils Used :

Five different soils were used in this study. The important physical and chemical properties of these soils, as determined according to the United States Salinity Laboratory Staff (1954), are shown in Table 1. The used soils differed mainly in total soluble salts, carbonate content , soluble and exchangeable sodium and pH but were similar in texture. Each soil was sieved through 2 mm sieve and well mixed before being used. These soils are :

Soil No. I : Sandy loam (S.L. obtained from Kalubia Governorate.

Soil No. II : Calcareous sandy loam (Cal. S.L.) obtained from Burg El-Arab,

Soil No. III : Alkalinized soil (Alk. S.L.) prepared from the sandy loam by treating with sodium carbonate (3 kg/ton of soil).

Soil No. IV : Saline-alkaline soil (Sal. Alk. S.L.) synthetically prepared from sandy loam soil upon treatment with sodium carbonate (3 kg/ton), sodium chloride (2 kg/ton) and calcium chloride (2 kg/ton).

TABLE 1.— General properties of the used soils (oven dry basis).

Soil properties	S.L.	Cal. S.L.	Alk. S.L.	Sal. Alk. S.L.	Sal. S.L.
Total nitrogen, %	0.033	0.028	0.034	0.030	0.027
Total soluble salts, %	0.26	0.20	0.19	0.42	0.53
Total carbonates, %	0.1	38.4	0.3	0.4	0.1
E.S.P.*	14.0	20.8	19.0	68.8	20.1
S.A.R.**	2.0	1.9	1.5	3.9	6.1
Clay, %	13.6	17.3	13.6	13.2	13.5
Silt, %	10.5	6.9	10.0	10.8	10.6
Sand, %	75.7	75.6	76.8	75.5	75.3
Water holding capacity, %	44.9	34.8	44.2	44.5	44.1
Cation exchange capacity, m. eq./100 g.	21.4	24.9	21.0	20.9	21.5
pH (saturated soil extract).	7.3	7.9	8.2	7.6	7.2

* E S P = (Exchangeable Na/cation exchange capacity) × 100

** S A R = Soluble Na / $\sqrt{(\text{soluble Ca} + \text{soluble Mg}) / 2}$.

Soil No. V : Salinized soil (Sal. S.L.) obtained by treating the sandy loam with sodium chloride and calcium chloride (2 kg NaCl + 2 kg $CaCl_2$/ton of soil.

EXPERIMENTAL PLAN :

Cotton (*Gossypium barbadense var. menoufy*) was grown in large tin pots. The pots, holding 85 to 90 kg of air dry soil per pot, were about 45 cm in diameter and 45 cm in height. The orifices of the pots were tightly closed so that no water was allowed to drain. Soil was added to the pots so that it depth in any pot was 36 cm regardless of the kind of the used soil.

The experiment consisted of 50 pots, 10 per each soil, half of which were used with ammonium sulphate fertilizer and the other half with calcium fertilizer. So, the experiment comprised 10 treatments which were performed in 5 replicates distributed in complete randomized blocks. The cotton was sown on 31 st March and harvested on 30th September.

Seeds of cotton were sown in 3 pits per pot and the seeds were covered sand. After emergence, the plants were thinned to 6 plants per pot. The pots were watered with equal volumes of tap water at the beginning and whenever needed. Superphosphate and potassium sulphate fertilizers were used at the rate of 49 and 30 kg per feddan respectively and were both added after thinning the plants. The nitrogenous fertilizer (ammonium sulfate 20, 5 %, N) or calcium nitrate (15.5% N) was used at the rate of 146 kg per feddan and half of it was added with the other two fertilizers while the other half was applied after two months from sowing. Insecticides, in usual concentrations, were applied to each pot to control insects.

The experiment was carried out in a wire greenhouse at the Soil Salinity Laboratory at Alexandria, E.A.R.

NITROGEN DETERMINATIONS :

The nitrogen contents of the cotton materials, substances added to pots and soil samples were determined according to Chapman and Pratt (1961), Hortwitz *et al* (1955), and Ward and Johanston (1962).

During growth, thinned plants and fallen leaves were separately collected from each pot. At harvest, the crop from each pot was divided to roots, stalks burs, seeds and lint. All these plant materials were, separately, dried at 66-68°C for 48 hr., weighted, ground (if possible) and analysed for its total nitrogen contents.

Nitrogen contents of the seeds used for planting and the sand added to pots for covering the seeds as well as the applied nitrogen, potassium and phosphorus fertilizers, irrigation water and insecticide solutions were determined.

Soil samples from each soil before cultivation and from each pot after the harvest of the crop were analysed for total nitrogen, ammonium-N, Nitrite-N and nitrate-N. Moisture Content of each soil sample was determined by drying at 105-110°C for 24 hr. in order to calculate nitrogen contents on dry basis.

RESULTS AND DISCUSSION

NITROGEN ADDITIONS :

Nitrogen was added in the form of seeds, sand user for covering the seeds, fertilizers, irrigation water and insecticide solutions. The data presented in Table 2 show the amount of nitrogen added per pot.

TABLE 2. - NITROGEN ADDED TO THE SOILS

Nitrogen source	Nitrogen, mg/pot with soil				
	S.L.	Cal. s.L.	Alk. S.L.	Sal. Alk. S.L.	Sal. S.L.
Sand cover	28	28	28	28	28
K & P-fertilizer	10	10	10	10	10
Insecticide solns.	14	14	14	14	14
Irrigation wate	221	221	212	221	22
Ammonium sulphate treatment					
Seeds	268	180	185	266	503
N-Fertilizer	2200	2403	2243	2198	2198
Total	2741	2856	2701	2737	2971
Calcium nitrate treatment					
Seeds	308	266	224	274	515t
N-Fertilizer	1717	1876	1750	1716	1716
Total	2298	2415	2247	2263	2501

The nitrogen content of the used seeds was found to be 3.65%. The pots were seeded twice or three times due to differences and difficulties in germination so that the total amount of the seeds ranged from 4.1 to 14.1 gm/pot. The nitrogen added in the seeds varied between 180 and 515 mg per pot. The sand contained 0.02% nitrogen and 140 gm/pot were used to cover the seeds. Amounts of the applied nitrogen fertilizer varied according to the oven dry weight of the soil in each pot. The weight of the added ammonium sulphate or calcium nitrate ranged between 11.35 and 12.41 gm per pot.

The used potassium sulphate, superphosphate and insecticide solutions were found to contain little nitrogen and contributed 24 mg N/pot in any treatment. During the growing season, the plants were irrigated 18 times and the total volume of the water was 86 liters per pot. The nitrogen content of the used water varied between 2 and 3 P.P.M. and the nitrogen added was 221 mg per pot.

As shown in Table 2, the nitrogen added in the form of the aforenamed materials ranged from 2.70 to 2.97 gm per pot fertilized with ammonium sulphate. In the calcium nitrate treatment, the total added nitrogen varied between 2.25 and 2.50 gm per pot. These differences in the total amounts of the added nitrogen were mainly due to the quantity and kind of the applied nitrogen fertilizer as well as to the amounts of the seeds used with each type of soil.

NITROGEN RECOVERED IN COTTON PLANTS :

During growth, the thinned plants and fallen leaves and at harvest, the roots, stalks, burs, lint and seeds were separately collected from each pot. The dry weight and also the percentage of nitrogen of each of these plant materials differed according to type of soil and kind of applied nitrogen fertilizer. Generally more plant materials were obtained from the calcium nitrate than from the ammonium sulphate treatment. Also, more plant materials were obtained from the calcareous (Cal. S.L.) and the alkalinized (Alk. S.L.) soils regardless of the kind of applied nitrogen fertilizer. The saline soil (Sal. S.L.) gave the least amount of plant materials.

The nitrogen found in the thinned plants and fallen leaves and the nitrogen recovered in the different parts of the harvested crop are shown in Table 3 for the ammonium sulphate and in Table 4 for the calcium nitrate treatment. In the case of the ammonium sulphate fertilizer, the nitrogen recovered in the plants before and after the harvest varied between 1.53 to 2.10 gm per pot In the calcium nitrate treatment, the different plant materials contained from 1.82 to 2.07 gm nitrogen per pot. These data indicate that the nitrogen removed by the cotton plants differed according to type of soil and kind of nitrogen fertilizer. It should be stated here that, under field condition the nitrogen detected in the thinned plants, fallen leaves and roots would be found in the soil.

TABLE 3.—NITROGEN RECOVERED IN PLANTS FERTILIZED WITH AMMONIUM SULPHATE

Plant material	Nitrogen, mg/pot with soil				
	S.L.	Cal. S. L.	Alk. S.L.	Bad. Alk. S. L.	Sal. S.L.
1. Before harvest :					
Thinned plants	110	211	183	89	108
Faller leaves	111	140	151	136	108
Total	251	351	331	225	216
2. After harvest :					
Roots	170	207	219	185	172
Stalks	113	150	128	131	194
Burs	456	440	330	369	480
Lint	37	50	48	36	71
Seed	730	931	918	725	876
Total	1506	1748	1613	1119	1313

CHANGES IN SOIL NITROGEN :

In drawing a nitrogen balance sheet, it is necessary to take into account the initial and final nitrogen contents of the soil. Total nitrogen as well as ammonium-N, nitrite-N and nitrate N were determined before cultivation and after the harvest of the crop. The nitrite-N and nitrate-N contents of the used soils either before cultivation and after the harvest did not exceed 1 P.P.M. For this reason, only total nitrogen is taken into consideration.

Table 5 summarizes the results of the total nitrogen analysis of the soils before cultivation (initial) and after the harvest (final). These results indicate that, under experimental conditions, total nitrogen content of each soil decreased due to growing cotton plants. It is known that cropping of non-legumes decreases soil nitrogen (Salter and Green 1933, Sanchelli 1964 and Viets 1965). All tested soils showed nitrogen losses which ranged from 5.2% to 31.9% for the ammonium sulphate fertilizer and from 9.5% to 25.9% for the calcium nitrate treatment. In both treatments, loss of nitrogen was

TABLE 1.—NITROGEN RECOVERED IN PLANTS FERTILIZED WITH CALCIUM NITRATE.

Plant material	Nitrogin, mg/pot with soil				
	S.L.	Cal. S. L.	Alk. S.L.	Sal. Alk. S. L.	Sal. S. L.
1. Before harvest :					
Thinned plants	133	142	208	144	122
Fallen leaves	147	117	123	143	191
Total	280	259	331	287	313
2. After harvest :					
Roots	153	217	205	186	193
Stalks	128	166	98	112	145
Burs	492	371	284	443	186
Lint	38	48	12	40	32
Seeds	801	979	875	747	658
Total	1612	1811	1504	1528	1511

highest from the alkalinized soil (Alk.S.L.) and least in the salinized soil (Sal.S.L.). Also, it is noticed that nitrogen losses from the alkalinized soil were higher with ammonium sulphate than with calcium nitrate fertilizer. Such nitrogen losses are indicative of nitrogen mineralization in each soil.

NITROGEN BALANCE :

On the basis of the pervious tables, a balance sheet is drawn up in table 6 for the ammonium sulphate fertilizer and in Table 7 for the calcium nitrate fertilizer. The data presented in these tables indicate that not all of the added nitrogen was recovered by the cotton plants. Part of the added nitrogen or lost from the soil was taken up by the crop but a great part of this nitrogen disappeared from the soil-plant system. The not loss in nitrogen which disappeared and could not be traced in the system is referred to as unaccounted for or not recovered nitrogen.

TABLE 5. TOTAL NITROGEN CONTENT OF THE SOILS BEFORE CULTIVATION (INITIAL) AND AFTER THE HARVEST OF THE CROP (FINAL).

Soil type	Nitrogen, P.P.M.		Nitrogen loss	
	Initial	Final	P.P.M.	% (of initial)
Ammonium sulphate treatment :				
S.L.	331.3	251.0	80.3	24.2
Cal. S.L.	279.8	247.2	32.6	11.7
Alk. S.L.	343.3	233.8	109.5	31.9
Sal. Alk. S.L.	301.3	248.9	52.4	17.3
Sal. S.L.	268.3	253.2	14..	5.2
Calcium nitrate treatment :				
S.L.	331.3	278.7	52.6	15.9
Cal. S.L.	279.8	244.5	35.3	12.6
Alk. S.L.	343.3	251.2	89.1	25.9
Sal. Alk. S.L.	301.3	258.3	43.0	14.3
Sal. S.L.	268.3	242 8	25.5	9.5

The unaccounted for nitrogen varied from 2.53 to 9,40 gm/pot in the case of ammonium sulphate fertilizer (Table 6) and from 2.66 to 7.48 gm/pot in the calcium nitrate treatment (Table 7). In both treatments, the nitrogen not recovered was highest in the alkalinized soil (Alk.S.L.) and least with the saline soil (Sal.S.L.). In general, the nitrogen losses were greater in the ammonium sulphate than in the calcium nitrate treatment. Jansson (1963), Walker *et al.* (1956) and Tyler & Broadbent (1958) found that nitrogen not recovered was higher with sodium nitrate than with ammonium sulphate. This contradiction might be due to the use acid soils by these workers while the soils used in this investigation were alkaline in reaction (Table 1). The unaccounted for nitrogen expressed on percentage basis and as kg. per Feddan are presented in Table 8.

Statistical anlysis showed that the differences in the unaccounted for nitrogen between the used soils were significant with the two nitrogen fertilizers.

TABLE 6.—NITROGEN BALANCE SHEET FOR THE AMMONIUM SULPHATE TREATMENT (AVERAGE OF 5 REPLICATES).

Nitrogen fraction*	Nitrogen, mg/pot with soil				
	S. L.	Cal. S.L.	Alk. S. L.	Sal. Alk. S. L.	Sal. S.L.
A	2.74	2.86	2.70	2.74	2.97
Soil, initial	25.74	23.75	27.19	23.28	20.82
Total	28.18	26.61	29.89	26.12	23.79
R_1	0.25	0.35	0.33	0.23	0.22
R_2	1.51	1.75	1.64	1.45	1.31
Soil, final	19.50	20.89	18.52	19.31	19.73
Total	21.26	23.08	20.49	20.99	21.26
Not recovered	7.22	3.53	9.40	5.13	2.53

* A : Added as fertilizers, seeds, and cover, insecticides and irrigation water.
R_1 : Removed by the thinned plants and falled leaves.
R_2 : Removed by the harvested crop including the roots, stalks, burs, lint and seeds

The data presented in Table 8 indicate that the nitrogen deficit (not recovered) from the soil-plant system was enormous and depended upon soil type and kind of applied nitrogen fertilizer. In general, these nitrogen losses were of the same size of that reported from other experiments (Allison 1955, 1965). This unaccounted for nitrogen was lost into the air as volatile compounds probably as ammonia, nitrogen gas and oxides of nitrogen.

The greatly increased nitrogen loss from the ammonium sulphate treated soil especially the alkaline sandy loam soil hints at ammonia volatilization as a cause of these losses. Ammonia might be volatilized readily from soils having pH values of more than 7. According to Allison (1965), ammonia losses increase with the increase in pH and temperature and were greatest in soils of low exchange capacity. The properties of the used soils (Table 1) and the high temperature during the growing season of cotton would favour the loss of nitrogen as ammonia.

TABLE 7. NITROGEN BALANCE SHEET FOR THE CALCIUM NITRATE TREATMENT (AVERAGE OF 5 REPLICATES).

Nitrogen fraction*	Nitrogen, mg/pot with soil				
	S. L.	Cal. S.L.	Alk. S. L.	Sal. Alk. S. L.	Sal. S.L.
A	2.30	2.42	2.25	2.26	2.50
Soil, initial	25.74	23.75	27.19	23.38	20.82
Total	28.04	26.17	29.44	25.64	23.32
R-	0.28	0.26	0.33	0.29	0.31
R-	1.61	1.81	1.50	1.53	1.51
Soil, final	21.65	20.75	20.13	20.01	18.84
Total	23.54	22.82	21.96	21.86	20.66
Not recovered	4.50	3.35	7.48	3.78	2.66

* A : Added as fertilizers, seeds, sand cover, insecticides and irrigation water.
R_1 : Removed by the thinned plants and fallen leaves.
R_2 : Removed by the harvested crop including the roots, stalks, nurs, lint and seeds.

TABLE 8. -LOSSES OF NITROGEN (NOT RECOVERED) FROM THE SOIL-PLANT SYSTEM.

Soil	N loss, %*		N loss, kg/Feddan	
	$(NH_4)_2SO_4$	$Ca(NO_3)_2$	$(NH_4)_2SO_4$	$Ca(NO_3)_2$
S.L.	25.3	16.0	92.9	57.9
Cal. S.L.	13.3	12.8	41.6	39.5
Alk. S.L.	31.4	25.4	118.7	94.4
Sal. Alk. S.L.	19.6	14.7	66.1	48.7
Sal. S.L.	10.6	11.4	32.6	34.3
L.S.D. at 0.05 level			7.2	13.0
L.S.D. at 0.01 level			9.8	17.6

* Percent of initial soils nitrogen + nitrogen added as fertilizers, seeds, sand cover, insecticides and irrigation water.

The loss of nitrogen in the calcium nitrate treatment would indicate that the nitrogen was lost also by denitrification. Gaseous losses of nitrogen denitrification would result from oxygen deficiency if nitrates were present or being formed. In pot experiments, there is a great chance for anaerobic conditions to exist more or less temporarily following the addition of water (Allison 1965).

In conclusion, the results of this cotton pot experiment emphasized the loss of nitrogen, in considerable amounts from all tested soils mainly through denitrification and volatilization processes. This nitrogen loss ranged between 11 and 31% depending upon soil type and nitrogen fertilizer.

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