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NITROGEN RETENTION IN COOL DESERT SOILS

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ABSTRACT

A 1.1-ha area in southern Curlew Valley was cultivated, seeded with crested wheatgrass and treated with organic amendments and nitrification inhibitors. It is expected that some surface, blue-green algae-lichen-fixed nitrogen may be accumulated in the soil organic matter. Since the treatments and evaluation of soil processes and plant yields will require three full seasons (three years), the data obtained in this first year on soil chemistry and biological activities are considered only as baseline values.

INTRODUCTION

Studies on several processes of nitrogen transformations in Curlew Valley soils have shown that there is extensive and considerable nitrogen fixation by surface (photosynthetic) microorganisms, the blue-green algae, which also act as primary producers. Most of the fixed nitrogen is released as NH_4^+, nitrified and denitrified in the presence of easily available organic substrate. The process is enhanced by the spring and fall rainy periods. Some of the nitrogen may also be lost due to volatilization of NH_3. The concentration of organic matter in these soils is low, and the C:N ratios are low (8;12) indicating an excess of nitrogen present, or conversely, the fact that all of the available organic carbon has been used for the immobiliaztion of nitrogen. The reverse process, mineralization of nitrogen, starts at a C:N ratio of about 20-30 in agricultural soils. By inhibiting nitrification, nitrogen loss would be minimized and, with a concurrent addition of organic matter, the excess nitrogen may be immobilized and stabilized.

OBJECTIVES

The objectives of this project are to determine:

1. The effect of the application of inhibitors of nitrification and of several carbohydrate-containing industrial and agricultural residue materials (sawdust, shredded paper and plowed-under sagebrush) on the facility of a desert soil to retain naturally fixed nitrogen upon inhibition of nitrification.
2. The feasibility of the treatment of objective 1 for concurrent seeding of treated areas with *Agropyron cristatum*, and the effect on its yield.

METHODS

Analytical methods and procedures for laboratory and field work in this project are the same as used for the project entitled "Nitrogen dynamics in stands dominated by some major cool desert shrubs" (Skujins and West 1974), where methods for determination of nitrification potential (DSCODE A3USQ06), dehydrogenase activity (A3UBJJ4), respiration (A3UBJJ1), proteolysis (A3USQ02) and pH (A3UBJJ6) have been described. Chemical analysis of soils (A3USQ01) was performed by the Soils Science Laboratory at Utah State University.

Table 1 shows the nitrogen retention treatment scheme. The experimental site in south Curlew Valley, Utah, was dominated largely by sagebrush (*Artemisia tridentata*) with a few annuals interspersed among the sagebrush. Most of the area chosen was covered by a blue-green algal lichen crust.

Prior to treatment, four adjacent 20 x 140-m strips were divided into seven 20 x 20-m plots, with each plot being 0.04 ha.

Soil samples were collected prior to any treatments on April 2, 1974, at the points marked on Table 1, with the depth of sampling for each point indicated at the bottom of Table 1. The numbers or numerals by each sampling point in Table 1 identify each sampling point.

According to the treatment scheme in Table 1, 2-chloro-6 (trichloromethyl) pyridine (N-Serve, Dow Chemical Co.) was sprayed uniformly over the surface of the designated plots on strips 1-4 on May 28, 1974.

A Hudson Utility sprayer (Hudson Mfg. Co., Chicago, Ill.) containing 93.3 ml of N-Serve (formulation M-3906, Dow Chemical Co., 240 g N-Serve/liter) diluted to 2 liters with distilled water was used. The pressure pump provided enough pressure so that a steady walking pace enabled uniform spraying of the diluted N-Serve over a 20 x 20-m plot. The above procedure was repeated for each of the plots sprayed, with an application rate of 560 g of N-Serve/ha.

For strip 1, all sagebrush plants were cut by chain saw and removed from the site. On strip 2 (on May 30, 1974) the sagebrush was plowed under using a notched disc plow. The depth of discing was approximately 10 cm. On strip 3, 840 kg of air-dry, shredded newspaper were spread uniformly and plowed under with the sagebrush (May 30, 1974). The newspaper shreds were approximately 1-5 cm^2 in size. Strip 4 was spread with 840 kg of air-dry, Douglas-fir sawdust on May 18, 1974, and plowed under with the sagebrush cover on May 30, 1974.

Soil samples were again obtained from each plot on August 8, 1974. On October 18 and 19, 1974, a second spraying of N-Serve was performed, but at a rate of 840 g of N-Serve/ha. The designated plots (Table 1) were seeded by a disc plow on November 12, 1974; Fairway crested wheatgrass (Seed I) and Siberian crested wheatgrass (Seed II) were seeded at a rate of 14.0 and 11.3 kg seed/ha, respectively. The depth of discing was approximately 0.3-0.5 cm.

Nitrification potential was determined according to the methods described in the 1973 progress report (A3USQ06; Skujins and West 1973). Samples (7-6)-1, (7-6)-2, 8-1, 8-2,

Table 1. Treatment scheme and pretreatment sampling locations[a]

Treatment	Sagebrush removed 1	Sagebrush plowed under 2	Shredded paper plowed under 3	Sawdust plowed under 4
N-serve	10-9 0	0	8	7-6 0
Seeded I (Fall, 1974)		12 ●		14 ●
Seeded II (Fall, 1974)				
N-serve Seeded I (Fall, 1974)	0 13	0 14-	15	0 16
N-serve Seeded II (Fall, 1974)		29 ●		27 ●
N-serve Seeded I (Fall, 1974)	31-32 0		33 0	34-35 0
N-serve Seeded II (Fall, 1974)				
No treatment				

[a] 0 sampled at 0-3 cm, and 5-20 cm depths, ● samples at 0-3, 5-20, 40-50, and 70-80 cm depths.

(10-9)-1, (10-9)-2, (14-15)-1, (14-15)-2 and 14-4 were perfused for 21 days with the last sampling day being day 21. Sampling days 18 and 20 were for 16-1, 16-2, 27-1, 27-2, 27-3, 27-4, 29-1, 29-2 and 29-3.

Soils were perfused for 20 days unless otherwise specified. April 4 samples were analyzed for fixed NH_4^+ and exchangeable NH_4^+ according to Skujins and West (1973) before and after perfusion. August 8 samples were analyzed for fixed NH_4^+, total N, exchangeable NH_4^+ and NO_2^- and NO_3^-, also according to Skujins and West (1973; A3USQ01).

RESULTS AND DISCUSSION

The project was initiated in 1974. Any data obtained on soil chemistry and biological activities should be considered as baseline values.

Initial (baseline) carbon, nitrogen and nitrate content are shown in Table 2 (A3USQ01), pH in Tables 3 and 4 (A3UBJJ6), respiration in Table 5 (A3UBJJ1), proteolysis in Table 6 (A3USQ02), dehydrogenase activity in Table 7 (A3UBJJ4). An example of nitrification potential data is shown in Table 8 (A3USQ06). Initial and subsequently periodic nitrification potential data are collected from all sampling sites and will be reported in the future as warranted by significant results.

The ammonium content in the April 4 samples is shown in Table 9. Organic N, ammonium and nitrate/nitrite contents for samples collected on August 8 are shown in Table 10 (A3USQ01).

Table 2. Chemical analysis, April 4, 1974

Sample	% Organic C	% Total N	µg/g NO_3^-
(7-6)-1	1.8	.22	3.5
(7-6)-2	1.6	.16	8.3
8-1	2.4	.25	25.5
8-2	1.3	.15	12.4
(10-9)-1	2.2	.24	32.3
(10-9)-2	1.6	.18	8.5
12-1	2.0	.23	4.0
12-2	1.4	.15	6.2
12-3	1.0	.12	5.3
12-4	.4	.06	2.8
13-1	1.9	.24	.7
13-2	1.6	.21	4.7
14-1	1.9	.26	16.0
14-2	1.1	.15	8.8
14-3	.9	.11	8.9
14-4	.4	.05	3.6
(14-15)-1	1.6	.20	3.7
(14-15)-2	1.3	.19	23.0
16-1	1.8	.21	2.0
16-2	1.8	.16	6.2
27-1	2.2	.23	1.8
27-2	1.4	.16	7.7
27-3	.8	.11	7.7
27-4	.5	.06	3.8
29-1			
29-2			
29-3			
29-4			
(31-32)-1	.8	.36	1.6
(31-32)-2			
33-1			
33-2			
(34-35)-1			
(34-35)-2			

The rate of application of N-Serve was increased for the October 1974 application from 560 to 840 g N-Serve/ha as the August 8 samples failed to show the presence of this chemical from biological tests. In addition, no change in the soil N fractions (organic N, fixed NH_4^+—N, exchangeable NH_4^+—N, or NO_2^- and NO_3^-) was observed. Therefore, it is assumed that, due to the extreme dryness and heat of the summer, the N-Serve had volatilized off from the soil surface.

Table 3. pH (initial collection), April 4, 1974

Sample	pH	Sample	pH
(7-6)-1	8.5	(14-15)-2	8.9
7-6-2	8.5	16-1	8.5
8-1	8.4	16-2	8.8
8-2	8.7	27-1	8.7
(10-9)-1	8.8	27-2	8.6
(10-9)-2	8.7	27-3	9.3
12-1	8.4	27-4	8.8
12-2	8.5	29-1	8.7
12-3	8.8	29-2	9.0
12-4	8.9	29-3	8.8
13-1	8.3	29-4	8.8
13-2	8.4	(31-32)-1	8.6
14-1	8.3	(31-32)-2	8.8
14-2	8.6	33-1	8.9
14-3	8.9	33-2	8.9
14-4	8.9	(34-35)-1	8.7
(14-15)-1	8.6	(34-35)-2	8.9

Table 4. pH, August 8, 1974, samples

Sample	pH	Sample	pH
1	8.5	8	8.5
2	8.8	13	8.5
3	8.4	14	8.8
4	8.5	15	8.8
5	8.4	16	8.9
6	8.8	29	8.4
7	8.6		

Table 5. Respiration (initial collection), April 4, 1974

Sample	µm CO_2 evolved/ dry g/min	RXN moisture (bars)	Sample	µm CO_2 evolved/ dry g/min	RNX moisture (bars)
(7-6)-1	62.3	-127	(14-15)-2	51.2	-9
(7-6)-2	82.3	-6	16-1	55.3	-163
8-1	67.8	-32	16-2	53.0	-6
8-2	62.9	-7	27-1	28.4	-24
(10-9)-1	72.8	-63	27-2	35.6	-9
12-1	82.4	-165	27-3	49.3	-4
12-2	43.7	-11	27-4	27.6	-26
12-3	52.7	-11	29-1	60.2	-54
12-4	25.3	-43	29-2	61.0	-7
13-1	75.3	-197	29-3	44.3	-14
13-2	35.5	-9	29-4	36.0	-38
14-1	48.0	-71	(31-32)-1	37.0	-172

Table 5, continued

Sample	µm CO_2 evolved/ dry g/min	RXN moisture (bars)	Sample	µm CO_2 evolved/ dry g/min	RNX moisture (bars)
14-2	49.4	-9	(31-32)-2	25.6	-8
14-3	23.4	-36	33-1	46.8	-9
14-4	35.7	-13	33-2	33.4	-8
(14-15)-1	37.3	104	(34-35)-1	63.0	-127
(10-9)-2	55.2	-8	(34-35)-2	46.6	-8

Table 6. Proteolysis (initial collection) April 4, 1974

Sample	% Hydrolysis	Sample	% Hydrolysis
(7-6)-1	40.0	(14-15)-2	17.0
(7-6)-2	16.0	16-1	30.0
8-1	43.0	16-2	15.0
8-2	14.0	27-1	39.0
(10-9)-1	47.0	27-2	4.2
(10-9)-2	20.0	27-3	5.2
12-1	25.0	27-4	3.6
12-2	2.5	29-1	38.8
12-3	4.2	29-2	13.5
12-4	0	29-3	4.6
13-1	43.5	29-4	4.0
13-2	14.0	(31-32)-1	40.5
14-1	39.0	(31-32)-2	17.0
14-2	5.0	33-1	49.0
14-3	1.8	33-2	18.0
14-4	4.0	(34-35)-1	42.4
(14-15)-1	41.0	(34-35)-2	18.0

Table 7. Dehydrogenase activity (initial collection), April 4, 1974

Sample	mg formazan formed/g dry soil	Sample	mg formazan formed/g dry soil
(7-6)-1	1.18	(14-15)-2	.42
(7-6)-2	.28	16-1	1.11
8-1	1.23	16-2	.25
8-2	.21	27-1	1.89
(10-9)-1	1.59	27-2	.18
(10-9)-2	.58	27-3	.05
12-1	.96	27-4	.04
12-2	.15	29-1	1.12
12-3	.02	29-2	.29
12-4	.01	29-3	.04
13-1	1.35	29-4	.03
13-2	.24	(31-32)-1	.24
14-1	1.77	(31-32)-2	.09
14-2	.04	33-1	1.43
14-3	.02	33-2	.30
14-4	.04	(34-35)-1	1.27
(14-15)-1	1.60	(34-35)-2	.41

Table 8. Nitrification potential, April 4, 1974, samples

	µg NH_4^+-N/g		µg NO_2^--N/g		µg NO_3^--N/g	
Days	(7-6)-1	(7-6)-2	(7-6)-1	(7-6)-2	(7-6)-1	(7-6)-2
*						
2	702	1017	9.1	.8	0	0
4	-	-	13.3	2.2	2.5	3.9
6	721	629	7.9	3.2	5.0	9.2
8	-	-	15.5	4.9	13.3	7.5
10	692	452	15.1	12.4	0	40.0
12	-	-	31.0	57.6	0	25.8
14	665	325	82.9	203	0	46.7
16	-	-	-	-	-	-
18	-	-	398	1083	0	54.2
21	85	0	1208	1392	15.8	72.5

* Initial NH_4^+-N added = 2333 µg/g.

** Soil analyzed at original field moisture
(7-6)-1-(0-3 cm) - 7.5% moisture
2 (5-20 cm) - 20.2%
Sampled between markers 6 and 7, (Plot IV).

Table 9. Ammonium content, April 4, 1974, samples

	µg NH_4^+/g			µg NH_4^+/g	
Sample	Fixed NH_4	Exchangeable NH_4	Sample	Fixed NH_4	Exchangeable NH_4
7-6-1	79.3	0.7	16-1	97.0	2.5
7-6-2	65.9	1.4	16-2	78.0	1.3
8-1	96.3	0.9	27-1	161	2.0
8-2	65.8	0.2	27-2	88	0
(10-9)-1	134.1	0.9	27-3	50	0
12-1	127.1	3.3	27-4	21.5	1.4
12-2	7.4	3.3	29-1	128.2	1.5
12-3	9.0	7.7	29-2	78	1.1
13-1	123.0	3.0	29-3	40	1.1
13-2	5.3	2.2	29-4	13	0.1
14-1	8.1	3.9	31-32-1	206	1.8
14-2	4.4	2.8	31-32-2	96.3	0.2
14-3	2.0	5.6	33-1	133.8	1.6
14-4-1	0.8	0	33-2	107.2	0.4
14-15-1	127.0	0.7	34-35-1	201	0.7
14-15-2	88.0	0	34-35-2	108.6	0.3

EXPECTATIONS

It is expected that considerable amounts of fixed nitrogen will be stabilized (immobilized) by the application of organic materials to soil. This would increase organic matter in soil with a subsequent improvement of soil structure forming a slow-releasing nitrogen pool, useful for plant nutrition.

It is possible that, under the conditions of our treatments, denitrification may take place, i.e., with an ultimate loss of total nitrogen and carbon. This process may be inhibited by addition of 2-chloro-6 (trichloromethyl) pyridine (N-Serve, Dow Chemical Co.), which inhibits nitrification, thus reducing the amount of nitrate available for denitrification during the period of ammonium incorporation in the organic matter.

Table 10. Soil nitrogen analysis, August 8, 1974, samples

Sample	Fixed NH_4^+-N	Organic N	Exchangeable NH_4^+-N	NO_2^-+NO_3^--N
		µg/g		
1	141	1869	1.4	15.4
2	126	1384	1.5	11.9
3	141	1440	1.4	13.6
4	106	1354	0.3	10.8
5	167	1863	3.6	19.5
6	117	1843	6.1	9.2
7	178	2123	2.8	17.9
8	582	1394	0.9	11.9
13	683	2073	1.4	
14	131	2089	0.0	13.5
15	83	1727	1.5	14.7
16	123	2027	1.4	18.9
29	473	1975	2.7	14.1

It is expected that increased retention of nitrogen and subsequent buildup of organic matter in soil will affect beneficially the yield of crested wheatgrass (*Agropyron cristatum*), the test plant.

The results of these treatments may be used to test several aspects of the proposed nitrogen cycle model.

The treatments and evaluation of soil processes and plant yields will require at least three years (three full seasons).

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