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Gaseous Losses of Nitrogen from the Soil of Semi-Arid Regions

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GASEOUS LOSSES OF NITROGEN FROM THE SOIL OF SEMI-ARID REGIONS

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ABSTRACT

Preliminary results indicate some losses of nitrate occurred during incubation under sterile conditions. The effects of organic carbon, moisture, temperature, soil depth, and time on denitrification were investigated. Overall nitrate losses from the system were more than doubled by the addition of glucose. Approximately one and one-half times as much nitrate was lost at 37 C as at 20 C. Saturated moisture conditions increased nitrate loss over moisture at field capacity but to a smaller degree. Soil depth was not a significant factor in nitrate loss. Increasing incubation time increased overall loss from 23% at five days to 26 and 30% at 10 and 15 days, respectively. The addition of organic C increased the amount of added N found in the soil organic N fraction. Without organic C addition most of the ^{15}N remaining was in nitrate form. Soil respiration was increased at two Santa Rita sites by amendments of N, organic C or the combination. Ammonium volatilization losses were not detected. Laboratory studies showed that C:N ratio may be an important factor influencing denitrification. At high C:N ratios (>45:1) increased immobilization may prevent excessive denitrification.

INTRODUCTION

Major emphasis in the 1973 investigation was on the quantity of gaseous N loss in relation to moisture, temperature, nitrate concentration, and organic carbon source with different incubation times. Previous work had shown the potential for gaseous N loss from all soil depths of two profiles sampled at each of two validation sites, Santa Rita and Silverbell.

Two field studies were established at the Santa Rita Validation Site in an attempt to link organic carbon transfer to gaseous N loss and N transformations under natural conditions.

OBJECTIVES

1. Determine the magnitude of non-biological and biological contributions to the overall process of gaseous loss of nitrogen.
2. Measure rate of gaseous loss of soil nitrogen from ecosystems located in a semi-arid region as a function of soil moisture, temperature, concentrations of oxygen, nitrate, and organic carbon.
3. Determine rates of decomposition of organic materials, ammonia volatilization, soil respiration, gaseous loss of N and transfer of organic nitrogen to soil nitrogen in ecosystems located in a semi-arid region. This study was intended as a field investigation starting in 1973 and continuing for 12 months. Completion was anticipated during 1974.

METHODS

Methyl bromide gas was used to sterilize soils to differentiate between biological and nonbiological activity. Three replicated samples from 3 depths (0-5, 10-15 and 25-30 cm) of a Sonoita sandy loam profile collected from the Santa Rita Validation Site were crushed and sieved. Fifty g samples were placed in a glass cylinder 45 mm in diameter and 60 cm long and each sample was separated with cotton. The ends of the cylinder were closed with No. 9 stoppers that were previously drilled and fitted with glass tubes. Tygon tubing was attached to the inlet of the glass connector of the cylinder and the dispenser from the CH_3Br source (DOWfume Mc-2, 98% CH_3Br - 2% Chloropicrin). Tygon tubing was also attached to the outlet of the glass cylinder and submerged in a CH_3OH trap to absorb escaping CH_3Br. Methyl bromide gas was passed slowly through the cylinder for 72 hr. After the gas sterilization period, 25 g of soil was transferred aseptically into sterile 125-ml erlenmeyer flasks. The soils were amended with 2.5 mg N and 1.5% C from sterile solutions of $K^{15}NO_3$ and glucose and incubated aerobically for 5 days at 37 C. Moisture content was 15% by weight. At the end of the incubation period, the soil was shaken 1 hr with 50 ml of 1N KCl, filtered and washed with 25 ml lN KCl and 20 ml deionized water. Final volume of the extract was 100 ml. Aliquots of the extract were taken and NH_4^+ and $NO_2^- + NO_3^-$ were determined by steam distillation with MgO and MgO plus Devardo's alloy. The NH_3 was collected in H_3BO_3 indicator solution and titrated with $KH(IO_3)_2$. Soils were lyophilized and saved for organic N analyses. Organic N was determined by micro-Kjeldahl digestion using H_2SO_4 and K_2SO_4:$CuSO_4$:Se catalyst (100:10:1) mix and steam distillation procedures. After N had been determined in the various fractions, samples were redistilled into dilute H_2SO_4 and ^{15}N was determined using mass spectrometry. Portions of CH_3Br sterilized soils were checked for sterility by checking for turbidity in nutrient broth and also by streaking 10:1 sterile water-soil solutions on agar plates and checking for colonies. After inoculating, the nutrient broth and agar plates were incubated at 37 C for 5 days and checked for sterility. Each soil depth was replicated 3 times and sub-sampled 3 times. The $K^{15}NO_3$, glucose and deionized water used in the amendments were also checked for contamination by streaking agar plates. All soils, solutions and materials were sterile.

Factors affecting denitrification were investigated on samples of a Sonoita sandy loam collected from the Santa Rita Validation Site. Soils were crushed and passed through a 2-mm sieve. Fifty g samples of soil from 0-5, 10-15 and 25-30 cm depths were placed into 125-ml erlenmeyer flasks. Soil amendments were 0 and 5 mg N, 0 and 1.5% C, and moisture content was adjusted to 8 and 15% by weight. All combinations of the amendments were added to the soils, mixed thoroughly and incubated aerobically at 20 and 37 C for 5, 10 and 15 days. The nitrogen added was in the form of $K^{15}NO_3$ which contained 33.376 excess atom % ^{15}N and the source of carbon was glucose. The overall experimental design can be summarized as follows: (2 reps x 3 depths x 2N x 2C x 2 temperatures x 2 moistures x 3 times).

At the end of the incubations the soils were shaken 1 hr with 1N KCl, filtered, washed with 50 ml of 1N KCl and 40 ml deionized water and the extract was adjusted to a final volume of 200 ml. The soils were lyophilized and saved for organic N analyses. The KCl extracts were frozen until ready for analyses. Standard procedures that have been described previously were used to determine NH_4^+-N NO_2^- + NO_3^--N, organic-N and ^{15}N in the various N fractions.

Abbreviated studies were conducted on 0-5- and 25-30-cm depths of Anthony sandy loam from the Santa Rita Validation Site and Rillito loam from the Silverbell Validation Site for verification. Soils were amended with 5 mg of labeled N, 1.5% C and 15% moisture and incubated at 20 and 37 C for 5 days. Fractionation and heavy isotopic procedures were the same as previously described.

Maximum denitrification that could be expected from the Sonoita sandy loam soils used in the extensive incubation study was determined by adding ^{15}N, C, and adjusting the moisture control to 15% by weight (saturation) and incubating anaerobically at 37 C for 5 days under an Argon atmosphere. At the end of the incubations these samples were fractionated into soil N forms as described previously and percent loss of added ^{15}N was determined.

Two field experiments were established before summer rains, June 20 and 21, 1973, to investigate decomposition rates of organic materials, nitrogen transformation and CO_2 and NH_3 evolution. The sites were located at the Santa Rita Validation Site on Anthony and Sonoita sandy loam soils. Aluminum cylinders 4.8 cm I.D. and 25 cm long were driven into the soil 10 cm deep and approximately 30 cm apart in three replications of a randomized block design and the amendments were mixed thoroughly in the upper 1 cm of soil inside the cylinder. Treatments were control, 6 mg $^{15}NH_4^+$-N, 6 mg $K^{15}NO_3$-N, 1 g of ground wheat straw, 1 g of ground wheat straw + 3 mg $^{15}NH_4^+$-N, 1 g of ground wheat straw + 3 mg $K^{15}NO_3$-N, 1 g of ground wheat straw + 12 mg $^{15}NH_4^+$-N, 1 g of ground wheat straw + 12 mg of $K^{15}NO_3$-N, and 1 g ground barley grain labeled with ^{15}N. Total volume of liquid material added was 25 ml. Atom % excess ^{15}N in $K^{15}NO_3$ and $(^{15}NH_4)_2SO_4$ sources were 33.376 and approximately 30.0, respectively. The barley grain varied in atom % excess ^{15}N from 4.686 to 5.614, depending on the particular treatment. These treatments were allowed to incubate under natural environmental conditions for 3, 6, 9, and 12 months. At the end of the specified time intervals, the soils in the cylinders were collected, subdivided and analyzed for soil N forms and organic carbon. Movement and transformation of N compounds were detected by standard fractionations, mass spectrometry and heavy isotopic procedures. Organic C was determined by combustion. At various time intervals throughout the field study, CO_2 and NH_3 evolution was measured by placing open mouth bottles containing 10 ml of 0.68 m KOH inside the cylinders and closing the top of the cylinders with rubber stoppers. Absorption intervals ranged from 24 to 48 hr. At the end of the time intervals the bottles containing the KOH were collected, capped tightly and returned to the laboratory for analyses. Ten ml of 0.6 M $BaCl_2$ was added to the KOH bottles and the samples were titrated with 0.6M HCl using phenolphthalein indicator. The evolution of CO_2 was expressed as mg $CO_2/m^2/hr$. Ammonia volatilization was measured using the same procedure except the absorption bottles contained 10 ml of boric acid indicator solution and the solutions were back titrated with standard 0.01 N $KH(IO_3)_2$. Master plans of the two field experiments are provided in Figures 1 and 2. Soil moisture, air temperature 2 to 3′ above the soil surface, surface soil temperature, and soil temperature at a 2-cm depth were recorded before and after each gas evolution measurement period.

A laboratory incubation experiment was initiated to measure the effect of C concentration on N immobilization. Samples from 0 to 5 cm of a Sonoita sandy loam were amended with 5 mg N as $K^{15}NO_3$ and concentrations of C as glucose that would result in additions of material with the following C:N ratios: 10:1, 15:1, 20:1, 25:1, 30:1, 35:1, 40:1, and 45:1. The samples were adjusted to 8% moisture by weight and incubated at 37 C for 5 days. At the end of the incubations, the soils were fractionated into NH_4^+-N, NO_2^- + NO_3^- - N and organic N and the percent loss of ^{15}N was determined. Analyses of the field samples have not been completed.

Plot plans of the field experiments showing treatments and sampling times are given in Figures 1 and 2.

Figure 1. Plan of field experiment established on June 21, 1973, to measure decomposition, N transformation, CO_2 and NH_3 evolution from profiles of Anthony sandy loam after 3, 6, 9, and 12 months (three replications; see text for the nine treatments)

III			II			I		
4	6	7	6	7	8	9	7	3
8	9	3	3	5	9	8	1	5
5	2	1	4	2	1	2	4	6
	9 mo.			3 mo.			6 mo.	
5	7	1	9	7	8	3	5	8
6	8	9	6	2	5	9	4	7
3	2	4	1	3	4	1	6	2
	12 mo.			6 mo.			3 mo.	
3	9	8	6	1	3	7	9	3
4	1	5	4	2	5	6	2	4
2	6	7	8	7	9	1	8	5
	6 mo.			12 mo.			12 mo.	
6	9	8	9	3	7	3	6	4
4	7	3	6	1	4	5	7	9
5	2	1	5	2	8	8	1	2
	3 mo.			9 mo.			9 mo.	

Figure 2. Plan of field experiment established on June 20, 1973, to measure decomposition, N transformation, CO_2 and NH_3 evolution from Sonoita sandy loam after 3, 6, 9, and 12 months (three replication; see text for the nine treatments).

III			II			I		
1	9	5	4	2	7	1	8	7
7	8	6	5	6	8	3	5	4
3	4 9 mo.	2	3	1 6 mo.	9	6	2 12 mo.	9
6	2	3	8	2	4	2	9	8
5	4	1	6	7	5	1	3	4
9	8 12 mo.	7	9	3 9 mo.	1	6	5 6 mo.	7
3	1	8	8	1	5	8	4	6
6	9	2	7	4	6	7	9	3
4	7 3 mo.	5	9	2 12 mo.	3	2	1 3 mo.	5
8	9	3	3	1	2	6	5	4
1	7	2	8	6	5	7	8	9
4	5 6 mo.	6	4	9 3 mo.	7	2	3 9 mo.	1

RESULTS

The magnitude of nonbiological contribution to gaseous losses of N has not been quantified. However, preliminary results (Table 1) indicate that all N added as $K^{15}NO_3$ did not remain as NO_3^- in soils sterilized with CH_3Br even though the soils and materials were sterile. Samples have been fractionated, but ^{15}N analyses are not complete and quantification of $K^{15}NO_3$ in the soil N forms is not possible at this time.

The effect of nitrogen, carbon, moisture, temperature, soil depth, and time on denitrification was investigated. Data for native soil N plus ^{15}N-labeled N in the NH_4^+, NO_2^- + NO_3^- and organic fractions are reported in Tables 2, 3 and 4. The total (native soil N + labeled N) NH_4-N fraction in the treated soils was not affected grossly by the factor investigated.

Table 1. Effect of methyl bromide sterilization on N forms in a Sonoita sandy loam

Depth	NH_4^+ - N	NO_2^- + NO_3^- - N	Organic N
cm		µg N/g of soil	
0 - 5	0.00	75.41	190.82
10 - 15	0.22	81.83	152.11
25 - 30	0.52	86.54	158.16

Table 2. Effect of nitrogen, carbon, moisture, temperature, and time on N fractions in the 0-5 cm depth of Sonoita sandy loam

Amendment		NITROGEN FRACTIONS											
		NH_4^+ - N				NO_2^- + NO_3^- - N				Organic N			
	ppm	20C		37C		20C		37C		20C		37C	
%C	NO_3^--N	8*	15	8	15	8	15	8	15	8	15	8	15
		µg N/g of soil											
5 days													
0	0	0.90	1.68	0.90	4.14	1.57	2.13	4.26	2.80	249.9	153.3	126.7	210.7
0	100	1.68	1.46	1.01	6.27	95.43	71.46	98.56	75.94	191.1	186.9	216.2	216.3
1.5	0	1.46	0.67	0.45	0.34	0.00	0.00	0.56	0.34	198.2	164.5	103.6	169.4
1.5	100	0.90	1.01	1.57	1.90	84.11	67.09	66.86	31.70	245.6	186.8	186.8	239.4
10 days													
0	0	1.23	1.57	1.46	5.38	3.92	1.46	6.96	4.59	271.6	186.9	147.0	156.8
0	100	0.67	1.01	0.90	9.97	91.95	93.74	99.84	73.36	214.9	244.3	204.3	215.6
1.5	0	1.01	0.67	0.11	0.34	0.56	0.00	0.45	0.00	212.8	196.1	195.2	241.5
1.5	100	2.80	3.47	2.80	3.47	45.58	26.21	10.64	18.70	296.1	243.6	242.8	254.1
15 days													
0	0	0.90	1.23	0.11	8.29	3.47	1.90	8.74	5.82	168.7	163.1	106.4	112.7
0	100	2.35	1.68	1.57	9.30	95.98	98.00	101.36	71.23	208.6	179.2	246.3	204.3
1.5	0	0.90	0.90	0.90	0.34	0.00	0.45	0.00	0.00	196.7	185.5	133.0	186.2
1.5	100	2.91	7.62	5.38	1.79	21.06	5.26	4.70	6.27	203.6	221.9	242.8	214.2

* Moisture content on a weight basis (also in Tables 3, 4, 5, 6, 7 and 8)

These factors did have a significant effect on the $NO_2^- + NO_3^-$-N and organic N fractions. Total $NO_2^- + NO_3^-$-N in all depths of the soils amended with nitrate remained relatively constant with few exceptions within temperature and moisture variables. However, the addition of organic C stimulated transformation of nitrate to either gaseous products or organic N forms. The disappearance of nitrate was greatest in soils adjusted initially to 15% moisture amended with nitrate and organic C and incubated at 37 C. The effect of additions of organic C in soils incubated at 20 C was similar to results observed in the 37 C incubations, except the magnitude of loss of nitrate was lower.

Addition of organic C in all soils, regardless of temperature or percent moisture, increased the total organic N fraction in the soils.

The effects of organic C, temperature, percent moisture, soil depth, and time on ^{15}N-labeled forms of soil nitrogen are reported in Tables 5, 6 and 7. Only traces of added $K^{15}NO_3$ appeared in the NH_4-N fraction and it was not directly associated with the variable investigated. Nitrate was reduced by the addition of organic C, increased temperature, increased moisture, and time of incubation in all soil depths. Only a small portion of the $K^{15}NO_3$

Table 3. Effect of nitrogen, carbon, moisture, temperature, and time on N fractions in the 10-15 cm depth of Sonoita sandy loam

Amendment		NITROGEN FRACTIONS											
		NH_4^+-N				$NO_2^- + NO_3^-$ - N				Organic N			
%C	ppm NO_3^--N	20C 8	20C 15	37C 8	37C 15	20C 8	20C 15	37C 8	37C 15	20C 8	20C 15	37C 8	37C 15
		µg N/g soil											
5 days													
0	0	1.23	1.51	1.23	1.01	1.01	0.40	2.02	0.45	128.76	131.60	134.23	147.02
0	100	1.46	0.00	0.67	0.67	88.48	94.08	89.26	96.10	113.40	146.97	134.84	166.55
1.5	0	0.56	1.12	0.56	0.00	0.00	0.34	0.00	0.00	154.72	163.75	149.11	212.12
1.5	100	0.78	1.01	3.81	0.45	76.83	74.82	15.46	36.74	177.05	167.98	236.62	153.99
10 days													
0	0	1.34	1.01	0.22	0.67	2.24	1.12	1.68	0.34	174.98	157.46	133.01	121.80
0	100	1.34	0.00	0.56	0.67	90.72	93.30	78.62	90.27	177.11	194.63	133.71	172.84
1.5	0	0.34	1.23	0.67	1.23	0.00	0.45	0.00	0.11	146.30	141.36	123.87	139.29
1.5	100	0.34	0.78	4.48	1.57	19.04	31.14	0.45	11.42	159.61	195.31	271.61	177.65
15 days													
0	0	1.80	1.68	1.12	1.23	2.69	0.00	2.13	0.56	155.40	172.89	123.24	122.47
0	100	1.90	1.68	1.23	3.02	94.64	100.24	80.19	55.89	139.29	133.67	112.71	192.48
1.5	0	1.23	1.34	0.22	0.45	0.45	0.45	0.00	0.00	146.28	160.29	167.31	146.28
1.5	100	0.56	0.90	3.70	0.90	13.66	29.79	0.56	5.04	209.99	271.62	214.19	161.01

Table 4. Effect of nitrogen, carbon, moisture, temperature, and time on N fractions in the 25-30 cm depth of Sonoita sandy loam

Amendment		NITROGEN FRACTIONS											
		NH_4^+ - N				$NO_2^- + NO_3^-$ - N				Organic N			
%C	ppm NO_3^--N	20C 8	20C 15	37C 8	37C 15	20C 8	20C 15	37C 8	37C 15	20C 8	20C 15	37C 8	37C 15
		µg N/g soil											
5 days													
0	0	0.78	1.12	1.23	1.01	0.45	1.01	1.79	0.00	200.87	160.99	166.58	228.91
0	100	2.13	2.13	0.67	1.23	95.65	83.44	101.81	96.88	223.31	180.62	220.56	207.91
1.5	0	1.01	0.56	0.22	0.67	0.22	0.11	0.11	0.00	183.39	178.47	198.78	174.29
1.5	100	1.23	1.34	3.70	0.45	59.14	57.57	3.70	24.98	188.99	205.10	222.53	203.72
10 days													
0	0	1.90	0.78	0.45	1.12	1.01	0.67	1.90	0.34	181.98	166.59	154.69	227.54
0	100	1.34	0.67	0.90	1.01	96.32	94.19	98.90	93.52	219.79	263.13	185.44	166.97
1.5	0	0.67	0.56	0.78	1.34	0.00	0.11	0.00	0.56	186.89	166.54	197.38	220.49
1.5	100	0.78	1.68	1.68	1.23	47.26	68.10	1.23	0.00	207.86	234.07	183.42	247.76
15 days													
0	0	2.24	1.57	0.90	0.78	1.57	1.68	1.57	0.22	203.03	161.65	230.32	106.39
0	100	2.69	1.01	2.35	1.01	95.87	96.10	84.34	96.77	246.39	193.22	179.88	181.26
1.5	0	0.78	2.46	0.90	1.23	0.22	0.34	0.00	0.00	189.68	204.37	173.56	254.06
1.5	100	1.80	1.68	14.90	0.67	36.62	23.30	2.02	0.00	219.75	250.56	233.08	321.99

appeared in the organic N fraction without the addition of organic carbon. Organic N in soils amended with organic C increased with temperature, percent moisture and time of incubation.

The effects of soil depth, temperature, moisture, organic C, and time on denitrification of $K^{15}NO_3$ in a Sonoita sandy loam are reported in Table 8 and illustrated in Figures 3, 4 and 5. Summarizations of data are reported in Table 9 and illustrated in Figure 6. Differences in denitrification of $K^{15}NO_3$ between different parts of the soil profile were insignificant. The magnitude of loss as influenced by soil depth was 26 to 27% of the total amendment. Temperature had a marked effect on denitrification. Higher losses (31.7%) were observed at 37 C and represented a 10% higher loss than was observed at 20 C (21.2%). The initial percent moisture at the beginning of incubation also affected denitrification losses. Samples adjusted to 15% moisture by weight, which corresponded to saturation, experienced 5 to 6% higher losses of $K^{15}NO_3$ than soils adjusted initially to 8% moisture by weight: denitrification losses were 23.6 and 29.3%, respectively, for 8 and 15% moisture contents. The addition of organic C had the largest effect on denitrification. Samples amended with organic C denitrified 38.5% of the added $K^{15}NO_3$, whereas only 14.5% was denitrified in the absence of the organic C amendment. Loss of ^{15}N in the presence of organic C represented a 24% increase and was shown to be the most influential factor investigated. Losses of ^{15}N increased stepwise with time of incubation. Similar studies

Table 5. Effect of nitrogen, carbon, moisture, temperature, and time on ^{15}N-labeled fractions in the 0-5 cm depth of a Sonoita sandy loam

Amendment %C	Amendment ppm NO_3^--N	NH_4^+ - N 20C 8	NH_4^+ - N 20C 15	NH_4^+ - N 37C 8	NH_4^+ - N 37C 15	NO_2^- + NO_3^- - N 20C 8	NO_2^- + NO_3^- - N 20C 15	NO_2^- + NO_3^- - N 37C 8	NO_2^- + NO_3^- - N 37C 15	Organic N 20C 8	Organic N 20C 15	Organic N 37C 8	Organic N 37C 15
		µg N/g of soil											
5 days													
0	100	0.00	0.00	0.36	0.40	89.71	66.31	93.15*	72.99	0.14	12.50	0.51	0.59
1.5	100	0.00	0.00	0.00	0.00	79.02	62.89	61.70	27.44	0.90	11.34	9.92	25.79
10 days													
0	100	0.00	0.00	0.00	0.34	74.27	87.67	88.42	65.97	0.21	0.11	0.98	0.82
1.5	100	0.00	0.00	2.41	0.00	43.21	23.96	9.50	12.84	42.00	33.54*	39.99	41.31
15 days													
0	100	0.00	0.00	0.00	0.89	86.99	90.15	89.83	62.05	1.09	0.47	0.94	0.77
1.5	100	0.00	0.00	4.33	0.00	38.19*	0.00	4.54	3.03	15.83	38.86	47.48	33.21

* = 1 replication

Table 6. Effect of nitrogen, carbon, moisture, temperature, and time on ^{15}N-labeled fractions in the 10-15 cm depth of a Sonoita sandy loam

Amendment %C	Amendment ppm NO_3^--N	NH_4^+ - N 20C 8	NH_4^+ - N 20C 15	NH_4^+ - N 37C 8	NH_4^+ - N 37C 15	NO_2^- + NO_3^- - N 20C 8	NO_2^- + NO_3^- - N 20C 15	NO_2^- + NO_3^- - N 37C 8	NO_2^- + NO_3^- - N 37C 15	Organic N 20C 8	Organic N 20C 15	Organic N 37C 8	Organic N 37C 15
		µg N/g of soil											
5 days													
0	100	0.00	0.00	0.00	0.00	79.04	87.44	75.41*	88.61	0.12	0.13	0.59	1.34
1.5	100	0.00	0.00	0.00	0.00	70.56	70.32	17.51	33.32	9.03	14.50	19.09	26.13
10 days													
0	100	0.00	0.00	0.00	0.00	86.47	87.28	72.15	81.90	0.16	0.16	0.42	0.52
1.5	100	0.00	0.00	0.00	0.00	16.67	27.94	0.00	22.36*	30.58	32.54	38.17*	33.32
15 days													
0	100	0.00	0.00	1.30	0.12	87.07	91.03	73.41	20.96*	0.18	0.08	0.42	0.41
1.5	100	0.00	0.00	3.04	0.00	12.20	22.62	0.00	5.07	42.58	54.52	55.63	37.26

* = 1 replication

Table 7. Effect of nitrogen, carbon, moisture, temperature, and time on ^{15}N-labeled fractions in 25-30 cm depth of a Sonoita sandy loam

Amendment		^{15}N-LABELED FRACTIONS											
		NH_4^+ - N				NO_2^- + NO_3^- - N				Organic N			
	ppm	20C		37C		20C		37C		20C		37C	
% C	NO_3^--N	8	15	8	15	8	15	8	15	8	15	8	15
		µ N/g of soil											
5 days													
0	100	0.00	0.00	0.00	0.00	89.51	76.96	97.03	91.31	0.58	0.78*	0.32	0.36
1.5	100	0.00	0.00	2.46	0.00	56.23	52.48	4.97	23.86	3.68	8.76	43.19	23.97
10 days													
0	100	0.00	0.00	0.00	0.00	86.40	87.27	88.94	87.93	0.60	0.52	0.74	0.80
1.5	100	0.00	0.00	0.00	0.00	45.06	60.39	1.13	0.00	24.66	29.39*	39.73	44.20
15 days													
0	100	0.00	0.00	0.00	0.00	86.88	88.90	78.51	89.99	0.54	0.46	2.72	0.66
1.5	100	0.00	0.00	0.00*	0.00	33.05	28.24*	2.67	0.00	31.61	52.30	50.70	70.38

* = 1 replication

Table 8. Effect of carbon, moisture, temperature, and time on denitrification in a Sonoita sandy loam

Amendment		% LOSS OF APPLIED N											
		5 days				10 days				15 days			
	ppm	20C		37C		20C		37C		20C		37C	
% C	NO_3^--N	8	15	8	15	8	15	8	15	8	15	8	15
0-5 cm depth													
0	100	8.41	20.68	4.01*	24.59	7.16*	10.52	8.87	31.57	9.53	7.62	7.47	35.06
1.5	100	18.53	24.34	27.00	45.73	20.72*	29.34	47.09	44.80	29.51	60.13	42.56	63.06
10-15 cm depth													
0	100	19.22	13.88	22.81	8.31	11.68	10.87	26.03	15.98	11.08	7.13	23.47	48.90
1.5	100	19.87	13.54	32.11	39.41	31.84	38.34	30.55	44.65	44.16	21.37	40.19	56.87
25-30 cm depth													
0	100	8.16	15.62	10.89*	6.55	11.32	10.50	8.58	9.55	10.89	8.91	17.20	7.60
1.5	100	38.93	37.58	48.41	51.25	28.94	23.31	58.35	54.95	34.08	46.68	31.53	65.32*

* = 1 replication

have been conducted on Anthony sandy loam from the Santa Rita Validation Site and Rillito loam and eroded loam soils from the Silverbell Validation Site to verify that the factors have the same general effect on denitirification in other soils in the Sonoran Desert. Incubations have been completed; however, samples have not been analyzed for ^{15}N.

Soil respiration measurements were made during the month of July and data are reported in Tables 10, 11, 12, and 13. The respiration studies were conducted under constant,wetting,and drying soil-moisture conditions. Under constant soil moisture conditions (Tables 10 and 12), soil respiration was higher in all amended soils than in the control, except one treatment in the Anthony sandy loam. Soil respiration was increased with amendments of N, organic C and organic C plus N. Ground barley grain was the best amendment for increasing soil respiration. Respiration was slightly higher with the ammonium-N source than with the nitrate-N source. Soil respiration under

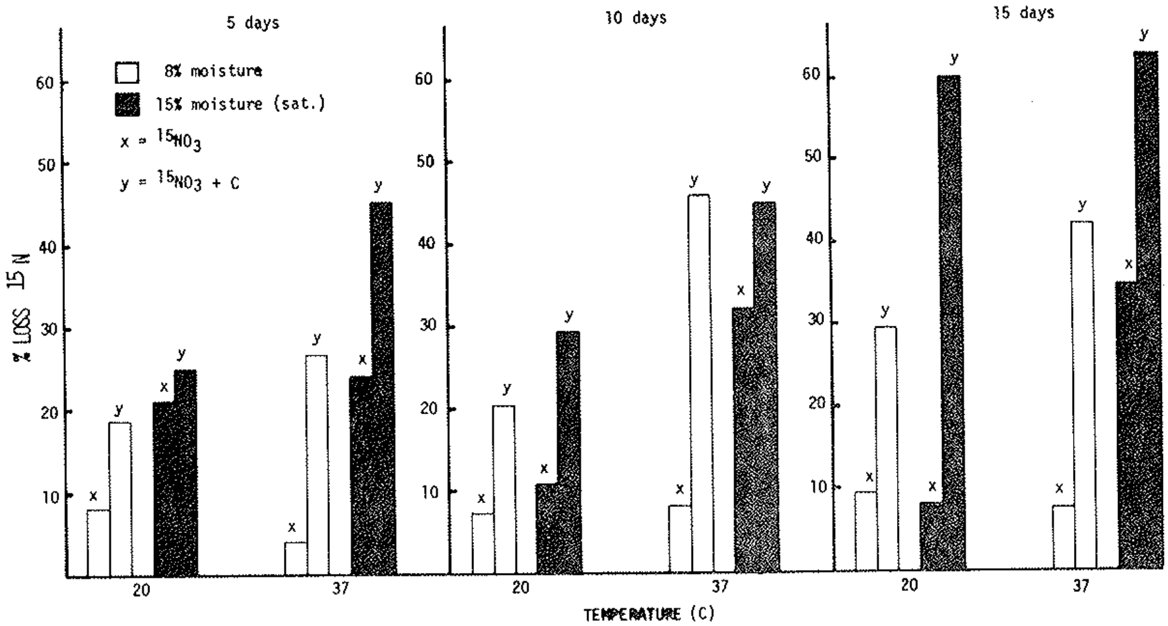

Figure 3. Percent loss of N^{15} at 0-5 cm under varying temperature, moisture and time regimes.

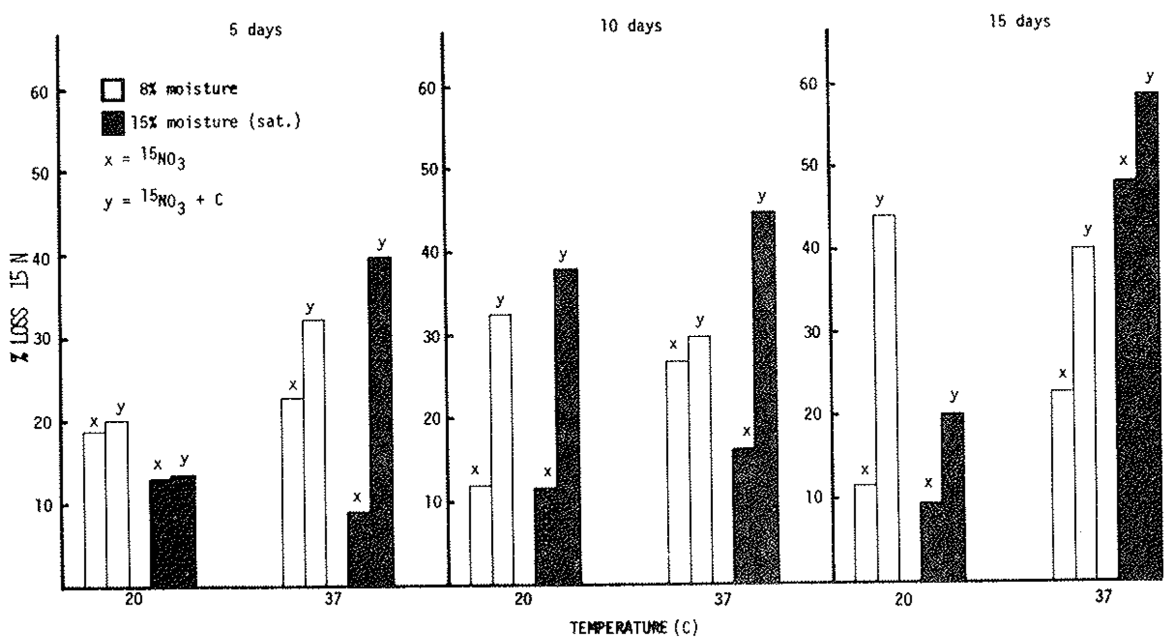

Figure 4. Percent loss of N^{15} at 10-15 cm under varying temperature, moisture and time regimes.

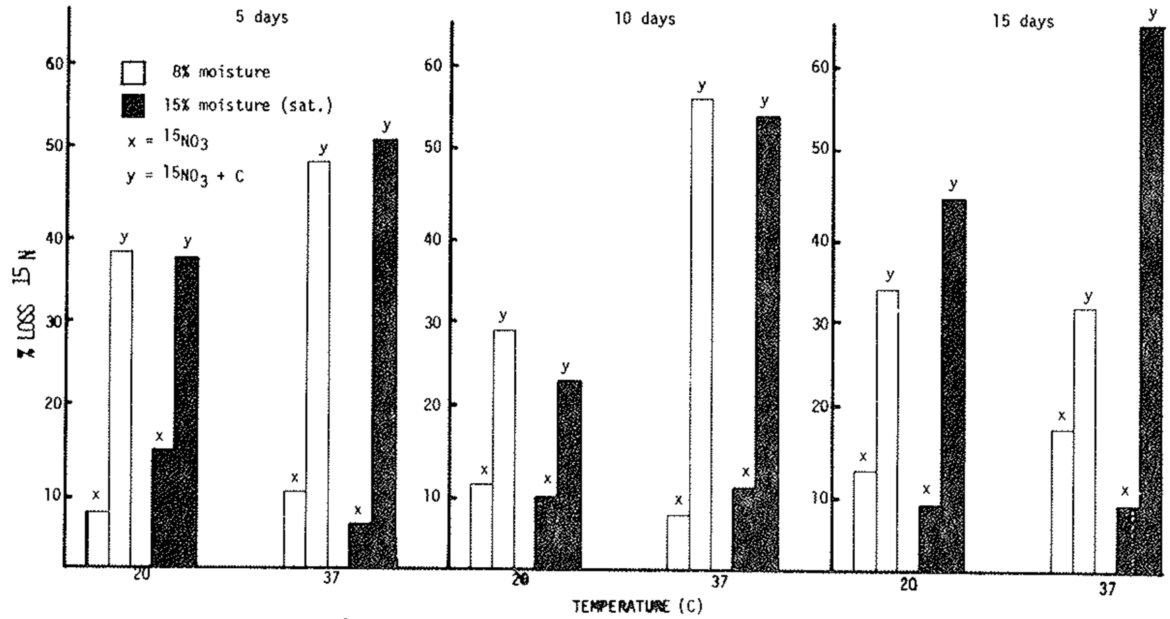

Figure 5. Percent loss of N^{15} at 25-30 cm under varying temperature, moisture and time regimes.

Table 9. Treatment means of percent loss of ^{15}N as influenced by soil depth, temperature, moisture, nitrogen, and nitrogen plus carbon, and time

	% Loss of ^{15}N
Depth	
0- 5 cm	26.18
10-15 cm	26.34
25-30 cm	26.88
Temperature	
20 C	21.23
37 C	31.70
Moisture	
8%	23.64
15% (Sat.)	29.29
Amendment	
N	14.46
N + C	38.47
Days	
5	23.33
10	25.65
15	30.43

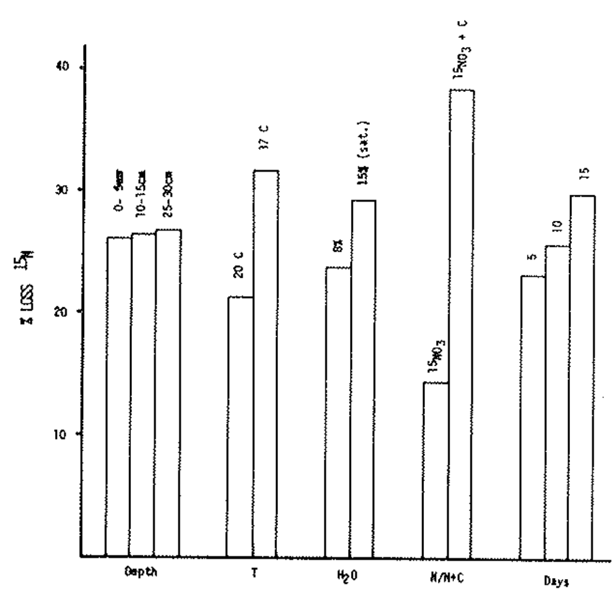

Figure 6. Summary of data on N^{15} loss depending on depth, temperature, moisture content, carbon supplementation and time.

increasing soil moisture conditions followed the same general trends as observed under constant soil moisture conditions, except the magnitude of CO_2 evolved was much larger. Under drying soil moisture conditions near the end of the month, there was some interchange of the effect of treatments on soil respiration. However, respiration remained highest in soils amended with barley grain. Ammonium-N at higher rates of application continued to increase respiration more than was observed when nitrate-N was mixed with wheat straw. At lower rates of ammonium-N, most of the N had probably been transformed to nitrate or other soil N forms. Air temperature, surface soil temperature, soil temperature at 2 cm and percent moisture at the beginning and end of the observations are also reported, which should be useful for modelling purposes. At the end of 3, 6, 9, and 12 months in the field, soil cores are being removed, brought into the laboratory, freeze dried, and stored for analysis for ^{15}N

Table 10. Carbon dioxide evolution from field decomposition experiments, July 3-5, 1973

	Site 1 Anthony sandy loam		Site 2 Sonoita sandy loam	
Date	Jul 3	Jul 5	Jul 3	Jul 5
Time	9:00 a.m.	8:10 a.m.	8:25 a.m.	7:40 a.m.
Ambient air	34 C	32 C	31 C	31 C
Soil surface	37 C	35 C	31 C	30 C
Soil subsurface 2cm	35 C	39 C	34 C	34 C
Soil moisture, %	0.34	0.37	0.39	0.46
Elapsed time of measurement of CO_2 (hrs)	47:05		47:25	

Treatment	mg CO_2 evolved/M^2/hr	
Control	81.4	104.0
6 mg N,$(^{15}NH_4)_2SO_4$	87.2	109.7
6 mg N,$(K^{15}NO_3)$	83.3	107.8
1 g wheat straw (w.s.)	131.1	123.0
1 g w.s. + 3 mg N $(^{15}NH_4)_2SO_4$	154.0	170.3
1 g w.s. + 3 mg N $(K^{15}NO_3)$	154.0	140.1
1 g w.s. + 12 mg N $(^{15}NH_4)_2SO_4$	148.3	155.2
1 g w.s. + 12 mg N $(K^{15}NO_3)$	138.8	151.4
1 g barley grain	270.5	335.5

Table 11. Carbon dioxide evolution from field decomposition experiments, July 11-13, 1973

	Anthony sandy loam		Sonoita sandy loam	
Date	Jul 11	Jul 13	Jul 11	Jul 13
Time	9:10 a.m.	8:20 a.m.	8:30 a.m.	7:25 a.m.
Ambient air	27 C	27 C	24 C	24 C
Soil surface	29 C	30 C	28 C	25 C
Soil subsurface, 2cm	25 C	33 C	24 C	29 C
Soil moisture, %	3.94	10.32	3.77	8.62
Elapsed time of measurement of CO_2 (hrs)	48:05		47:30	

Treatment	mg CO_2 evolved/M^2/hr	
Control	166.2	206.8
6 mg N,$(^{15}NH_4)_2SO_4$	156.8	157.2
6 mg N,$(K^{15}NO_3$	152.7	152.3
1 g wheat straw (w.s.)	254.3	304.6
1 g w.s. + 3 mg N $(^{15}NH_4)_2SO_4$	410.5	460.7
1 g w.s. + 3 mg N $(K^{15}NO_3)$	362.6	360.7
1 g w.s. + 12 mg N $(^{15}NH_4)_2SO_4$	677.8	639.9
1 g w.s. + 12 mg N $(K^{15}NO_3)$	633.2	557.0
1 g barley grain	1116.4	1011.5

Table 12. Carbon dioxide evolution from field decomposition experiments, July 23-25, 1973

	Anthony sandy loam		Sonoita sandy loam	
Date	Jul 23	Jul 25	Jul 23	Jul 25
Time	8:17	7:52	7:43	8:16
Ambient air	28 C	29 C	26 C	30 C
Soil surface	30 C	32 C	28 C	28 C
Soil subsurface, 2cm	33 C	28 C	24 C	29 C
Soil moisture, %	0.36	0.37	0.45	0.37
Elapsed time of measurement of CO_2 (hrs)	47:40		48:36	

Treatment	mg CO_2 evolved/ M^2/hr	
Control	105.2	65.6
6 mg N,$(^{15}NH_4)_2SO_4$	97.0	83.7
6 mg N,$(K^{15}NO_3)$	102.7	81.8
1 g wheat straw (w.s.)	102.7	89.2
1 g w.s. + 3 mg N$(^{15}NH_4)_2SO_4$	117.8	87.4
1 g w.s. + 3 mg N$(K^{15}NO_3)$	108.4	78.1
1 g w.s. + 12 mg N$(^{15}NH_4)_2SO_4$	112.1	80.0
1 g w.s. + 12 mg N $(K^{15}NO_3)$	110.3	98.5
1 g barley grain	131.0	105.9

Table 13. Carbon dioxide evolution from field decomposition experiments, July 30-31, 1973

	Anthony sandy loam		Sonoita sandy loam	
Date	Jul 30	Jul 31	Jul 30	Jul 31
Time	3:00 p.m.	2:50 p.m.	2:20 p.m.	2:30 p.m.
Ambient air	32 C	37 C	31 C	37 C
Soil surface	38 C	49 C	39 C	48 C
Soil subsurface, 2 cm	35 C	45 C	42 C	59 C
Soil moisture, %	1.17	0.91	1.31	1.07
Elapsed time of measurement of CO_2 (hrs)	24:00		24:15	

Treatment	mg CO_2 evolved/M^2/hr	
Control	128.2	109.8
6 mg N, $(^{15}NH_4)_2SO_4$	94.6	83.8
6 mg N, $(K^{15}NO_3)$	128.2	91.2
1 g wheat straw (w.s.)	263.1	232.3
1 g w.s. + 3 mg N$(^{15}NH_4)_2SO_4$	293.2	276.8
1 g w.s. + 3 mg N $(K^{15}NO_3)$	326.9	187.8
1 g w.s. + 12 mg N $(^{15}NH_4)_2SO_4$	293.2	341.4
1 g w.s. + 12 mg N $(K^{15}NO_3)$	218.1	236.0
1 g barley grain	355.4	357.6

movement and transformation and organic C. This experiment was designed with the assumption of the continuation of the project in 1974. Without operational funds, it is doubtful that analyses of samples can be completed.

The effects of increasing the carbon:nitrogen ratios in a Sonoita sandy loam on transformations of $^{15}NO_3$-N are reported in Table 14. Nitrate-N was immobilized and mineralized as ammonium-N in soils with amendments of C:N greater than 10:1.

Organic ^{15}N increased and $^{15}NO_3$-N decreased with increasing C:N ratios. Denitrification also increased with C:N ratios of 40:1 and 45:1. Increased immobilization may have prevented excessive ^{15}N losses at higher C:N ratios.

Table 14. Effect of organic carbon on the transformation of ^{15}N-labeled nitrate in a Sonoita sandy loam

C:N	$^{15}NH_4^+$-N	$^{15}NO_2^-$ + $^{15}NO_3^-$-N	Org-^{15}N	% Loss of ^{15}N
	µg N/g of soil			
10:1	0.741	57.22	20.81	18.49
15:1	11.761	37.70	26.90	18.80
20:1	6.53	41.10	28.12	21.59
25:1	12.08	39.25	31.54	14.21
30:1	13.44	22.81	31.71	31.23
35:1	19.05	28.75	33.26	16.09
40:1	9.53	24.55	33.28	30.27
45:1	11.88	13.20	37.23	35.57

DISCUSSION

Non-biological contributions to gaseous losses of ^{15}N have not been quantified. Preliminary results indicate that perhaps some loss is occurring but studies are not complete.

Results of 1971 and 1972 (Tucker and Westerman, 1973b; Westerman and Tucker, 1973) showed that the magnitude of loss was dependent on the availability of an adequate organic carbon source for energy, favorable temperature, adequate moisture but not necessarily saturation, and time. Of the factors investigated, organic carbon had the greatest effect on gaseous N losses. The magnitude of loss of N was not affected appreciably by variation in soil depth.

Microbial respiration in the field experiments was influenced by amendments of N and organic C. Ground barley grain had a greater stimulatory effect on soil respiration than any other amendment investigated. However, soil respiration was increased with amendments of N and wheat straw. Samples at 3 and 6 months for decomposition of organic materials, transformation, movement, and denitrification of $K^{15}NO_3$ have been collected but have not been analyzed. Analyses of samples will be completed pending further financial support.

Increasing organic carbon in desert soil profiles not only has an effect on denitrification but also increases immobilization rate. Immobilization represents an N conservation measure in desert ecosystems.

EXPECTATIONS

Field studies were established to investigate organic carbon, N movement, transformations and denitrification over a period of one year. This study cannot be continued or completed without financial assistance.

Data obtained quantifying denitrification losses in Sonoran Desert soils as influenced by moisture, temperature, soil depth, organic carbon and NO_3^- concentration as well as the soil respiration studies should be very useful in modelling ecosystems in semi-arid regions.

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