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1975 PROGRESS REPORT

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V. STUDIES ON DENITRIFICATION AND NITROGEN FIXATION: COMPARISON OF BIOLOGICAL PROCESSES IN WESTERN DESERTS

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ABSTRACT

Our desert comparison studies appear to verify that the microbial and biochemical activity rates, from each of the IBP Desert Biome sites, correlate with physical and chemical soil properties. Soil moisture, temperature and pH, C:N ratios, conductivity and precipitation patterns are of most importance. However, the complete analyses of these soils are still continuing, and thus, a full appreciation of all the data will not be achieved until all of the results have been compiled and evaluated.

Detailed examination of the nitrogen cycle by means of ^{15}N labeling indicates that the major loss of N from Great Basin Desert soils occurs via denitrification, while ammonia volatilization is of secondary importance. In the same study, heterotrophic nitrogen fixation was found to be significant. Thus, the C:N ratios of the surface soils assume greater importance as the carbon, derived from the filamentous blue-green algae *Lyngbia* and *Microcoleus*, represents the energy source driving these heterotrophic activities. Finally, fixation of NH_4^+ on clay potentiates an important nitrogen-conserving process.

Further examination of nitrogen fixation and the monitoring of the flux of such fixed nitrogen are required, and will be carried out during the upcoming year. Similarly, as additional desert comparison data become available, defined correlations between microbial activities and soil properties may be achieved. Thus, it is expected that the information developed will be of value in the construction of models for various components of the desert ecosystem.

INTRODUCTION

For the past five years our laboratory has been measuring the microbial and biochemical activity rates of soils from Curlew Valley, Utah, a cool Great Basin desert. We have characterized activities in soil profiles, their dependence on annual climatic seasons, and determined soil nutrient pools and fluxes, especially those of nitrogen.

Acetylene reduction and ^{15}N tests were employed to investigate the nitrogen cycle. Autotrophic and heterotrophic nitrogen fixation, ammonia volatilization, nitrification and denitrification were studied. The influence of applied 2-chloro-6 (trichloromethyl) pyridine, fresh plant material and plant litter on nitrogen fixation and denitrification both in the field and in laboratory studies was of prime interest.

Comparative studies on biological activities and nitrogen cycling were conducted in the Great Basin (Curlew Valley and Pine Valley), Chihuahuan (playa and bajada), Sonoran and Mohave deserts.

METHODS

SAMPLING AREAS

The study sites used are established IBP validation study sites: Las Cruces, New Mexico (Jornada); Tucson, Arizona (Silverbell); Mercury, Nevada (Rock Valley); Milford, Utah (Pine Valley); and Snowville, Utah (Curlew Valley).

Jornada

The Jornada validation area, representative of the Chihuahuan Desert, is located on the New Mexico State University Jornada Experimental Ranch. There are two designated sites within the area, the playa and the bajada (Fig.1).

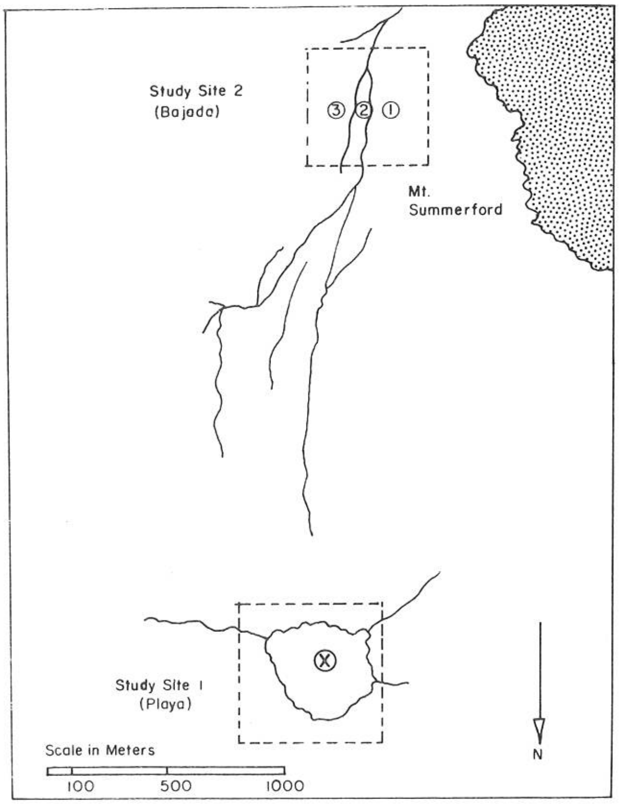


Figure 1. Relative position of playa study site and bajada study site at the Jornada Validation Site (Whitford et al. 1973). Soil sampling stations are designated within each site. Playa - located 65 m south of marking 3/3 and 25 m north of 2/3; Bajada 1 - located 28 m west of marking 4/1; Bajada 2 - located 20 m west of marking 3/2; Bajada 3 - located 24 m east of marking 3/4.

The playa site is at a lower elevation in the form of a depression where water may accumulate to 30-45 cm depth during the rainy season. This phenomenon has resulted in a dense vegetative cover.

The principal vegetation of the playa bottom, where a 12-m^2 sampling station was located, includes *Panicum obtusum*, *Xanthium strumarium* and *Hymenoxys oderata*. *Panicum obtusum* contributes most to the standing crop but there are other perennials dominating the playa bottom according to moisture change, including *Sida leprosa*, *Cyperus esculentus*, *Hoffmanseggia densiflora* and *Hilaria mutica*.

The dominant soil type of the playa bottom is sandy loam. These soils have strong genetic horizons with the carbonate accumulation horizons being most distinctive. In some areas, the argillic horizon has been partly or completely engulfed or has been mixed by soil fauna, or both (Whitford et al. 1973).

The bajada site is an alluvial fan dissected by large arroyos (washes) and smaller arroyos which converge on the large arroyos. Areas between the arroyos are the upland areas. Three 12-m^2 sampling stations were established at the bajada site. Station 1 is less than 100 m from a small arroyo on an upland area. Station 2 is on the edge of a large arroyo and Station 3 is on an upland area 200-300 m from any arroyos.

Principal vegetation at Station 1 includes *Larrea tridentata*, *Flourensia cernua*, *Yucca elata* and *Yucca baccata*. The dominant vegetation at Station 2 includes *Chilopsis linearis*, *Fallugia paradoxa* and *Prosopis glandulosa* var. *torreyana*. *Larrea tridentata* is the dominant vegetation at Station 3.

Bajada soils have prominent horizons of silicate clay accumulation and prominent carbonate accumulation horizons which are commonly within about 60 cm of the surface. These are typified as sandy clay loam. Station 1 soils are shallow, with a caliche layer 5-100 cm in the profile. Generally, along the arroyos (characterized by Station 2) there is no caliche layer. Station 3 soils are deep soils with a caliche layer to 3 m (Whitford et al. 1973).

The highest amount of precipitation in the Jornada area occurs during the months of July through October and the lowest occurs in April through early June, with the average amounts being 200-250 mm annually.

Silverbell

The Silverbell Validation Site, representative of the Sonoran Desert, is located near the Silverbell Mountains northwest of Tucson, Arizona. A 12-m^2 sampling station was established in the southeast corner of the Silverbell Validation Site (Fig. 2).

Principal vegetation of the area includes *Ambrosia deltoidea*, *Larrea tridentata*, *Cercidium microphyllum*, *Acacia constricta*, *Olneya tesota*, *Carnegiea gigantea* and numerous species of *Opuntia*.

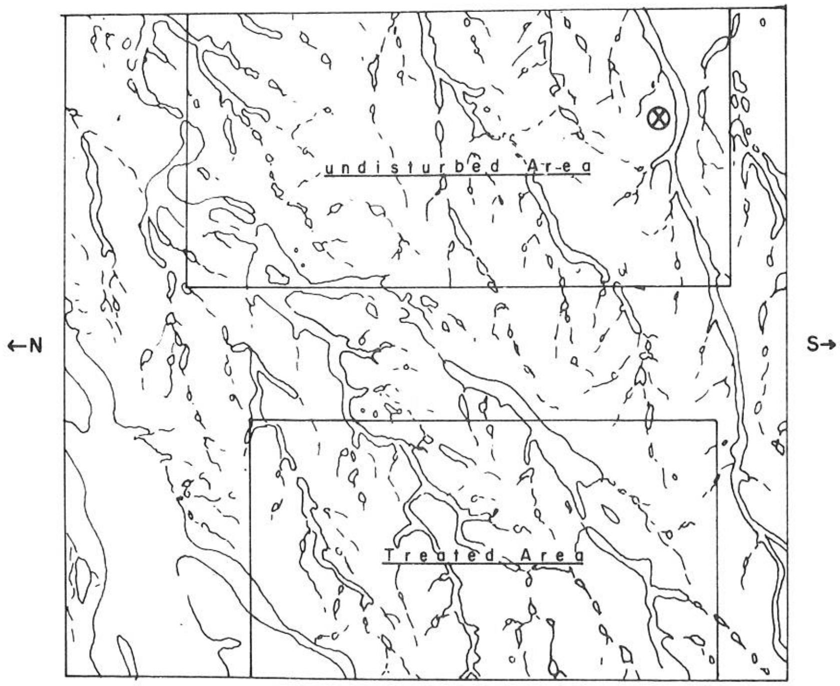


Figure 2. Silverbell Validation Site (Thames et al. 1973) and relative position of sampling station (x) located 82 m north of south fence and 90 m west of gate.

The soils in the sampling station location are described to have been formed in calcareous alluvium primarily from andesite, basalt, granite and quartzite. They are calcareous throughout with maximum carbonate accumulation generally occurring at a depth of 30-50 cm. In some areas, the carbonates form a weakly cemented layer at this depth. The textures of the soil are gravelly sandy loam and gravelly loam. The soils are well drained and have moderate permeability. Annual precipitation averages 300-600 mm (Thames et al. 1973).

Rock Valley

The Rock Valley Validation Site, representative of the Mohave Desert, is located at the south portion of the ERDA Nevada Test Site in Nye County, Nevada (Fig. 3).

The dominant shrubs of the area where a 12-m² sampling station was located include *Larrea tridentata*, *Ambrosia dumosa*, *Krameria parvifolia*, *Lycium andersonii*, *Lycium pallidum* and *Ephedra nevadensis* with *Bromus* and *Festuca* being the dominant grass species.

Soils of this site are derived from a heterogeneous, highly calcareous alluvium composed primarily of Cambrian limestones with some tuff and basalt. The soil's surface is a well-developed desert pavement underlain with a massive and strongly cemented caliche layer at depths ranging from 30-70 cm which is virtually impervious to plant roots but serves as a restrictive layer preventing moisture loss to greater depths in the soil. There is an indication of the presence of considerable amounts of amorphous clays with a low cation exchange capacity.

The general precipitation pattern has been for greatest amounts to occur during August through November and least to occur during April through early July and ranges from 200-250 mm per year (Turner et al. 1973).

Pine Valley

The Pine Valley Validation Site, representative of the southern Great Basin Desert, is located on the Desert Experimental Range in Millard County, Utah (Fig. 4).

Dominant shrubs of the area, where a 12-m² sampling station was located, include *Atriplex confertifolia*, *Ceratoides lanata*, *Artemisia spinescens* and *Sphaeralcea grossulariafolia*. The dominant perennial grass is *Hilaria jamsii* (Frischknecht, pers. comm.).

Baseline data characterizing the soils of the validation site have not been completed to this date.

Precipitation patterns have been for the greatest amount to occur during July through October with the least amount occurring in May (U.S. Weather Bureau, Desert Experimental Range). Average precipitation is 220 mm per year.

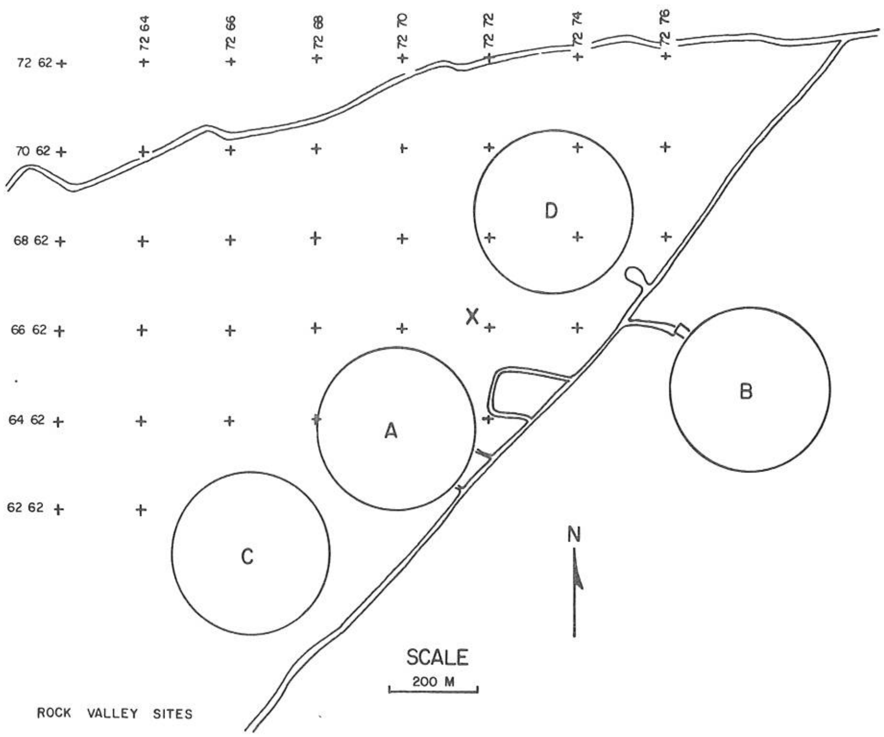


Figure 3. Rock Valley Validation Site (Turner et al. 1973) with designated sampling stations (x) located in the general area of zone 20, 23 m northwest of stake #6672.

Curlew Valley

The Curlew Valley Validation Site, a representative cool desert of the Great Basin, is located west of Snowville, Utah. Samples were taken at four preselected stations, three in noncultivated areas and one in a seeded area. Stations were at the IBP Desert Biome soil survey pits Nos. 21, 15, 22 and 14. The samples were collected not farther than 5 m from any pit.

Dominant vegetation at pit No. 21 includes *Atriplex nuttallii*, *Atriplex confertifolia* and *Sitanion hystrix*. Dominants at pit No. 15 are *Artemisia tridentata* with *Atriplex confertifolia* and *Elymus cinereus*, invaded by *Halogeton glomeratus*. Soil survey pit No. 22, cultivated some years ago, was dominated by *Agropyron cristatum* (syn. *A. desertorum*) and reinvaded by *Atriplex confertifolia*. At pit No. 14 there is mixed flora of *Atriplex confertifolia*, *Descurainia pinnata*, *Lepidium perfoliatum*, *Atriplex nuttallii* and *Sitanion hystrix* (Skujins 1973).

Precipitation at this site occurs mostly in the winter with dry summers with amounts ranging from 300-350 mm per year.

The monthly precipitation pattern for the five sites for 1975 is shown in Table 1.

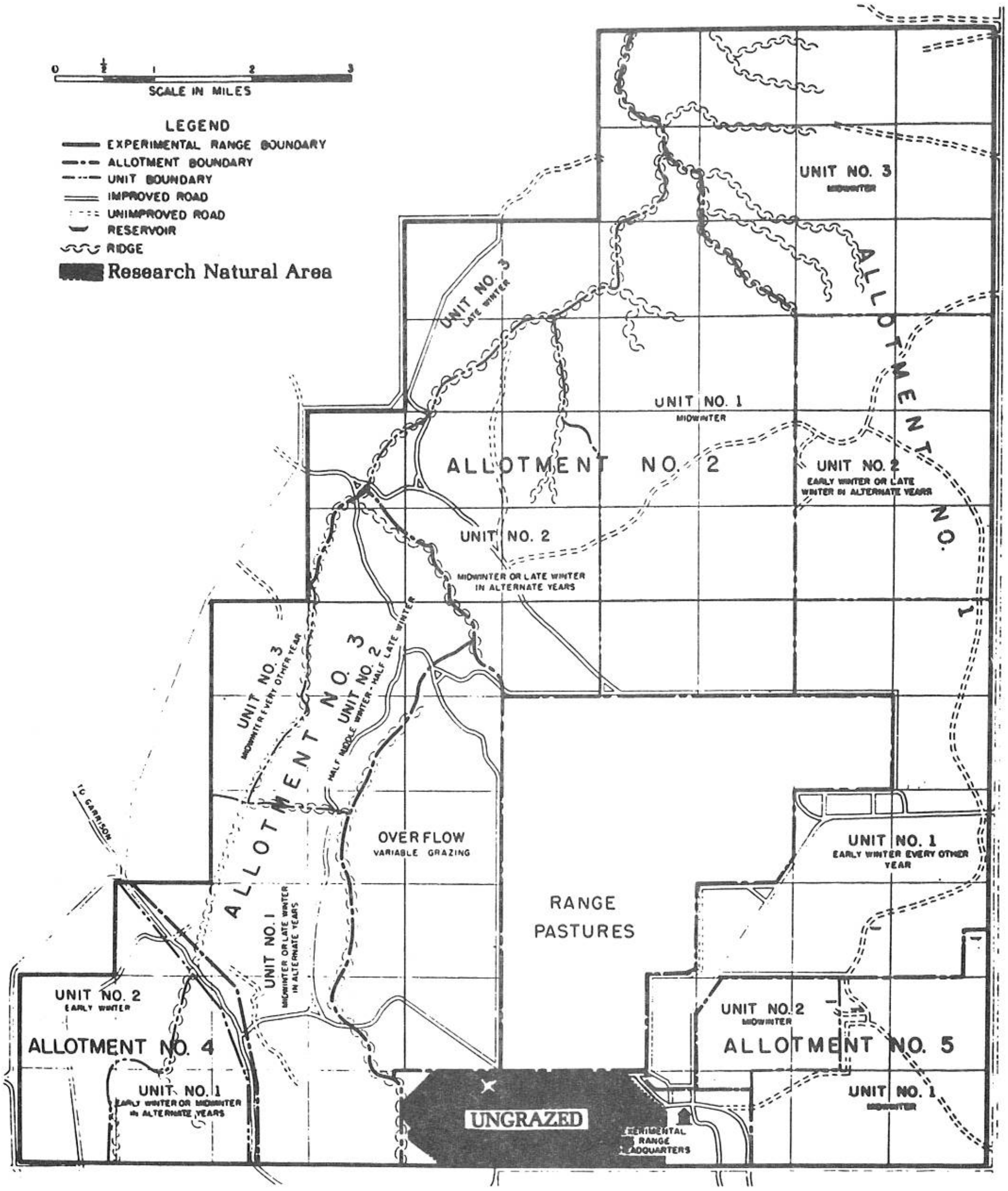


Figure 4. Desert Experimental Range map showing Pine Valley Validation Site (ungrazed area) (Jorgensen and Richins 1974). Designated sampling station (x) located 14 m east of southwestern station.

Table 1. 1975 monthly precipitation pattern (cm)

	Jornada				
Month	Bajada	Playa	Silverbell	Rock Valley	Pine Valley
January	1.85	1.65	0.50	0.10	0.60
February	0.68	0.83	0.38	0.40	0.85
March	1.05	0.83	3.93	2.65	2.10
April	0.05	0.08	1.55	0.98	1.25
May	0.30	0.20	0.08	0.80	2.45
June	0	0	0	0	1.75
July	1.63	2.93	1.63	0	1.75
August	2.90	3.18	1.85	0.18	3.25
September	7.55	7.35	1.08	0.53	0.28
October	1.25	1.30	1.00		1.23
November	0.80	0.85	1.38		0.30
December	0.30	0.60	1.30		
TOTAL	18.36	19.80	14.68		

Sample collecting dates in 1975 were: 1) Jornada, playa and bajada -- March 17, June 27, August 13, December 16; 2) Silverbell: March 19, June 28, August 14, December 15; 3) Rock Valley: March 21, July 29, December 12; 4) Pine Valley: March 23, July 31, December 11; 5) Curlew Valley: June 10.

ANALYSES

Analyses performed on soils collected from these sites included: Chemical; total N, organic C, NO_3^-, exchangeable NH_4^+, **fixed** NH_4^+, pH, salinity, soil temperature, air temperature, moisture tension; Biological-Biochemical; 1) N-cycle -- N_2 fixation by blue-green algae, extent of blue-green algae/lichen cover, potential of N_2 fixation by heterotrophs, proteolytic activity, number of proteolytic organisms, ammonification, nitrification potential, denitrification potential (with ^{15}N), number of chitinolytic organisms; 2) General biological-biochemical characterization -- number of aerobic bacteria, number of streptomycetes, number of fungi, ATP analysis, respiration (CO_2 release), dehydrogenase, number of cellulolytic organisms.

Field sampling in 1975 was planned according to seasonal moisture changes; not all of the analyses have been completed to date, however.

Sample Designations:

Jornada:

Playa = P
Bajada site I = B-1
Bajada site II = B-2
Bajada site II = B-3

Depths

surface 0-5 cm = 1
5-20 cm = 2
40-50 cm = 3
70-80 cm = 4

Silverbell = S
Rock Valley = RV
Pine Valley = PV

Curlew Valley:

Artemisia tridentata-dominated = 5
Ceratoides lanata-dominated = 6
Atriplex confertifolia-dominated = 7

Total N, organic C, $\mathbf{NO_3^-}$ and **salinity** were done by the USU soil testing laboratory according to previously described methods (Skujins and West 1974).

Soil and **air temperature** were measured at intervals during the day at each sampling period.

pH was measured using a 1:1 water suspension.

Moisture tension was measured during respiration experiments using a Model MJ55 psychrometric microvoltmeter with a Model C-51 sample chamber psychrometer (Wescor, Inc., Logan, Utah) calibrated to LiCl and NaCl standards (Skujins and West 1974).

Methods for **proteolytic activity, respiration, dehydrogenase activity, number of aerobic bacteria** and **number of fungi** (Skujins and West 1973), **nitrification potential** (Skujins and West 1974) and **ATP** (Skujins 1975) have been described.

Number of microorganisms was determined by weighing out a 1-g soil sample into 99 ml of sterile distilled water and shaking the flask vigorously. One ml of this suspension was diluted as needed and a 1.0-ml aliquot of appropriate dilution was added to a plate and appropriate, cooled agar poured onto it. Plates were incubated at 30 C for 3 to 5 days. For **proteolytic organisms**, colonies surrounded with clear areas on skim milk were counted. **Chitinolytic organisms** were determined by omitting glucose from soil extract agar and adding 5 to 10 ml of precipitated chitin suspension to the media. Colonies with clear zones around them were counted. The number of **cellulolytic organisms** was determined by counting clear zones around colonies grown on soil extract agar to which 50 ml of sterile heavy cellulose suspension was added and in which glucose was omitted.

^{15}N STUDIES

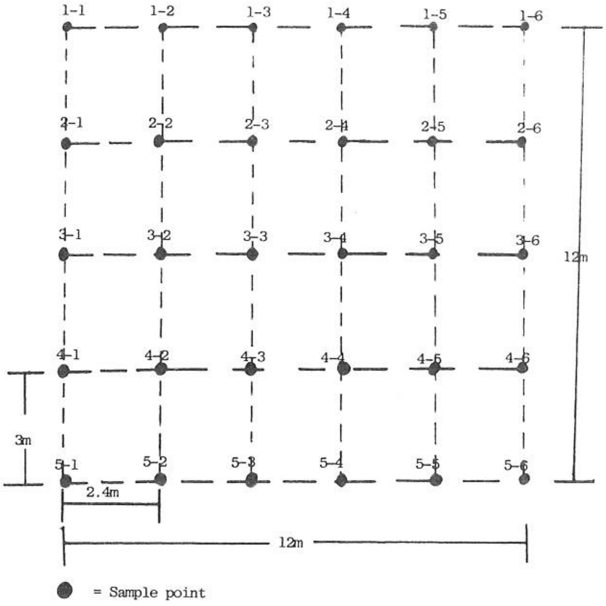
The procedures using exogenously supplied $(^{15}NH_4)_2SO_4$ have been previously described (Skujins and West 1974), except that the experimental time period was shortened from 5 to 3 weeks, and that all soils were allowed to air-dry after wetting rather than being maintained at a constant water tension of —1 or —15 bars. In addition, the effect of 2-chloro-6 (trichloromethyl) pyridine (N-Serve, Dow Chemical Co.) on nitrogen fixation, nitrification and denitrification was studied in the laboratory. In all cases, N-Serve was applied to the soil at a rate of 7 μg/g soil.

ACETYLENE REDUCTION STUDIES

Diurnal in situ nitrogen fixation was measured at the *Artemisia*, *Ceratoides*, and *Atriplex* sites on the west side of Curlew Valley. The exact location of each site and the description of vegetative cover have been previously described by Skujins and West (1973), except that two duplicate soil cores were employed, one set at field moisture, while the other set was wetted with 1.0 ml of distilled water prior to the injection of acetylene.

In situ diurnal nitrogen fixation was also measured at the other US/IBP Desert Biome sites at Jornada, Silverbell, Rock Valley and Pine Valley. In all cases, each sampling station (12-m^2 plot) had, within its boundaries, the principal vegetative forms of the area. The procedure for setting up the experimental system and the method of sampling and storage of the ethylene gas sample have been previously described (Skujins and West 1973). Two duplicate soil cores were employed, one set at field moisture conditions, and the other set wetted with 1.0 ml of distilled water.

In a more detailed study, a grid of 30 samples was used with formaldehyde-treated and nonmoistened soil core controls at the Pine Valley site on May 14-15, 1976. The grid used is illustrated below.



	Time	Number of samples Wet	Field moisture	Formal-dehyde
Dark fixation	2000 - 0600	30	1	1
Sunrise fixation	0600 - 0800	30	1	1
	0800 - 1000	30	1	1
	1000 - 1200	30	1	1
	1200 - 1400	30	1	1

RESULTS

Soil moisture content (Tables 2a and 2b) and water potential of the soils at each of the sampling periods, reported in Table 3, may be compared to the amount and occurrence of precipitation (Table 1). The values between moisture content and moisture tension correlate inversely since, in most cases, as moisture increases water tension decreases.

Another environmental factor affecting microbial activity during the year is temperature. Mean diurnal soil and air temperatures for each collection period at each site were measured and are given in Table 4.

The abiotic factors of moisture content, water tension and soil temperature are compared in Figure 5. Highest soil temperatures were during the summer sampling periods but March temperatures were higher for the southern sites.

Soil reaction (pH) values are given in Tables 5a and 5b. Soils from Jornada, Rock Valley and Pine Valley are slightly alkaline, whereas Silverbell soils tend towards neutrality.

Table 6 shows values obtained from chemical analysis of the soils. Given are percent nitrogen and percent carbon values from which C:N ratios are obtained. Electrical conductivity values indicate that salinity is relatively low; however, Jornada site playa surface samples appear to exhibit comparatively higher salinity throughout the year than other samples. Nitrate values indicate that NO_3^- levels are generally higher in surface samples but that there is a leaching effect as indicated by Silverbell August samples.

Texture analysis of these desert soils (Table 7) indicates that the samples are mostly sandy loam with the exceptions of playa and Curlew samples which are clay loam and silt loam, respectively. The bajada and Rock Valley samples have the greatest percentage of sand. This accounts for the lower net activity when values are adjusted for discard.

Microbial analysis of surface samples is reported in Table 8 with values given for number of aerobic bacteria (Fig. 6), fungi (Fig. 7), proteolytic organisms (Fig. 8), chitinolytic organisms (Fig. 9) and cellulolytic organisms (Fig. 10). Number of aerobic bacteria fell within 10^5 to 10^6 range for all sites during the year. Fungi ranged in numbers from 10^3 to 10^4. Numbers of chitinolytic and cellulolytic organisms tend to decrease from March to December for Jornada soils but the opposite was generally true for other soils.

Respiration values, measured as CO_2 release, are given Tables 9a and 9b. Dehydrogenase and proteolytic activities are given in Tables 10a, 10b, 11a and 11b, respectively. The results of these biochemical activities are compared in Figure 11. Proteolytic activity increased markedly throughout the year in Silverbell soils but stayed generally the same for other soils except for Pine Valley which had a significant increase in July.

ATP concentration in several samples for which analysis has been completed are given in Table 12. ATP concentration tends to correlate well with dehydrogenase activity. The greatest activity is found in August Silverbell samples where 5.4×10^{-1} μg/g was extracted. All samples have values of the magnitude 10^{-1} or 10^{-2}. Considering that the average ATP concentration of a bacterial cell is 5×10^{-10} μg, these high concentrations of ATP are probably contributed by algal or fungal cells which, of course, contain much more ATP than bacteria due to their size.

Table 2a. Percent moisture content in 1975 (surface, 0-5 cm)

Sample	March	June	July	August	December
Jornada					
P	12.0	5.2	-	10.5	7.8
B-1	0.8	1.0	-	1.5	2.2
B-2	0.8	0.9	-	1.4	3.1
B-3	1.4	0.9	-	1.4	1.9
Silverbell					
S	3.1	0.8	-	10.3	6.3
Rock Valley					
RV	4.3	-	1.2	-	2.3
Pine Valley					
PV	10.3	-	7.2	-	2.1
Curlew Valley					
5	-	5.1	-	-	-
6	-	3.0	-	-	-
7	-	5.1	-	-	-

Table 2b. Percent moisture content at Rock Valley in 1974

Sampling Station	15I	24I	30I	18II	25III	19IV	22V	25VI	23VII	9IX
Ambrosia	5.3	3.4	3.5	3.5	2.0	1.7	0.9	1.2	16.3	1.1
Bare	3.0	2.5	1.8	4.0	2.2	1.4	1.3	1.4	14.3	1.0
Krameria	3.6	4.1	3.1	2.5	2.4	1.3	1.0	0.9	12.0	1.0
Larrea	4.3	3.3	2.0	2.4	1.0	0.9	1.0	0.9	13.8	1.0

Table 3. Water potential (—bars) in 1975 (surface, 0-5 cm)

Sample	March	June	July	August	December
Jornada					
P	145	329	-	176	180
B-1	252	300	-	214	298
B-2	246	295	-	249	254
B-3	267	300	-	276	271
Silverbell					
S	80	329	-	24	161
Rock Valley					
RV	16	-	316	-	232
Pine Valley					
PV	6	-	118	-	257
Curlew Valley					
5	-	64	-	-	-
6	-	212	-	-	-
7	-	189	-	-	-

Table 4. Collection period mean diurnal temperatures in 1975 (° C)

Sample	March Air	March Soil	June Air	June Soil	July Air	July Soil	August Air	August Soil	December Air	December Soil
Jornada										
P	6	7	29	32	-	-	24	25	0	0
B-1	9	13	30	36	-	-	29	29	-2	-1
B-2	10	13	31	35	-	-	28	31	-1	-1
B-3	11	14	33	36	-	-	28	28	-3	-3
Silverbell										
S	21	22	31	35	-	-	32	34	8	10
Rock Valley										
RV	14	16	-	-	29	30	-	-	3	4
Pine Valley										
PV	3	3	-	-	29	20	-	-	7	6

Table 5a. pH values of samples studied (1975)

Sample		March	June	July	August	December
Jornada						
P	(1)	7.6	7.7	-	7.3	8.1
	(2)	7.6	-	-	-	8.0
	(3)	7.7	-	-	-	-
	(4)	7.5	-	-	-	-
B-1	(1)	7.5	7.7	-	6.5	8.1
	(2)	8.3	-	-	6.3	8.2
	(3)	8.5	-	-	6.8	-
	(4)	8.6	-	-	-	-
B-2	(1)	7.8	8.1	-	7.4	8.0
	(2)	8.2	-	-	7.9	8.1
	(3)	7.4	-	-	8.1	-
	(4)	8.0	-	-	7.9	-
B-3	(1)	7.5	8.2	-	7.9	7.8
	(2)	7.9	-	-	8.0	8.1
	(3)	8.2	-	-	8.2	-
	(4)	8.1	-	-	8.2	-
Silverbell						
S	(1)	7.6	6.5	-	7.7	7.7
	(2)	7.5	-	-	7.2	7.8
	(3)	7.8	-	-	7.6	-
	(4)	-	-	-	7.5	-
Rock Valley						
RV	(1)	8.3	-	8.2	-	8.1
	(2)	8.1	-	-	-	8.3
	(3)	8.3	-	-	-	-
	(4)	8.2	-	-	-	-
Pine Valley						
PV	(1)	8.1	-	8.4	-	8.3
	(2)	8.3	-	8.5	-	8.7
	(3)	8.3	-	8.4	-	-
	(4)	8.3	-	9.3	-	-

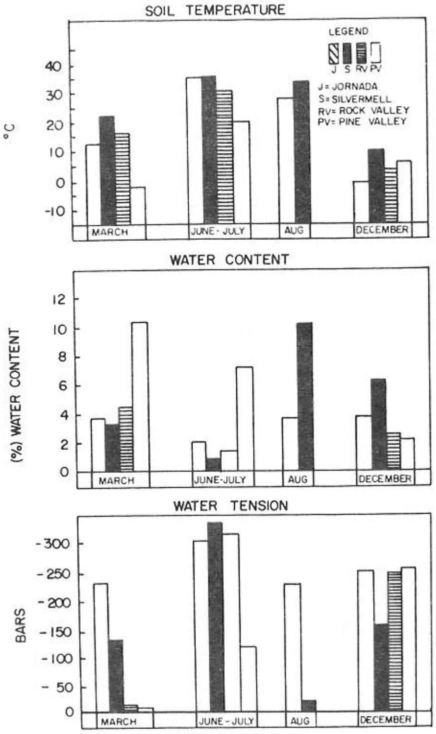


Figure 5. Comparison of soil temperature, moisture content and water tension at the several sampling stations.

Table 5b. pH values at Rock Valley (1974)

Sampling Station	15I	24I	30I	18II	25III	19IV	22V	25VI	23VII	9IX
Ambrosia	8.2	8.9	8.8	8.5	8.4	8.6	8.6	8.4	8.5	8.5
Bare	8.2	8.7	8.7	8.5	8.5	8.5	8.7	8.5	8.2	8.5
Krameria	8.2	8.8	8.7	8.5	8.5	8.4	8.3	8.4	8.5	8.3
Larrea	8.2	8.7	8.8	8.6	8.4	8.4	8.3	8.5	8.5	8.4

Table 6. Chemical analysis

Sample	Total N %	Org. C %	C:N Ratio	NO_3^- µg/g	ECe mmhos/cm
March 1975					
Jornada					
P (1)	0.17	1.53	9.0	11.0	0.7
(2)	0.10	0.88	8.8	4.7	0.4
(3)	0.07	0.62	8.8	2.9	0.4
(4)	0.06	0.46	7.7	2.0	0.4
B-1 (1)	0.04	0.24	6.0	0.8	0.5
(2)	0.05	0.31	6.2	0.5	0.4
(3)	0.03	0.19	6.3	0.2	0.4
(4)	0.03	0.21	7.0	0.2	0.4
B-2 (1)	0.04	0.30	7.5	0.4	0.5
(2)	0.05	0.38	7.6	0.4	0.5
(3)	0.05	0.24	4.8	0.3	1.2
(4)	0.04	0.17	4.3	0.2	---
B-3 (1)	0.05	0.40	8.0	0.6	9.5
(2)	0.05	0.39	7.8	0.5	0.4
(3)	0.04	0.33	8.3	0.3	0.4
(4)	0.05	0.26	5.2	0.2	0.5
Silverbell					
S (1)	0.08	0.58	7.3	1.9	0.4
(2)	0.06	0.31	5.2	3.7	0.6
(3)	0.06	0.38	6.3	7.9	0.6
Rock Valley					
RV (1)	0.04	0.23	5.8	0.6	0.3
(2)	0.03	0.22	7.3	0.3	0.4
(3)	0.04	0.30	7.5	0.6	0.5
(4)	0.04	0.27	6.8	1.1	0.4
Pine Valley					
PV (1)	0.05	0.41	8.2	2.4	0.5
(2)	0.05	0.39	7.8	2.7	0.4
(3)	0.06	0.40	6.7	4.4	0.5
(4)	0.05	0.39	7.8	1.2	0.6
June 1975					
Jornada					
P (1)	0.16	1.36	8.5	14.9	0.9
(2)	0.11	1.14	10.3	4.9	0.5
B-1 (1)	0.04	0.40	10.0	0.9	0.5
(2)	0.04	0.41	10.3	0.2	0.3
B-2 (1)	0.04	0.41	10.3	0.8	0.4
(2)	0.04	0.42	10.5	0.2	0.3
B-3 (1)	0.05	0.46	9.2	1.2	0.4
(2)	0.06	0.56	9.3	0.5	0.5
Silverbell					
S (1)	0.05	0.52	10.4	2.0	0.4
(2)	0.04	0.36	9.0	1.0	0.4
July 1975					
Rock Valley					
RV (1)	0.03	0.36	12.0	0.4	0.2
(2)	0.03	0.32	10.7	0.3	0.2
Pine Valley					
PV (1)	0.05	0.48	9.6	1.1	0.4
(2)	0.05	0.46	9.2	0.8	0.5
(3)	0.05	0.40	8.0	0.6	0.5
August 1975					
Jornada					
P (1)	0.13	1.22	9.4	9.8	0.6
B-1 (1)	0.03	0.30	10.0	0.9	0.3
(2)	0.04	0.30	7.5	0.4	0.3
(3)	0.03	0.28	9.3	0.5	0.3
B-2 (1)	0.05	0.41	8.2	1.1	0.3
(2)	0.04	0.38	9.5	0.6	0.3
(3)	0.04	0.33	8.3	0.6	0.3
(4)	0.03	0.32	10.7	0.1	0.4
B-3 (1)	0.04	0.34	8.5	1.2	0.3
(2)	0.04	0.28	7.0	0.8	0.2
(3)	0.04	0.28	7.0	0.8	0.3
(4)	0.03	0.35	11.7	0.6	0.2
Silverbell					
S (1)	0.10	0.97	9.7	4.8	0.6
(2)	0.05	0.47	9.4	23.3	0.4
(3)	0.05	0.32	6.4	3.4	0.6
(4)	0.04	0.32	8.0	3.1	0.4
December 1975					
Jornada					
P (1)	0.10	0.32		3.6	0.6
(2)	0.07	0.48		3.6	0.6

Table 6, continued

Sample	Total N %	Org. C %	C:N Ratio	NO_3^- µg/g	ECe mmhos/cm
December 1975					
Jornada					
B-1 (1)	0.04	0.30		0.9	0.4
(2)	0.03	0.29		1.1	0.4
B-2 (1)	0.04	0.35		1.6	0.4
(2)	0.04	0.30		0.4	0.4
B-3 (1)	0.04	0.21		0.5	0.4
(2)	0.04	0.37		0.4	0.4
Silverbell					
S (1)	0.12	1.14		18.3	0.9
(2)	0.05	0.39		2.3	0.5
Rock Valley					
RV	.04	.3	7.5	1.6	.3
Pine Valley					
PV	.06	.6	10.0	1.8	.4

Table 7. Texture analysis

	Mechanical Analysis (hydrometer)			Soil Type
P	21	47	32	Clay Loam
B-1	77	11	12	Sandy Loam
B-2	73	14	13	Sandy Loam
B-3	73	15	12	Sandy Loam
S	62	28	10	Sandy Loam
RV	70	24	6	Sandy Loam
PV	23	28	6	Sandy Loam
Curlew 5	32	55	13	Silt Loam
Curlew 6	38	51	11	Silt Loam
Curlew 7	26	61	13	Silt Loam

Table 8. Microbial numbers of organisms per g of soil (surface, 0-5 cm)

Sample	Aerobic Bacteria	Fungi	Proteolytic Organisms	Chitinolytic Organisms	Cellulolytic Organisms
March 1975					
Jornada					
P	8.5×10^6	1.3×10^5	1.8×10^7	1.1×10^7	1.3×10^4
B-1	4.8×10^5	1.0×10^4	1.7×10^5	1.2×10^5	4.8×10^4
B-2	2.5×10^5	6.0×10^3	8.7×10^4	3.6×10^4	1.0×10^5
B-3	2.1×10^6	9.2×10^3	1.4×10^5	1.8×10^4	1.1×10^5
Silverbell					
S	3.1×10^6	1.3×10^4	2.7×10^5	1.3×10^4	1.1×10^4
Rock Valley					
RV	7.8×10^5	5.1×10^3	4.0×10^5	5.1×10^3	1.5×10^4
Pine Valley					
PV	8.9×10^5	4.5×10^3	2.4×10^5	4.5×10^3	3.2×10^5
June 1975					
Jornada					
P	4.5×10^7	2.4×10^4	2.1×10^6	2.5×10^6	4.1×10^6
B-1	1.9×10^6	1.1×10^4	3.2×10^6	8.9×10^4	1.4×10^6
B-2	6.7×10^5	7.3×10^3	2.3×10^4	7.9×10^4	1.1×10^5
B-3	2.2×10^6	5.0×10^3	8.8×10^4	1.4×10^5	2.0×10^6
Silverbell					
S	2.7×10^6	9.4×10^3	9.0×10^4	3.5×10^5	1.7×10^6
Curlew Valley					
5	-	-	1.9×10^6	5.6×10^5	5.9×10^5
6	-	-	1.9×10^6	2.6×10^5	3.9×10^4
7	-	-	1.2×10^6	3.4×10^5	7.5×10^5
July 1975					
Rock Valley					
RV	8.2×10^5	4.4×10^3	1.3×10^5	4.8×10^4	4.3×10^5
Pine Valley					
PV	8.0×10^5	2.9×10^3	1.7×10^5	1.1×10^5	5.3×10^5
August 1975					
Jornada					
P	1.1×10^7	5.8×10^4	1.2×10^6	4.2×10^5	8.2×10^5
B-1	8.5×10^5	1.7×10^4	9.4×10^4	1.9×10^4	4.2×10^5
B-2	6.5×10^5	4.4×10^3	1.5×10^4	1.6×10^3	1.5×10^5
B-3	9.0×10^5	1.8×10^4	6.4×10^4	2.3×10^4	1.4×10^5
Silverbell					
S	2.1×10^5	1.6×10^4	2.2×10^5	8.4×10^4	6.1×10^5
December 1975					
Jornada					
P	4.6×10^6	1.1×10^5	1.4×10^6	4.9×10^5	2.1×10^5
B-1	5.4×10^5	2.5×10^4	1.6×10^5	1.1×10^5	1.1×10^5
B-2	3.2×10^5	6.9×10^3	9.8×10^4	1.1×10^5	7.3×10^4
B-3	3.1×10^5	1.2×10^4	6.3×10^4	6.5×10^4	1.1×10^5
Silverbell					
S	1.2×10^6	1.7×10^4	9.0×10^4	3.0×10^5	7.6×10^4
Rock Valley					
RV	3.0×10^5	4.4×10^3	1.2×10^5	1.6×10^5	6.4×10^4
Pine Valley					
PV	5.2×10^5	6.6×10^3	1.4×10^5	1.3×10^5	9.4×10^4

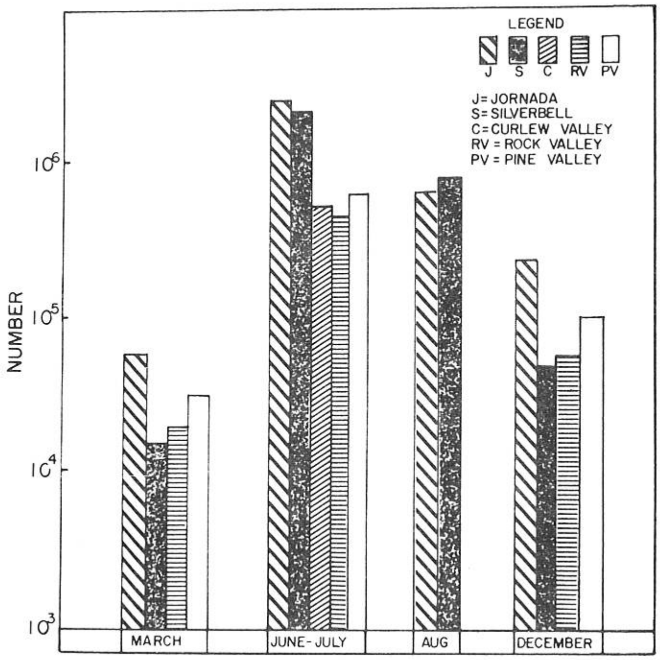


Figure 6. Comparison of aerobic bacterial count.

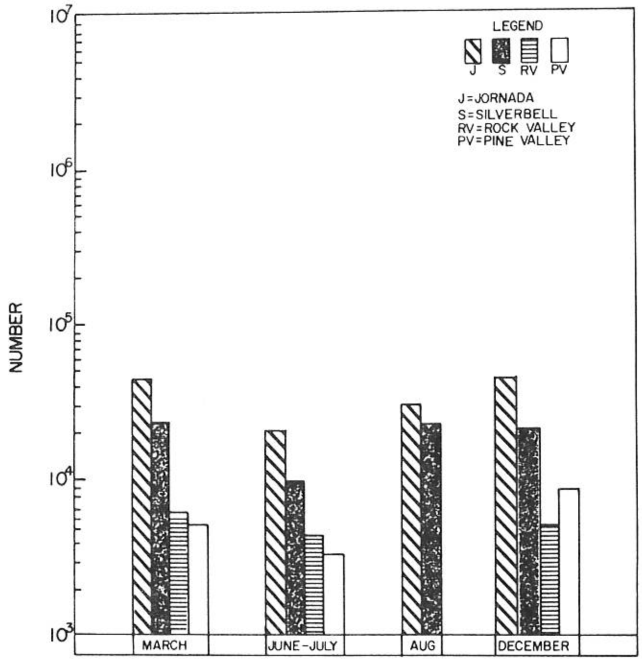


Figure 8. Comparison of the number of proteolytic organisms.

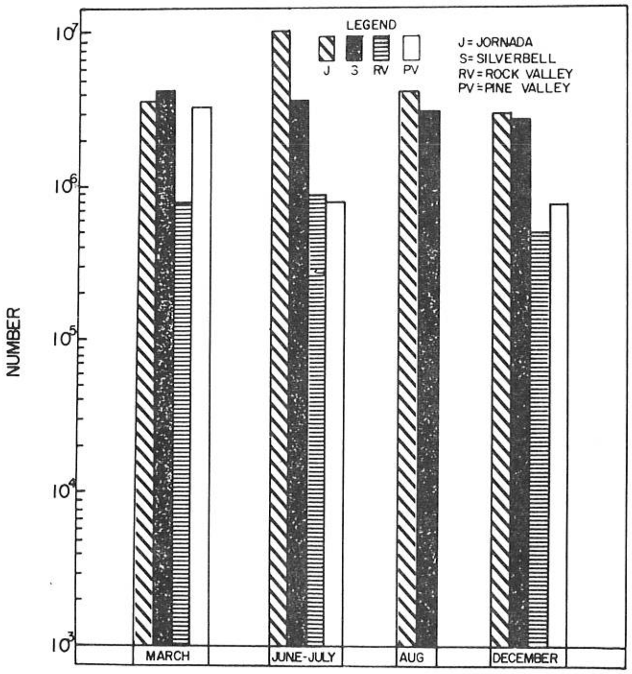


Figure 7. Comparison of fungal count.

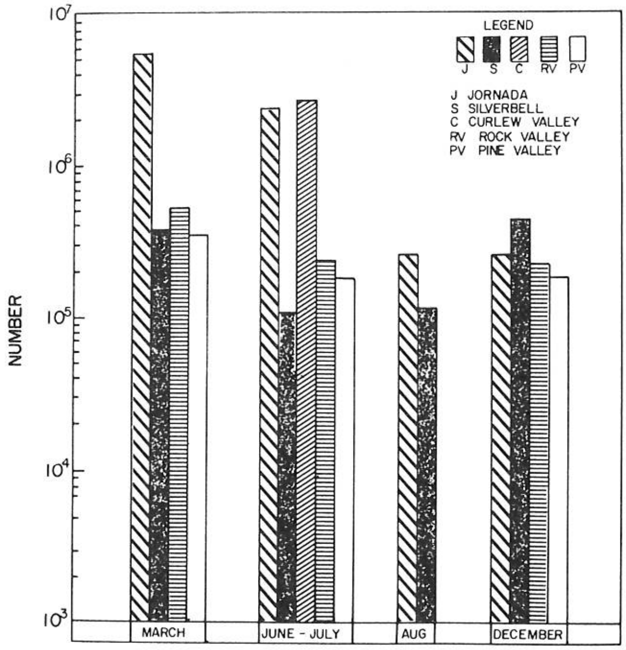


Figure 9. Comparison of the number of chitinolytic organisms.

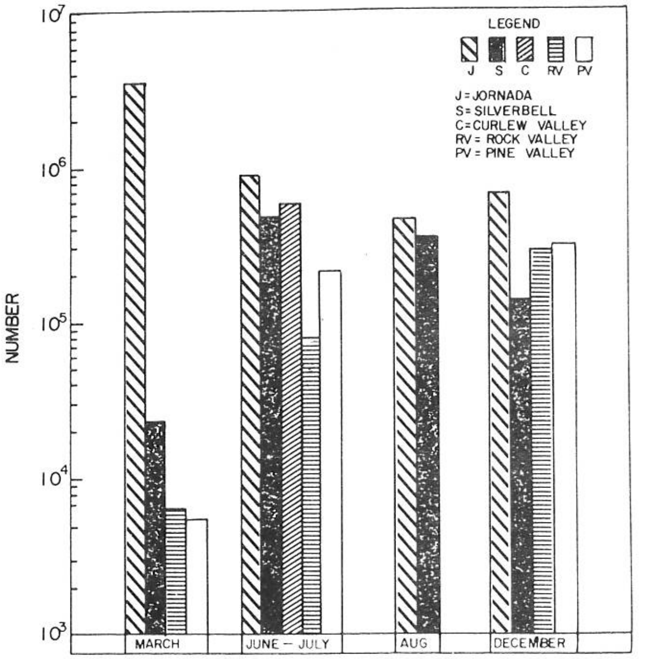


Figure 10. Comparison of the number of cellulolytic organisms.

Table 9a. Respiration in μ moles CO_2 evolved per g per min, 1975 (surface, 0-5 cm)

Sample	March	June	July	August	December
Jornada					
P	27.3	11.6	-	7.6	31.3
B-1	9.6	1.8	-	4.5	13.8
B-2	10.2	1.5	-	9.6	8.3
B-3	5.2	6.5	-	7.0	5.2
Silverbell					
S	7.1	4.0	-	9.0	13.7
Rock Valley					
RV	10.0	-	0.9	-	6.3
Pine Valley					
PV	16.3	-	4.2	-	2.8
Curlew Valley					
5	-	11.4	-	-	-
6	-	5.3	-	-	-
7	-	9.1	-	-	-

Table 9b. Respiration at Rock Valley, 1974, in μ moles CO_2 evolved per g per min

Sampling Station	15I	24I	30I	18II	25III	19IV	22V	25VI	23VII	9IX
Ambrosia	16.9	45.3	48.0	23.8	40.0	57.4	28.4	16.2	57.3	18.9
Bare	6.4	8.9	16.4	14.7	32.1	34.0	25.9	6.0	8.7	21.0
Krameria	25.6	48.6	60.7	20.3	44.5	48.0	38.4	16.0	36.9	20.4
Larrea	49.2	30.7	38.7	29.8	39.8	48.9	40.0	11.1	46.9	28.3

Table 10a. Dehydrogenase activity in mg formazan formed per g of soil, 1975 (surface, 0-5 cm)

Sample	March	June	July	August	December
Jornada					
P	.074	.059	-	.046	.049
B-1	.032	.037	-	.023	.026
B-2	.047	.035	-	.007	.009
B-3	.020	.049	-	.008	.010
Silverbell					
S	.070	.056	.009	.480	.067
Rock Valley					
RV	.036	-	.010	-	.045
Pine Valley					
PV	.056	-		-	.048

Table 10b. Dehydrogenase activity at Rock Valley, 1974, in mg formazan formed per g dry soil

Sampling Station	15I	24I	30I	18II	25III	19IV	22V	25VI	23VII	9IX
Ambrosia	1.478	.84	.77	1.04	.255	.488	1.160	1.27	1.05	.89
Bare	.593	.28	.15	.50	.061	.101	.162	.31	.37	.16
Krameria	1.271	.81	.84	1.24	.174	.111	.747	1.24	.84	.86
Larrea	1.463	.77	.90	1.33	.174	.182	.757	.67	1.39	2.57

Table 11a. Proteolytic activity in percent hydrolysis (surface, 0-5 cm)

Sample	March	June	July	August	December
Jornada					
P	6.5	3.5	-	4.4	6.1
B-1	3.0	3.9	-	3.9	7.4
B-2	6.1	3.3	-	2.8	2.8
B-3	6.5	5.2	-	4.8	10.4
Silverbell					
S	7.4	11.1	-	16.5	19.3
Rock Valley					
RV	8.1	-	9.4	-	9.7
Pine Valley					
PV	2.8	-	18.1	-	9.9

Table 12. ATP concentration in μg ATP per g dry soil

	March		June-July		August		December	
	*U/A		U/A		U/A		U/A	
P	.0140	.0140	.0189	.0187	.0123	.0121	.0240	.0240
B-1	.0436	.0415	.0298	.0292	.0380	.0353	.0351	.0315
B-2	.0294	.0277	.0229	.0213	.0505	.0404	.0358	.0261
B-3	.0236	.0217	.0329	.0312	.0266	.0234	.0359	.0298
S	.0461	.0429	.0239	.0222	.5452	.4743	1.174	.9864
RV	.0387	.0313	.0153	.0124			.0564	.0322
PV	.1365	.1214	.0123	.0103			.0539	.0377

*U - unadjusted for % removal of particles >5 mm.

A - adjusted for % removal of particles >5 mm.

Table 11b. Proteolytic activity at Rock Valley, 1974, in percent hydrolysis

Sampling Station	15I	24I	30I	18II	25III	19IV	22V	25VI	23VII	9IX
Ambrosia	34.5	42.0	31.0	29.5	25.0	30.0	31.0	23.0	34.5	25.0
Bare	14.0	12.0	4.0	14.0	7.5	7.5	12.0	1.0	12.0	0
Krameria	33.0	26.0	33.0	29.5	16.0	16.5	19.0	17.0	27.0	23.0
Larrea	39.0	19.0	27.0	23.5	20.0	20.0	21.0	23.0	42.5	31.0

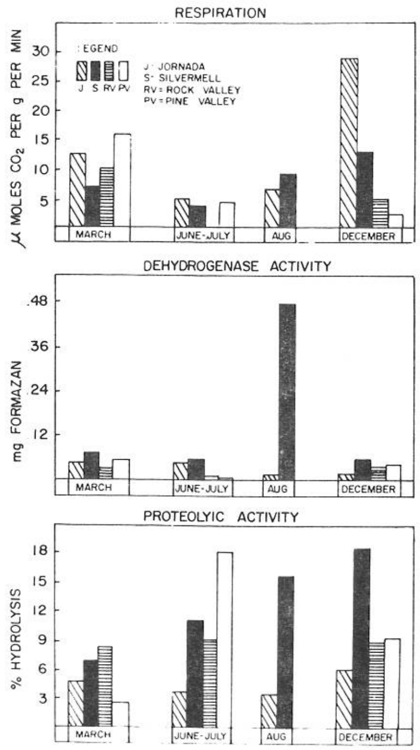


Figure 11. Comparison of respiration, dehydrogenase and proteolytic activities.

Table 13. Activity of samples below 5-cm depth in March 1975

Sample	Aerobic Bacteria #/g	Fungi #/g	Cellulolytic Organisms #/g	Chitinolytic Organisms #/g
Jornada				
P (2)	2.3×10^6	2.5×10^4	1.4×10^5	5.3×10^5
(3)	1.8×10^6	7.1×10^4	1.6×10^5	4.3×10^5
(4)	2.1×10^6	4.2×10^3	1.4×10^5	2.1×10^5
B-1 (2)	1.2×10^6	4.8×10^3	1.1×10^5	5.2×10^5
(3)	2.8×10^5	1.3×10^3	4.0×10^3	1.7×10^5
(4)	1.9×10^6	1.2×10^3	3.2×10^3	2.3×10^5
B-2 (2)	3.6×10^6	4.2×10^4	8.2×10^3	6.9×10^5
(3)	2.2×10^6	3.2×10^3	7.6×10^3	4.7×10^5
(4)	2.9×10^6	6.7×10^3	7.4×10^3	2.6×10^5
B-3 (2)	1.8×10^6	3.2×10^3	1.5×10^5	1.2×10^5
(3)	1.7×10^6	2.0×10^3	1.6×10^5	1.3×10^5
(4)	2.0×10^6	9.2×10^2	1.6×10^5	2.6×10^5
Silverbell				
S (2)	1.5×10^6	2.6×10^3	2.0×10^5	1.4×10^5
(3)	1.3×10^5	1.5×10^3	1.1×10^5	6.1×10^3
Rock Valley				
RV (2)	1.6×10^6	1.1×10^3	1.4×10^5	1.5×10^5
(3)	6.4×10^5	7.2×10^2	5.0×10^4	2.1×10^5
(4)	1.2×10^6	2.8×10^3	1.1×10^5	1.5×10^5
Pine Valley				
PV (2)	8.0×10^5	1.9×10^3	2.3×10^5	1.4×10^5
(3)	6.2×10^5	2.8×10^3	1.6×10^5	6.0×10^4
(4)	9.8×10^4	1.2×10^3	7.3×10^4	6.7×10^3

Sample	Proteolytic Organisms #/g	Proteolysis % Hydrolysis	Dehydrogenase mg formazan/g	Respiration µmoles CO_2/g/min
Jornada				
P (2)	4.9×10^5	1.0	.019	39.8
(3)	2.8×10^5	0	.007	29.1
(4)	7.4×10^4	39.2	.010	32.0
B-1 (2)	4.1×10^5	6.9	.011	14.1
(3)	6.1×10^4	3.0	0	14.9
(4)	6.9×10^4	48.0	0	6.3
B-2 (2)	4.1×10^5	7.4	.015	9.9
(3)	2.0×10^5	4.8	.002	10.2
(4)	3.3×10^5	3.0	0	9.7
B-3 (2)	1.6×10^5	6.9	.004	5.1
(3)	2.1×10^5	15.0	0	7.3
(4)	1.6×10^5	0.9	0	8.9
Silverbell				
S (2)	4.0×10^5	2.5	.005	6.7
(3)	4.6×10^4	0.6	.003	5.7
Rock Valley				
RV (2)	8.9×10^4	5.5	.004	9.1
(3)	4.1×10^5	1.2	.002	2.5
(4)	4.0×10^5	1.9	0	7.8
Pine Valley				
PV (2)	4.2×10^5	7.2	.005	9.8
(3)	3.1×10^5	5.7	.005	9.6
(4)	7.3×10^4	4.3	.001	2.4

Sample	Dehydrogenase mg formazan/g	Respiration µmoles CO_2/g/min	Proteolysis % hydrolysis
July 1975			
Pine Valley			
PV (2)	.001	4.6	6.1
(3)	.001	6.7	4.9
August 1975			
Jornada			
B-1 (2)	.011	0.6	3.8
(3)	.001	2.5	0
B-2 (2)	.013	6.8	2.4
(3)	.002	8.0	0.8
(4)	.003	6.4	2.7
B-3 (2)	.002	5.3	5.0
(3)	.001	9.8	5.9
(4)	.001	12.1	9.2
Silverbell			
S (2)	.004	5.7	3.6
(3)	.001	6.5	36.7
(4)	0	4.6	1.4
December 1975			
Jornada			
P (2)	.005	32.1	5.0
B-1 (2)	.004	4.0	2.2
B-2 (2)	.006	5.3	2.3
B-3 (2)	.002	8.8	5.5
Silverbell			
S (2)	.022	9.5	11.0
Rock Valley			
RV (2)	.001	0.8	0.9
Pine Valley			
PV (2)	.008	5.6	4.4

Biological analyses of samples below 5 cm which were collected in March, July, August and December are presented in Table 13. Activity generally decreases with depth.

Table 14 illustrates the data for both clay-fixed and exchangeable NH_4^+—N are in the highest concentrations in playa samples. August Silverbell samples have a significant increase in fixed ammonium-nitrogen but have little exchangeable. Nitrate values for this sample, however, are high, thus indicating an increased nitrifying activity.

Nitrification potentials for March, August and December samples are given in Tables 15a, 15b and 15c. The nitrification potential is greater in Silverbell August samples than in March samples. However, the greatest nitrification potential for Silverbell is found in December. Playa and Silverbell samples seem to have the greatest overall nitrification potential of all the desert sites.

Table 16 lists the amount of ethylene produced at the various desert sites. The Silverbell site has the greatest amount of ethylene produced, followed by Rock Valley, Jornada-playa, Pine Valley and Jornada-bajada. It should also be noted that although the Jornada-bajada site had the lowest acetylene-reducing activity at its field moisture, the wetted soil cores had a higher level of ethylene produced than did Jornada-playa or Pine Valley. It is observed that the wetted soil cores have a greater acetylene-reducing capacity than do the soil cores at field moisture. However, under both conditions, the maximum amount of ethylene production occurs shortly after sunrise (Figs. 12-16).

Table 17 lists the amount of ethylene produced in situ at Curlew Valley during the month of September 1975. Again, the wetted soil cores produced more ethylene than did the soil cores at field moisture. However, the maximum amount of acetylene reduced is observed to have occurred between the afternoon hours of 1200 and 1400 or 1500 hr (Figs. 17-19).

Table 18 compares the nitrogen fixation potentials (acetylene reduction) of Curlew Valley and Pine Valley from transect samples. It is observed that the mean of the nine Pine Valley transects is not significantly different from the means reported from the *Artemisia* and *Atriplex* transects of Curlew Valley. However, the *Ceratoides* transect mean is significantly different from the *Artemisia, Atriplex* and Pine Valley means. Thus, in general, the potential to fix nitrogen from both Curlew Valley and Pine Valley is apparently equal.

Table 19 illustrates the in situ, diurnal nitrogen fixation data at Pine Valley, employing the 30-sample grid experimental system. It is noted that a maximum occurs between 2030 to 0600 hr in the moistened soil cores.

EXOGENOUSLY SUPPLIED $(^{15}NH_4)_2SO_4$ AMENDMENTS TO SOILS

Tables 20 and 21 list the amount of ^{15}N volatilized ammonia from $(^{15}NH_4)_2SO_4$ amended soils maintained at either —1 bar or —15 bars water tension, respectively, during a 5-week incubation period. The amount of volatilized ammonia ranged from 9.835 to 12.641 μg ^{15}N for soils maintained at —1 bar tension, and 6.331 and 9.664 μg ^{15}N for soils at —15 bars tension. In all cases, the total loss of nitrogen through ammonia volatilization amounts to approximately 1% (0.69 to 1.39).

Tables 22 and 23 provide the data concerning the ^{15}N-labeled soil nitrogen fractions of the ammonium sulfate amended soils. For the soils maintained at —1 bar moisture tension, 74.74 to 78.31% of the applied $(^{15}NH_4)_2SO_4$ was lost, while soils maintained at —15 bars tension had lost 61.51 to 80.28% of the applied ^{15}N. Under both conditions the nitrate-nitrogen had the greatest atom percent ^{15}N enrichment (0.7542 to 1.9465), and the highest level of ^{15}N (63.9 to 190.7 μg ^{15}N). Organic nitrogen was second to nitrate-nitrogen in the amount of ^{15}N (41.175 to 118.563 μg ^{15}N), but was very low in the amount of ^{15}N enrichment (0.0545 to 0.1279 atom percent excess). Clay-fixed ammonium-nitrogen was the only other source of ^{15}N of importance with a range of 24.395 to 37.525 μg ^{15}N, or an atom percent excess of 9.3788 to 0.4376. However, it should also be noted that the *Ceratoides* soil at —1 bar moisture tension has a nitrite-nitrogen level of 32.9 μg ^{15}N (0.3609 atom percent excess).

Tables 24 and 25 report the ^{15}N ammonia volatilization losses from $(^{15}NH_4)_2SO_4$ amended, air-dried soils, and from $(^{15}NH_4)_2SO_4$ plus plant material amended soils maintained at —15 bars water tension. The extent of ammonia loss ranges from 0.025 to 2.35%. In both experimental conditions the *Atriplex* soils have the greatest loss, while the *Artemisia* soils have the least.

Tables 26 and 27 list the soil ^{15}N fractions for both the $(^{15}NH_4)_2SO_4$, air-dried soils and the $(^{15}NH_4)_2SO_4$ plus plant material-amended soils maintained at —15 bars water tension. Again, in both experimental systems, a high loss of applied $(^{15}NH_4)_2SO_4$ occurs (83 ± 1.5% for the air-dried soils, and 89.9 ± 0.20% for the soils at —15 bars tension). However, only in the ammonium sulfate treated soils does nitrate-nitrogen predominate (52.2 to 67.6 μg ^{15}N or 0.5220 to 0.6760 atom percent excess). In the ammonium sulfate plus plant material amended soils, the organic nitrogen fraction has the greatest level of ^{15}N (39.638 to 51.865 μg ^{15}N) but does have a low atom percent excess of ^{15}N (0.0351 to 0.0510). Nitrate-nitrogen levels range from 0.17 to 3.10 μg ^{15}N, or an atom percent excess of 0.0017 to 0.007. Clay-fixed ammonium-nitrogen has the highest atom percent excess level of ^{15}N (0.4572 to 0.4681) and trails organic nitrogen in the amount of ^{15}N present (33.193 to 40.701 μg ^{15}N).

Table 28 presents the data of volatilized $^{15}NH_3$ from an $(^{15}NH_4)_2SO_4$ amended, air-dried soil over a three-week incubation period. Again, volatilization losses are low (0.014 to 4.04% of the applied ^{15}N) with the greatest loss occurring in the *Atriplex* amended soil.

Table 29 and Figures 20 to 25 list and demonstrate the loss of nitrogen via ammonia volatilization from an air-dried, and $(^{15}NH_4)_2SO_4$ amended, air-dried soil. In all cases, the peak of volatilization occurred during the first week of incubation, and the percent loss of nitrogen is again low (0.044 to 0.515%), with the greatest losses from the *Atriplex* soils.

Table 30 gives the data concerning the soil fraction analysis of the unamended, air-dried soils at time zero and after three weeks. In all three of the soils tested, a net increase in organic nitrogen occurs.

Table 31 indicates such increases in organic nitrogen (10.823 to 17.503 mg N), and the percent increase (13.63 to 23.07%). In addition, with the exception of the *Artemisia* soil, the increase in nitrate-nitrogen is again high, with little or no nitrite-nitrogen (Table 30). In the *Artemisia* soil, nitrite-nitrogen is roughly two times greater than nitrate-nitrogen. Clay-fixed ammonium-nitrogen decreases, with the *Artemisia* soil again being the exception, with a slight increase in the clay fixation of ammonium ion. The soil pH either remains essentially constant or decreases.

Table 32 and Figures 26-30 present the data concerning the losses of nitrogen via ammonia volatilization from air-dried soils amended with either $(^{15}NH_4)_2SO_4$ plus plant material or $(^{15}NH_4)_2SO_4$ plus N-Serve. With the exception of the *Atriplex*, ammonia volatilization was greater in the N-Serve treated soils than in the plant material amended soils. The *Atriplex* soil amended with plant material volatilized 1.3 mg more ammonia than did its N-Serve treated counterpart. The overall percent loss of nitrogen by volatilization is low (0.055 to 2.433%) but is greater than the previously reported volatilization losses.

Tables 33 and 34 give the soil nitrogen fractions of the plant material and N-Serve treated soils for initial and fixed experimental time periods. In all cases, there is a net loss of nitrogen. Table 35 demonstrates that this represents a loss of 20.501 to 56.014 mg N, or a percent denitrification of 14.76 to 33.86. Nitrate again dominates over the level of nitrite, but there is an increase in clay-fixed ammonium in all cases. In addition, there is also a slight increase in exchangeable ammonium, as well as an increase in soil pH.

Table 36 gives the data concerning the soil nitrogen fraction analysis of the $(^{15}NH_4)_2SO_4$ amended, air-dried soils. It is again observed, with the exception of the *Atriplex* soil, that an increase in organic nitrogen occurs. This increase is equivalent to 9.37 to 9.937 mg N or 10.31 to 10.93% (Table 31). The *Atriplex* soil, however, has lost 4.475 mg N or a 5.09% decrease in nitrogen. The levels of nitrate-nitrogen are greater than the levels of nitrite-nitrogen, with the *Artemisia* soil having the highest level of nitrite. However, the level of nitrate-nitrogen in this soil is greater than the nitrite level by a factor of about two. Clay-fixed ammonium-nitrogen experiences some moderate fluctuations with a net loss of ammonium ion. The soil pH, in all three cases, again decreases with time.

Tables 31 and 35 are nitrogen balance sheets summarizing the previously described data. Initial and total nitrogen, milligrams N denitrified and percent denitrification, and milligrams N fixed and percent nitrogen fixation are all given.

Table 14. Fixed and exchangeable NH_4^+ in μg NH_4^+ per g dry soil*

Sample	March		June-July		August		December	
	Fixed	Exchange	Fixed	Exchange	Fixed	Exchange	Fixed	Exchange
P	98.3	2.6	102.4	4.3	73.3	3.2	75.7	2.9
B-1	13.7	0.8	13.8	0.9	11.7	1.5	12.8	0.7
B-2	20.0	0.9	11.6	1.5	21.4	2.0	20.2	1.5
B-3	17.9	0.9	15.9	1.8	12.3	2.0	12.4	0.9
S	40.3	2.1	23.2	3.2	75.4	1.3	56.4	2.4
RV	27.0	1.2	14.9	1.5			13.2	0.8
PV	18.7	0.8	22.9	0.9			23.6	0.9

*adjusted values for % discarded particles >5 mm.

Table 15a. Nitrification potential, March 1975, in mg N per g soil (surface, 0-5 cm)

	Jornada											
	P			B-1			B-2			B-3		
Day	NH_4^+	NO_2^-	NO_3^-	NH_4^+	NO_2^-	NO_3^-	NH_4^+	NO_2^-	NO_3^-	NH_4^+	NO_2^-	NO_3^-
2	1.155	.009	.011	1.611	0	.005	1.610	0	.004	1.466	0	0
4	-	.035	.035	-	0	0	-	.001	.006	-	.001	0
6	.868	.145	.043	1.391	0	.005	1.094	0	.002	1.340	.001	0
8	-	.366	.128	-	0	.002	-	0	.005	-	.001	.004
10	.636	.653	.231	1.552	.001	0	.933	.001	.008	1.180	.001	.002
12	-	.818	.258	-	.002	.002	-	0	0	-	.001	.004
14	-	1.050	.438	-	.006	.002	-	.022	0	-	.001	.016
16	.003	.904	.574	1.109	.007	.003	.870	.085	0	1.103	.002	.018
18	-	.485	.694	-	.010	0	-	.221	0	-	.002	.018
20	.001	.207	.685	1.011	.014	0	.527	.024	0	.201	.002	.010

	Silverbell			Rock Valley			Pine Valley		
	S-1			RV-1			PV-1		
Day	NH_4^+	NO_2^-	NO_3^-	NH_4^+	NO_2^-	NO_3^-	NH_4^+	NO_2^-	NO_3^-
2	1.528	.001	.004	1.226	.001	0	1.575	.001	0
4	-	0	0	-	.003	.001	-	.001	0
6	1.467	0	0	1.090	.012	.005	1.313	.002	.001
8	-	0	.003	-	.041	.015	-	.001	.014
10	1.362	0	.019	.966	.096	.002	1.175	.002	.004
12	-	0	.017	-	.245	.006	-	.003	0
14	-	0	.024	-	.540	.015	-	.003	0
16	1.132	0	.031	.358	.642	.009	.924	.010	.006
18	-	0	.033	-	.829	.015	-	.052	.017
20	.417	0	.039	.191	.723	.005	.315	.146	.012

Table 15b. Nitrification potential, August 1975, in μ g N per g dry soil*

	Playa			Bajada 1			Bajada 2			Bajada 3			Silverbell		
Day	NH_4^+	NO_2^-	NO_3^-	NH_4^+	NO_2^-	NO_3^-	NH_4^+	NO_2^-	NO_3^-	NH_4^+	NO_2^-	NO_3^-	NH_4^+	NO_2^-	NO_3^-
2	1086	1.9	3.6	1597	0.8	0.6	1261	0	0.5	1416	0.7	0	1847	0.7	2.3
4	--	8.0	13.8	--	2.0	0	--	0	0	--	1.2	0.6	--	2.3	6.9
6	892	14.4	12.2	1337	2.7	0.6	1247	0	0	1406	1.4	0	1889	5.8	32.6
8	--	78.0	49.3	--	3.8	3.3	--	0.3	0	--	1.9	7.7	--	6.6	65.3
10	1100	142.3	61.3	1046	5.8	4.7	1226	0.5	0	1278	0.6	5.5	1609	4.4	101.1
12	--	443.3	92.3	--	4.2	4.6	--	0.9	0	--	0.7	8.4	--	0.5	109.5
14	--	443.6	141.3	--	5.9	3.3	--	1.2	0	--	0.2	6.2	--	0.3	120.2
16	713	666.6	216.4	1664	9.1	12.7	904	1.5	0	1535	0	8.0	1397	0.4	165.9
18	--	959.1	239.8	--	8.6	12.2	--	1.2	1.8	--	0	18.4	--	0.4	139.4
20	119	613.2	369.6	1064	9.7	12.9	685	1.4	0	832	0.2	14.3	1108	0.5	143.4

*Average of duplicate samples - values adjusted for discarded particles >5 mm.

Table 15c. Nitrification potential, December 1975, in μ g N per g dry soil*

	Playa			Bajada 1			Bajada 2			Bajada 3		
Day	NH_4^+	NO_2^-	NO_3^-	NH_4^+	NO_2^-	NO_3^-	NH_4^+	NO_2^-	NO_3^-	NH_4^+	NO_2^-	NO_3^-
2	1330	3	0	1632	0.1	0	1387	0	0	1589	0.3	0
4	--	7	4	--	0.1	0.6	--	0.6	2.4	--	0.7	0
6	1350	38	11	1641	1.2	0.6	1281	1.1	0	1499	0.8	0
8	--	130	62	--	2.7	0.5	--	2.5	2.3	--	0.7	5.4
10	1742	198	61	1195	4.5	6.0	913	5.4	4.5	1193	0.5	5.1
12	--	419	91	--	9.1	5.4	--	11.9	5.3	--	0.5	2.5
14	--	--	--	--	--	--	--	--	--	--	--	--
16	450	712	146	1160	30.7	1.5	710	124.0	0	976	4.0	2.8
18	--	1003	215	--	45.4	1.5	--	191.0	0	--	11.2	8.3
20	403	1907	183	1399	59.0	8.8	613	346.0	5.7	1017	19.1	13.6

Table 15c, continued

Day	Silverbell NH_4^+	Silverbell NO_2^-	Silverbell NO_3^-	Rock Valley NH_4^+	Rock Valley NO_2^-	Rock Valley NO_3^-	Pine Valley NH_4^+	Pine Valley NO_2^-	Pine Valley NO_3^-
2	1697	0.2	0.6	921	0.3	0	1343	1.0	0
4	--	0.8	24.8	--	1.2	0	--	2.1	0.5
6	1621	5.1	28.9	881	1.1	0.7	1083	2.9	1.8
8	--	19.3	57.3	--	0.8	1.4	--	2.6	0
10	1173	28.5	75.3	418	0.5	0	756	1.9	4.3
12	--	32.7	98.9	--	0.4	0	--	2.0	4.2
14	--	--	--	--	--	--	--	--	--
16	1070	45.3	164.6	510	0	1.4	653	0.6	0
18	--	50.8	199.1	--	0.1	2.7	--	2.6	0
20	1290	62.5	232.0	474	0.3	3.8	70.9	1.8	1.0

*Average of duplicate samples - values adjusted for discarded particles >5 mm.

Table 16. In situ diurnal nitrogen fixation in nm C_2H_4 per 24 hr

Site		June	July	August	December	Total
Jornada-playa	1*	64.04	--	23.98	17.91	105.93
	2	71.21	--	42.69	12.73	126.63
Jornada-bajada	1-1	97.08	--	6.04	12.41	115.53
	1-2	83.84	--	48.30	7.38	139.52
	2-1	28.34	--	11.96	16.27	56.57
	2-2	36.71	--	33.85	16.21	86.77
	3-1	11.57	--	1.83	6.13	19.53
	3-2	84.29	--	34.03	17.33	135.65
Silverbell	1	83.57	--	71.63	11.99	167.19
	2	144.60	--	87.33	24.60	256.53
Rock Valley	1	--	116.16	--	5.24	121.40
	2	--	229.49	--	8.41	237.90
Pine Valley	1	--	66.42	--	16.15	82.57
	2	--	68.43	--	9.00	77.43

*1 = soil core at field moisture
2 = wetted soil

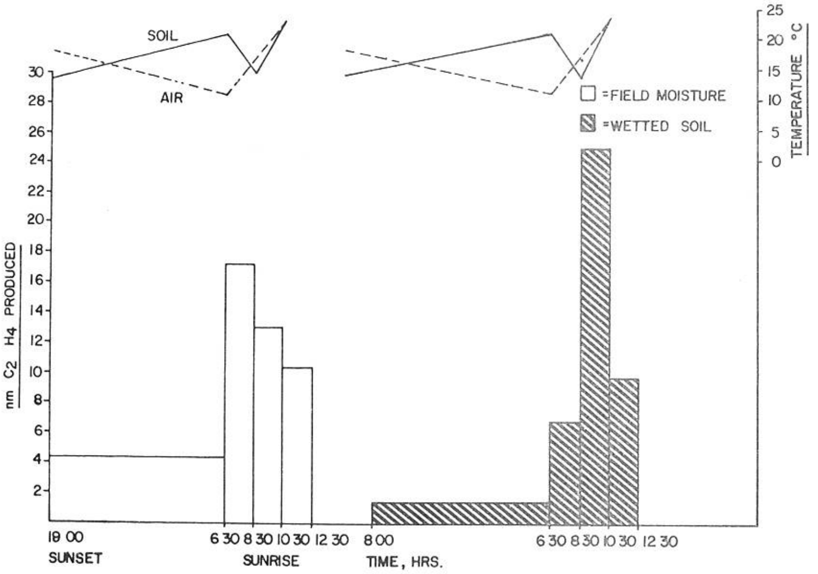


Figure 12. Average diurnal in situ N_2 fixation: Jornada, playa site.

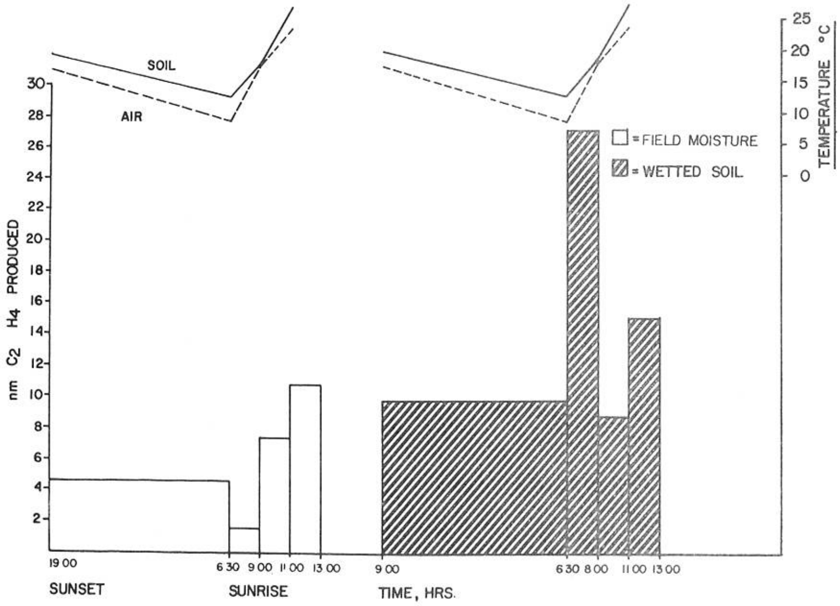


Figure 13. Average diurnal in situ N_2 fixation: Jornada, bajada site.

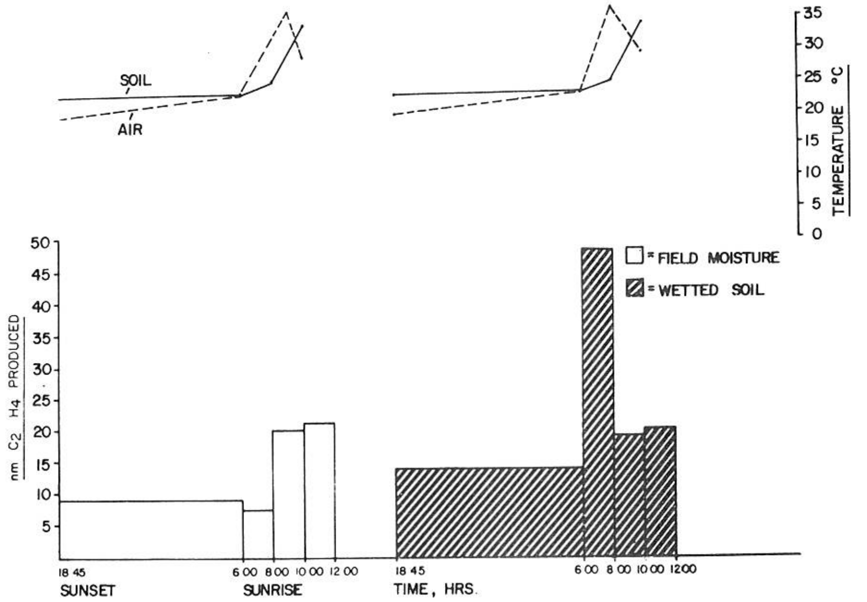


Figure 14. Average diurnal in situ N_2 fixation: Silverbell site.

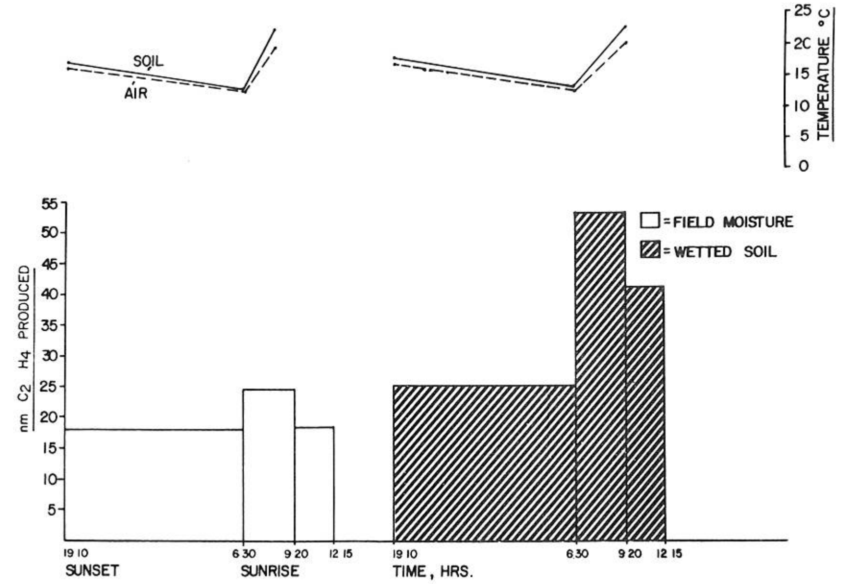


Figure 15. Average diurnal in situ N_2 fixation: Rock Valley site.

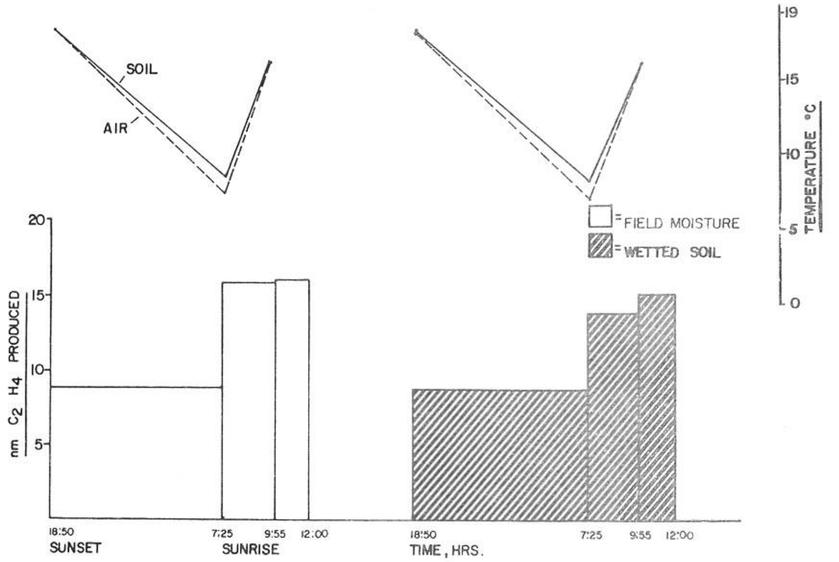


Figure 16. Average diurnal in situ N_2 fixation: Pine Valley site.

Table 17. In situ diurnal nitrogen fixation in Curlew Valley, September 19-20, 1975, in nm C_2H_4

Site		Morning Fixation 7 00 to 12 00 hrs	Afternoon Fixation 12 00 to 19 30 hrs	Night (Dark) Fixation 19 30 to 7 00 hrs	Total nm C_2H_4
Atriplex	1*	4.28	24.45	2.07	30.00
	2**	9.03	21.97	6.92	37.92
Ceratoides	1	12.42	9.9	5.29	27.61
	2	15.42	41.01	4.61	61.04
Artemisia	1	15.24	36.54	2.80	54.58
	2	13.59	59.91	2.7	76.20

*1 = soil cores at field moisture
**2 = wetted soil

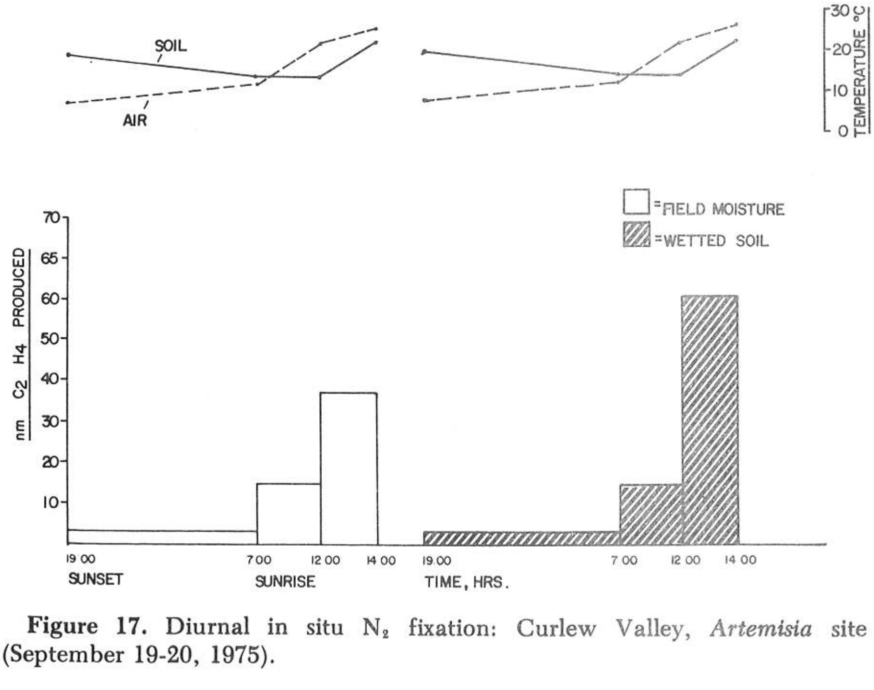


Figure 17. Diurnal in situ N_2 fixation: Curlew Valley, *Artemisia* site (September 19-20, 1975).

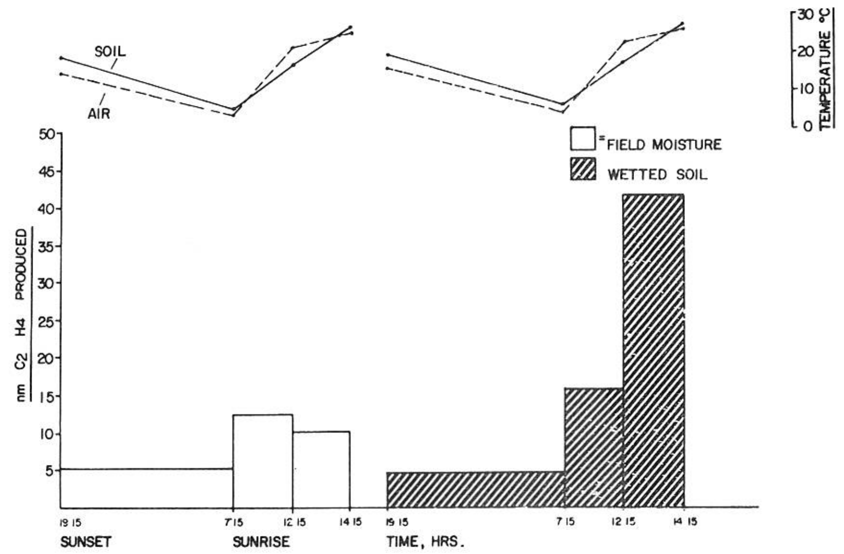


Figure 18. Diurnal in situ N_2 fixation: Curlew Valley, *Ceratoides* site (September 19-20, 1975).

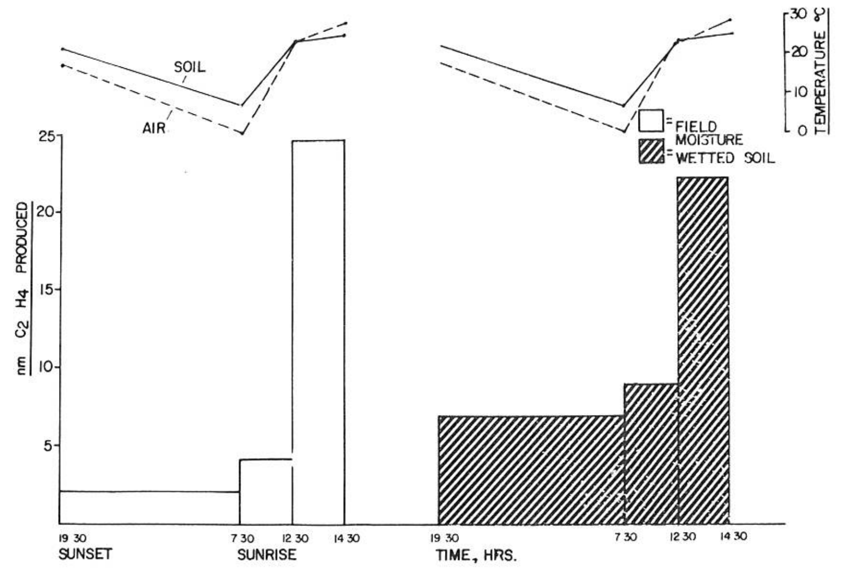


Figure 19. Diurnal in situ N_2 fixation: Curlew Valley, *Atriplex* site (September 19-20, 1975).

Table 18. Nitrogen fixation potential of Curlew Valley and Pine Valley soil cores in nm C_2H_4 produced per 24 hr

Curlew Valley*			Pine Valley	
Artemisia	Ceratoides	Atriplex	1	15.95
5.22	0.19	6.08	2	9.71
			3	4.45
			4	10.45
			5	5.22
			6	3.82
			7	1.01
			8	14.39
			9	3.51

*Mean of 15 cores. From Rychert (1975)

Ave. = 7.61

Table 19. nm C_2H_4 produced, Pine Valley site (average of 30 samples)

2030 - 0600 hr:	0.902	Wetted soil cores
	0.00	Field moisture control
	0.00	Formaldehyde control
0600 - 0800 hr:	0.00	Wetted soil cores
	0.00	Field moisture control
	0.00	Formaldehyde control
0800 - 1000 hr:	0.00	Wetted soil cores
	0.00	Field moisture control
	0.00	Formaldehyde control
1000 - 1200 hr:	0.00	Wetted soil cores
	0.00	Field moisture control
	0.00	Formaldehyde control
1200 - 1400 hr:	0.00	Wetted soil cores
	0.00	Field moisture control
	0.00	Formaldehyde control

Table 20. ^{15}N lost as volatilized NH_3 from $(^{15}NH_4)_2SO_4$ amended soils maintained at —1 bar. All values expressed as μg $^{15}NH_3$—^{15}N volatilized from 100 g of soil

Time	Artemisia	Ceratoides	Atriplex
24 hrs.	0.976	3.860	1.690
1 wk.	0.895	1.058	1.645
2 wks.	1.996	0.892	1.614
3 wks.	6.845	1.607	2.661
4 wks.	0.948	0.414	1.117
5 wks.	1.957	2.020	1.108
Total $^{15}NH_3$	12.641	9.851	9.835
% Volatilized	1.386	1.080	1.078

Table 21. ^{15}N lost as volatilized NH_3 from $(^{15}NH_4)_2SO_4$ amended soils maintained at — 15 bars. All values expressed as μg $^{15}NH_3$—^{15}N volatilized from 100 g of soil

Time	Artemisia	Ceratoides	Atriplex
24 hrs.	0.392	4.050	4.451
1 wk.	2.951	1.725	2.196
2 wks.	0.665	0.246	0.638
3 wks.	0.747	0.697	0.880
4 wks.	0.673	--	--
5 wks.	0.903	1.727	1.499
Total $^{15}NH_3$	6.331	8.445	9.664
% Volatilized	0.694	0.926	1.060

Table 22. Soil ^{15}N fractions from $(^{15}NH_4)_2SO_4$ amended soils maintained at —1 bar

Site	N Fraction	µg ^{15}N/100g soil	Atom % Excess ^{15}N	% Loss ^{15}N
Artemisia	Exchangeable $^{15}NH_4^+$	0.050	.0007	
	Fixed $^{15}NH_4^+$	36.460	.3788	
	Organic ^{15}N	70.090	.0752	
	$^{15}NO_2^-$	11.500	.0234	
	$^{15}NO_3^-$	99.600	.8369	
	$^{15}NH_3$	12.641	--	
	Total	230.341	--	74.74
Ceratoides	Exchangeable $^{15}NH_4^+$	0.000	.0000	
	Fixed $^{15}NH_4^+$	34.500	.4151	
	Organic ^{15}N	56.623	.0663	
	$^{15}NO_2^-$	32.900	.3609	
	$^{15}NO_3^-$	63.900	.7542	
	$^{15}NH_3$	9.851	--	
	Total	197.77	--	78.31
Atriplex	Exchangeable $^{15}NH_4^+$	0.010	.0001	
	Fixed $^{15}NH_4^+$	28.250	.4376	
	Organic ^{15}N	41.175	.0545	
	$^{15}NO_2^-$	0.000	.0000	
	$^{15}NO_3^-$	122.600	1.4476	
	$^{15}NH_3$	9.835	--	
	Total	201.870	--	77.86

Range: 76.97 ± 1.79

Table 23. Soil ^{15}N fractions from $(^{15}NH_4)_2SO_4$ amended soils maintained at —15 bars

Site	N Fraction	µg ^{15}N/100g soil	Atom % Excess ^{15}N	% Loss ^{15}N
Artemisia	Exchangeable $^{15}NH_4^+$	0.110	.0062	
	Fixed $^{15}NH_4^+$	37.525	.4181	
	Organic ^{15}N	63.389	.0594	
	$^{15}NO_2^-$	0.000	.0000	
	$^{15}NO_3^-$	72.500	.9159	
	$^{15}NH_3$	6.331	--	
	Total	179.855	--	80.28
Ceratoides	Exchangeable $^{15}NH_4^+$	0.010	.0001	
	Fixed $^{15}NH_4^+$	34.033	.3792	
	Organic ^{15}N	118.563	.1279	
	$^{15}NO_2^-$	0.000	.0000	
	$^{15}NO_3^-$	190.700	1.9465	
	$^{15}NH_3$	8.445	--	
	Total	351.051	--	61.51
Atriplex	Exchangeable $^{15}NH_4^+$	0.010	.0001	
	Fixed $^{15}NH_4^+$	24.395	.3941	
	Organic ^{15}N	58.241	.0775	
	$^{15}NO_2^-$	0.000	.0000	
	$^{15}NO_3^-$	94.600	.8868	
	$^{15}NH_3$	9.664	--	
	Total	186.910	--	79.50

Range: 73.63 ± 9.45

Table 24. ^{15}N lost as volatilized NH_3 from $(^{15}NH_4)_2SO_4$ amended, air-dried soils for five weeks. All values expressed as µg $^{15}NH_3$ volatilized from 100 g of soil

Time	Artemisia	Ceratoides	Atriplex
24 hrs	0.170	0.324	17.300
1 wk	0.019	7.822	2.921
2 wks	0.023	0.049	0.898
3 wks	0.006	0.087	0.111
4 wks	0.009	0.083	0.149
5 wks	0.004	0.018	0.064
Total	0.231	8.383	21.443
% Volatilized	0.025	0.919	2.35

Table 25. ^{15}N lost as volatilized NH_3 from $(^{15}NH_4)_2SO_4$ plus plant material amended soils maintained at —15 bars. All values expressed as µg $^{15}NH_3$ volatilized from 100 g of soil

Time	Artemisia	Ceratoides	Atriplex
24 hrs	0.232	0.258	7.572
1 wk	0.009	0.070	1.971
2 wks	0.008	0.022	0.035
3 wks	0.013	0.008	0.010
4 wks	0.004	0.007	0.040
5 wks	0.086	0.006	0.018
Total	0.352	0.371	9.646
% Volatilized	0.039	0.041	1.058

Table 26. Soil ^{15}N fractions from $(^{15}NH_4)_2SO_4$ amended, air-dried soils (five weeks)

Site	N Fraction	µg ^{15}N/100g soil	Atom % Excess ^{15}N	% Loss ^{15}N
Artemisia	Exchangeable $^{15}NH_4^+$	0.460	.0016	
	Fixed $^{15}NH_4^+$	24.40	.4253	
	Organic ^{15}N	45.347	.0526	
	$^{15}NO_2^-$	0.000	.0000	
	$^{15}NO_3^-$	67.600	.6760	
	$^{15}NH_3$	0.231	--	
	Total	138.038	--	84.86
Ceratoides	Exchangeable $^{15}NH_4^+$	0.200	.0010	
	Fixed $^{15}NH_4^+$	28.748	.4259	
	Organic ^{15}N	72.250	.0738	
	$^{15}NO_2^-$	0.000	.0000	
	$^{15}NO_3^-$	52.200	.5220	
	$^{15}NH_3$	8.383	--	
	Total	161.781	--	82.26
Atriplex	Exchangeable $^{15}NH_4^+$	6.500	.01430	
	Fixed $^{15}NH_4^+$	21.577	.3916	
	Organic ^{15}N	42.956	.0431	
	$^{15}NO_2^-$	8.110	.0811	
	$^{15}NO_3^-$	64.790	.6479	
	$^{15}NH_3$	21.443	--	
	Total	165.376	--	81.87

Range: 83.03 ± 1.50

Table 27. Soil ^{15}N fractions from $(^{15}NH_4)_2SO_4$ plus plant material amended soils maintained at —15 bars

Site	N Fraction	μg ^{15}N/100g soil	Atom % Excess ^{15}N	% Loss ^{15}N
Artemisia	Exchangeable $^{15}NH_4^+$	0.300	.0014	
	Fixed $^{15}NH_4^+$	40.701	.4681	
	Organic ^{15}N	51.865	.0510	
	$^{15}NO_2^-$	0.430	.0017	
	$^{15}NO_3^-$	0.170	.0012	
	$^{15}NH_3$	0.352	--	
	Total	93.818	--	89.71
Atriplex	Exchangeable $^{15}NH_4^+$	1.570	.0017	
	Fixed $^{15}NH_4^+$	33.193	.4572	
	Organic ^{15}N	39.638	.0351	
	$^{15}NO_2^-$	3.100	.0013	
	$^{15}NO_3^-$	3.100	.007	
	$^{15}NH_3$	9.646	--	
	Total	90.247	--	90.1

Range: 89.91 ± 0.20

Table 28. ^{15}N lost as volatilized NH_3 from $(^{15}NH_4)_2SO_4$ amended, air-dried soils for three weeks. All values expressed as μg $^{15}NH_3$ volatilized from 100 g of soil

Time	Artemisia	Ceratoides	Atriplex
1 wk	0.053	11.429	35.816
2 wks	0.039	0.059	0.272
3 wks	0.032	0.048	0.770
Total	0.124	11.536	36.858
% Volatilized	0.014	1.27	4.04

Table 29. Ammonia volatilization from treated and untreated $(^{15}NH_4)_2SO_4$ amended soils. All values expressed as μ g NH_3 volatilized from 100 g of soil

	Air-Dry (Control)		
Time	Artemisia	Ceratoides	Atriplex
1 wk	22.4	64.4	126.6
2 wks	1.4	7.0	42.0
3 wks	2.8	9.8	14.0
Total Volatilized	33.6	78.4	200.8
% Loss	0.044	0.099	0.265

	$(^{15}NH_4)_2SO_4$ - Air-Dry		
Time	Artemisia	Ceratoides	Atriplex
1 wk	49.5	178.5	287.7
2 wks	14.7	19.6	52.5
3 wks	13.3	25.9	112.0
Total Volatilized	77.5	224.0	452.2
% Loss	0.085	0.246	0.515

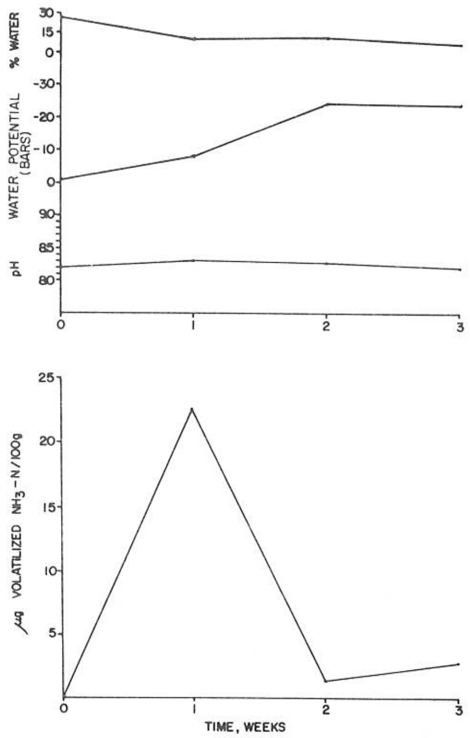


Figure 20. Ammonia volatilization from an air-dried *Artemisia* site surface soil.

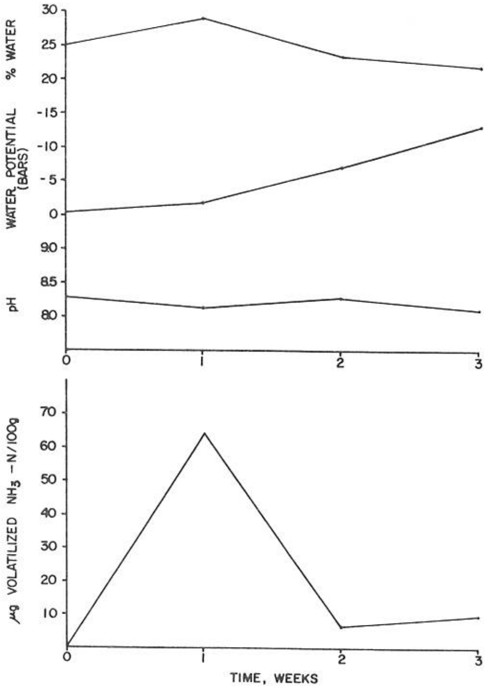


Figure 21. Ammonia volatilization from an air-dried *Ceratoides* site surface soil.

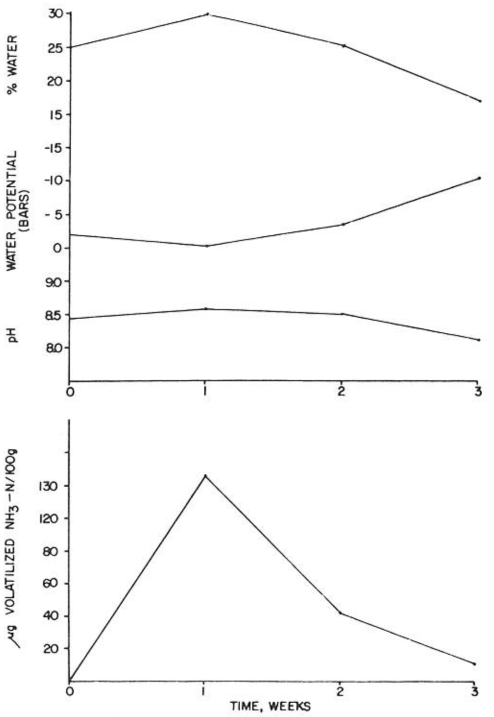


Figure 22. Ammonia volatilization from an air-dried *Atriplex* site surface soil.

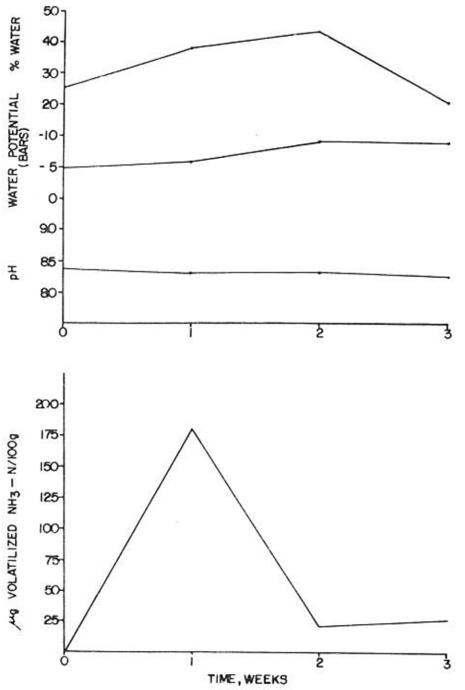


Figure 24. Ammonia volatilization from an $(^{15}NH_4)_2SO_4$ amended, air-dried *Ceratoides* site surface soil.

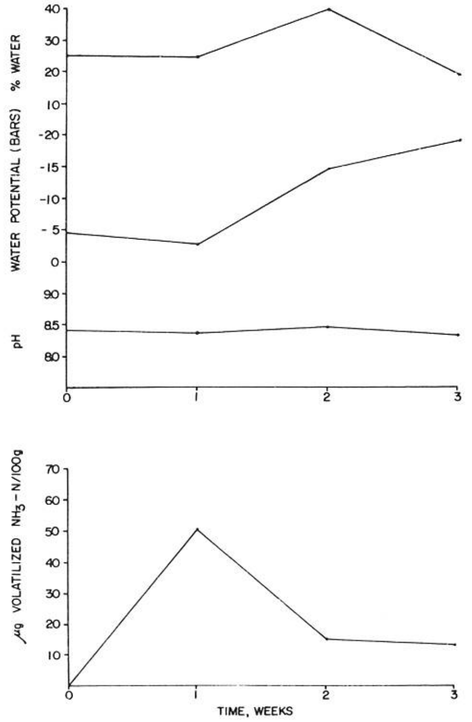


Figure 23. Ammonia volatilization from an $(^{15}NH_4)_2SO_4$ amended, air-dried *Artemisia* site surface soil.

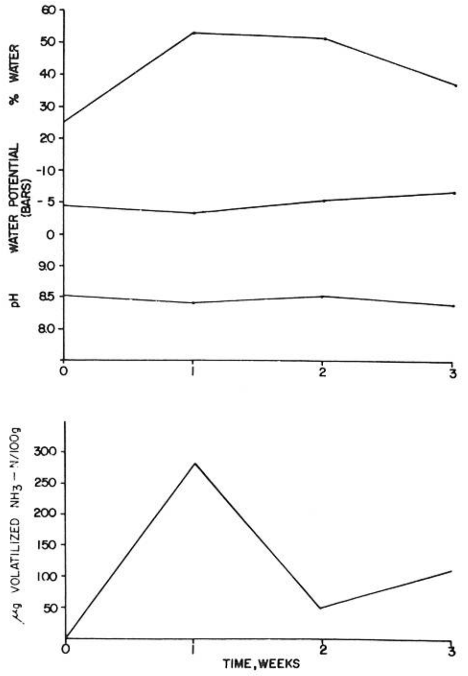


Figure 25. Ammonia volatilization from an $(^{15}NH_4)_2SO_4$ amended, air-dried *Atriplex* site surface soil.

Table 30. Soil analysis of organic N, total NH_4^+, NO_2^- and NO_3^- for untreated soils air-dried for three weeks. Values expressed as μg N per g soil

Fraction	Soil Sample (Time: 0) Artemisia	Ceratoides	Atriplex
Exchangeable NH_4^+	3.50	1.40	2.10
Fixed NH_4^+	71.63	73.03	65.45
Organic N	680.17	713.42	690.90
NO_2^- + NO_3^-	3.97	6.30	0.23
Total N/100g	75.927 mg	79.415 mg	75.868 mg
pH	8.20	8.29	8.42

Fraction	Soil Sample (Time: 3 weeks) Artemisia	Ceratoides	Atriplex
Exchangeable NH_4^+	14.35	8.40	4.90
Fixed NH_4^+	80.85	66.85	64.75
Organic N	758.80	775.25	821.45
NO_2^-	26.25	4.90	0.00
NO_3^-	17.15	46.20	40.60
NH_3 (volatilized)	33.60	78.40	200.80
Total N/100g	89.774 mg	90.238 mg	93.371 mg
pH	8.21	8.12	8.10

Table 32. Ammonia volatilization from $(^{15}NH_4)_2SO_4$ amended, air-dried soils treated with either fresh plant material or N-Serve. All values expressed as μg NH_3 volatilized from 100 g of soil

Time	$(^{15}NH_4)_2SO_4$ + Plant Material - Air-Dry Artemisia	Ceratoides	Atriplex
1 wk	47.6	452.9	2497.6
2 wks	7.0	31.5	391.3
3 wks	17.5	21.0	43.4
Total Volatilized	72.1	505.4	2932.3
% Loss	0.055	0.364	2.433

Time	$(^{15}NH_4)_2SO_4$ + N-Serve - Air-Dry Artemisia	Ceratoides	Atriplex
1 wk	110.6	395.5	810.6
2 wks	58.8	205.8	517.3
3 wks	35.7	179.2	298.8
Total Volatilized	205.1	780.5	1626.7
% Loss	0.132	0.468	1.219

Table 31. N balance sheet. All values expressed in mg N

	Air Dry			$(^{15}NH_4)_2SO_4$ - Air Dry		
	Art.	Cer.	Atp.	Art.	Cer.	Atp.
Initial Total N	75.927	79.415	75.868	90.781	90.903	87.868
Final Total N	89.774	90.238	93.371	100.151	100.840	83.393
mg of N Denitrified	--	--	--	--	--	4.475
% Denitrified	--	--	--	--	--	5.09
mg N_2 Fixed	13.847	10.823	17.503	9.37	9.937	--
% N_2 Fixed	18.24	13.63	23.07	10.31	10.93	--

Initial total N = total N + NO_2^- + NO_3^- + 3.0 mg $(^{15}NH_4)_2SO_4$. Plant material amendments include 1 g plant material per 100 g soil

Final total N = total N + NO_2^- + NO_3^- + volatilized NH_3 per 100 g soil

N_2 fixed = heterotrophic nitrogen fixation

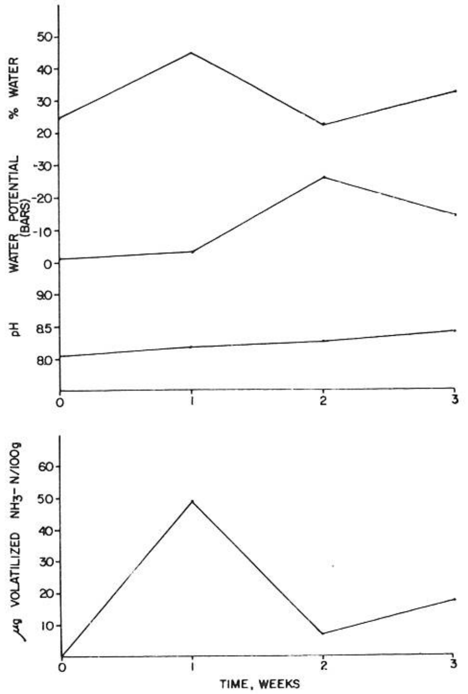


Figure 26. Ammonia volatilization from an $(^{15}NH_4)_2SO_4$ plant material amended, air-dried *Artemisia* site surface soil.

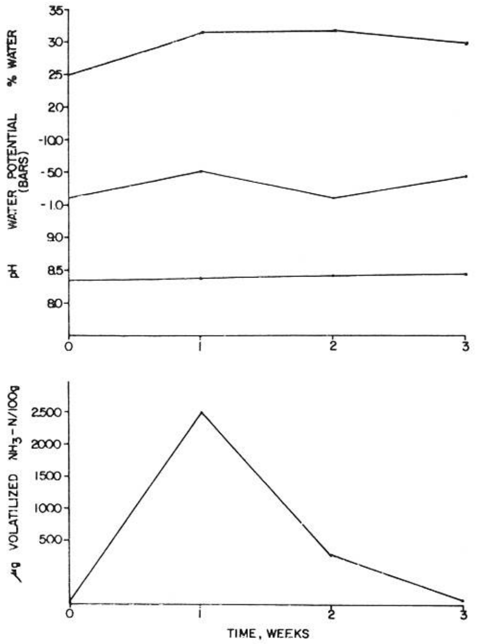


Figure 28. Ammonia volatilization from an $(^{15}NH_4)_2SO_4$ plant material amended, air-dried *Atriplex* site surface soil.

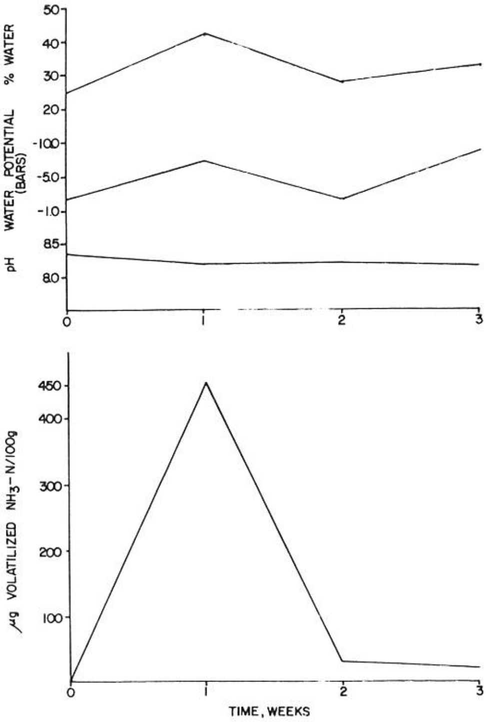


Figure 27. Ammonia volatilization from an $(^{15}NH_4)_2SO_4$ plant material amended, air-dried *Ceratoides* site surface soil.

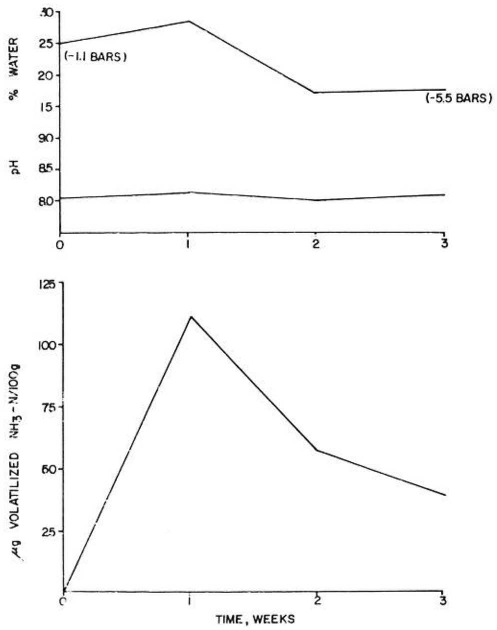


Figure 29. Ammonia volatilization from an $(^{15}NH_4)_2SO_4$ and N-Serve amended, air-dried *Artemisia* site surface soil.

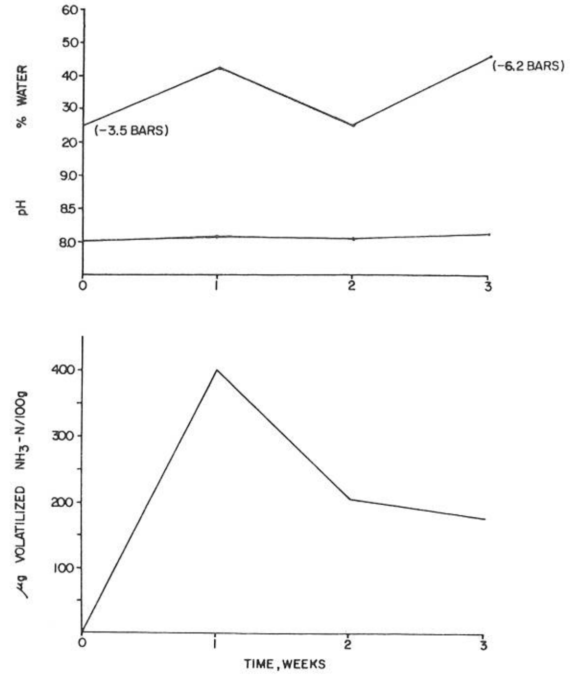


Figure 30. Ammonia volatilization from an $(^{15}NH_4)_2SO_4$ and N-Serve amended, air-dried *Ceratoides* site surface soil.

Table 33. Soil analysis of organic N, total NH_4^+, NO_2^- and NO_3^- for $(^{15}NH_4)_2SO_4$ plus plant material amended, air-dried soils. Values expressed as µg N per g soil

	Soil Sample (Time: 0)		
Fraction	Artemisia	Ceratoides	Atriplex
Exchangeable NH_4^+	4.79	3.15	2.69
Fixed NH_4^+	62.52	65.80	60.14
Organic N	1073.69	1149.58	974.75
NO_2^- + NO_3^-	14.59	10.50	7.47
*Total N/100g	132.38 mg	138.94 mg	120.545 mg
pH	8.03	8.11	8.33

	Soil Sample (Time: 3 weeks)		
Fraction	Artemisia	Ceratoides	Atriplex
Exchangeable NH_4^+	6.65	6.30	3.68
Fixed NH_4^+	77.44	84.18	70.35
Organic N	959.26	1030.93	835.98
NO_2^-	0.70	5.43	0.00
NO_3^-	2.10	52.50	40.78
NH_3 (volatilized)	72.10	505.40	2932.30
Total N/100g	104.687 mg	118.439 mg	98.011 mg
pH	8.37	8.16	8.43

*Total N includes 3.0 mg of added $(^{15}NH_4)_2SO_4$ + plant nitrogen (1% amendment)

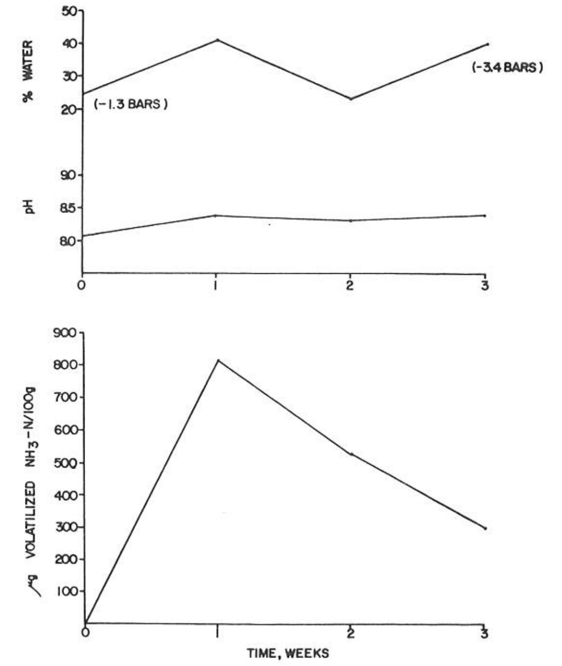


Figure 31. Ammonia volatilization from an $(^{15}NH_4)_2SO_4$ and N-Serve amended, air-dried *Atriplex* site surface soil.

Table 34. Soil analysis of organic N, total NH_4^+, NO_2^- and NO_3^- for $(^{15}NH_4)_2SO_4$ plus N-Serve amended soils. Values expressed as µg N per g soil

	Soil Sample (Time: 0)		
Fraction	Artemisia	Ceratoides	Atriplex
Exchangeable NH_4^+	6.07	4.90	3.27
Fixed NH_4^+	59.50	63.47	58.10
Organic N	1467.20	1585.73	1258.60
NO_2^- + NO_3^-	25.20	14.70	14.70
*Total N/100g	155.797 mg	166.880 mg	133.467 mg
pH	8.03	8.03	8.07

	Soil Sample (Time: 3 weeks)		
Fraction	Artemisia	Ceratoides	Atriplex
Exchangeable NH_4^+	8.40	10.50	12.08
Fixed NH_4^+	70.70	80.07	60.47
Organic N	898.43	971.95	792.40
NO_2^-	6.83	0.00	2.10
NO_3^-	44.10	38.33	29.05
NH_3 (volatilized)	205.10	780.50	1626.70
Total N/100g	103.051 mg	110.866 mg	91.237 mg
pH	8.10	8.13	8.40

*Total N includes 3.0 mg of added $(^{15}NH_4)_2SO_4$

Table 35. N balance sheet. All values expressed in mg N

	$(^{15}NH_4)_2SO_4$ + Plant Material			$(^{15}NH_4)_2SO_4$ + N-serve		
	Air Dry			Air Dry		
	Art.	Cer.	Atp.	Art.	Cer.	Atp.
Initial Total N	132.380	138.940	120.545	155.797	166.880	133.467
Final Total N	104.687	118.439	98.011	103.051	110.866	91.237
mg of N Denitrified	27.693	20.501	22.534	52.746	56.014	42.23
% Denitrified	20.92	14.76	18.69	33.86	33.57	31.64
mg N_2 Fixed	--	--	--	--	--	--
% N_2 Fixed	--	--	--	--	--	--

Initial total N = total N + NO_2^- + NO_3^- + 3.0 mg $(^{15}NH_4)_2SO_4$. Plant material amendments include 1 g plant material per 100 g soil

Final total N = total N + NO_2^- + NO_3^- + volatilized NH_3 per 100 g soil

N_2 fixed = heterotrophic nitrogen fixation

Table 36. Soil analysis of organic N, total NH_4^+, NO_2^- and NO_3^- for $(^{15}NH_4)_2SO_4$ amended soils air-dried for three weeks. Values expressed as μg N per g soil

Artemisia

	Time Period			
Fraction	Time 0	1 Week	2 Weeks	3 Weeks
Exchangeable NH_4^+	1.99	9.1	6.3	7.70
Fixed NH_4^+	68.72	59.95	64.0	63.40
Organic N	800.10	805.25	673.10	864.10
NO_2^-	---	0.00	0.00	13.13
NO_3^-	---	16.10	19.25	22.40
NO_2^- + NO_3^-	7.0	---	---	---
NH_3 (volatilized)	---	49.5	64.2	77.5
*Total N/100g	90.781 mg	92.090 mg	79.329 mg	100.151 mg
pH	8.40	8.35	8.45	8.30

Ceratoides

	Time Period			
Fraction	Time 0	1 Week	2 Weeks	3 Weeks
Exchangeable NH_4^+	0.70	4.20	4.20	8.23
Fixed NH_4^+	73.91	75.57	80.95	64.35
Organic N	796.37	858.80	837.45	852.65
NO_2^-	---	0.00	0.00	4.20
NO_3^-	---	19.95	30.45	46.73
NO_2^- + NO_3^-	8.05	---	---	---
NH_3 (volatilized)	---	178.5	198.1	224.0
*Total N/100g	90.903 mg	99.031 mg	98.503 mg	100.840 mg
pH	8.38	8.29	8.29	8.24

Atriplex

	Time Period			
Fraction	Time 0	1 Week	2 Weeks	3 Weeks
Exchangeable NH_4^+	1.05	9.10	5.95	4.20
Fixed NH_4^+	64.67	55.05	62.75	59.83
Organic N	775.37	778.65	776.40	706.15
NO_2^-	---	0.00	0.00	2.28
NO_3^-	---	5.60	20.65	26.95
NO_2^- + NO_3^-	7.59	---	---	---
NH_3 (volatilized)	---	287.7	340.2	452.2
*Total N/100g	87.868 mg	88.128 mg	89.915 mg	83.393 mg
pH	8.52	8.43	8.53	8.39

*Total N includes 3.0 mg of added $(^{15}NH_4)_2SO_4$

DISCUSSION

Four distinct deserts are found in the western United States; the Chihuahuan, Sonoran, Mohave and Great Basin. The southernmost deserts are the Sonoran and Chihuahuan, and they extend into Mexico. The northernmost desert of the four is the Great Basin with the Mohave Desert sometimes considered as a transition between the Great Basin and the Sonoran. Vegetation points to the transitional character of the Mohave. *Artemisia tridentata*, one of the dominants of the Great Basin, mingles with *Larrea tridentata*, characteristic of the southern deserts. On the other hand, the Chihuahuan Desert may have been a part of a larger complex extending from the northernmost edge of the Mohave through the Sonoran with all these divisions tied together by *Larrea tridentata* which may exist as several races adapted to widely varying conditions of temperature and moisture (McLeary 1968).

In either case, there exist differences in climate, topography and dominant vegetation between each of these deserts. The average elevation of the Great Basin Desert is above 1200 m, whereas the elevation of the Mohave Desert is between 600 to 1200 m; the Sonoran from below 600 to 900 m and the Chihuahuan from 900 to 1200 m. In addition, temperatures in the Sonoran Desert are higher than any other desert region of the U.S. and rainfall in the interior portions is about equally divided between winter months (December-March) and summer months (July-September). Temperatures in the Chihuahuan are lower than in the Sonoran but precipitation is confined to summer months. Both the Great Basin and the Mohave are characterized by hot summers and comparatively colder winters than the deserts to the south and precipitation occurs primarily in the winter (McLeary 1968).

Vegetation that characterizes each of these deserts is as follows: Chihuahuan -- *Larrea tridentata*, *Flourensia cernua*, *Acacia* spp. and *Mortonia scabrella*; Sonoran -- *Larrea tridentata*, *Ambrosia deltoidea*, *Carnegiea* spp. and *Opuntia* spp.; Mohave -- *Larrea tridentata*, *Lycium andersonii* and *Krameria parvifolia*; Great Basin -- *Artemisia tridentata*, *Atriplex confertifolia* and *Ceratoides lanata* (MacMahon, pers. comm.).

Smith (1968) has stated that detailed characteristics of desert environments are a function of the interaction of the bedrock geology and surface processes through time. Differences between different deserts and between different parts within the same desert represent divergent patterns of this interaction. Characteristic of desert profiles is the limited extent to which parent materials have been altered by soil-forming processes. Microorganisms living in the soil influence soil formation and soil properties through their activities and, consequently, they influence the vegetation growing on the site (Major 1951). Willis (1963) and Bradshaw et al. (1964) substantiate this in stating that some variation in botanical composition between plant communities is attributable to the variation of soil nitrogen content and other mineral nutrients. Salisbury (1954) also has found that the ecological pattern of plant distribution seems to be due to soil characteristics alone in a study in south-central Utah.

Each distinct soil contains a specific type of microbial population depending on the properties of the soil and environmental conditions. The individual microbial populations of each soil within a region are the consequence of interactions between soil-forming factors such as climate, topography, parent material and time (Jenny 1941).

Edaphic factors which are prominent in arid zones operate almost always by modification of the water regime (Noy-Meir 1973). At low water contents, lowered biological activity is principally a question of moisture stress. It is apparent that the longer a soil remains dry, the greater the decomposition activity following "wetting-up" (Charley 1972). McLaren and Skujins (1968) point out that increased microbial activity upon rewetting may be due to disruption of aggregates upon drying and thereby making the organic substrates accessible to microorganisms when rewetted. Furthermore, the importance of rate of microbial response to wetting of the soil becomes apparent when rainfall characteristics of the environment are studied.

It has been established that several interacting factors influence the occurrence of the characteristically different deserts. Therefore, it is proposed that a study be developed to compare characteristics of these aforementioned desert soils at the microbial level during seasonal moisture changes. It is at this level that soil formation, soil properties and, subsequently, vegetation are differentiated.

DESERT COMPARISON

Sampling at the four different western desert sites was to follow seasonal moisture and vegetative changes for each desert and included dry and wet nonvegetative (dormant) seasons and dry and wet vegetative seasons. Dry and wet dormant seasons for all four sites were March and December, respectively. On the other hand, dry and wet vegetative seasons for Jornada and Silverbell were June and August, respectively. The wet and dry vegetative seasons for Pine Valley and Rock Valley were nonspecific in 1975 because the intermittent precipitation pattern did not follow annual averages. Consequently, only one sampling was done during the vegetative season, in July.

Although moisture is the main limiting factor influencing microbial activity of desert soils, it must coincide with elevated temperatures. Consequently, increased activity encountered was in soils sampled at both higher temperature and moisture. It must be noted, however, that considerable activity is measurable at water potentials as low as —250 bars, suggesting that the microbial population of arid regions is definitely acclimated to extremely xeric conditions (Dommergues and Mangenot 1970).

After a period of dry conditions, there is a definite burst of activity upon occurrence of moisture. This is especially evident with dehydrogenase activity, Silverbell site soils collected in August. This is not true for proteolytic activity; as in Silverbell site soils, it tends to increase from March through December. This may be due to higher decompositional activity occurring at this time of the year when a higher moisture is coupled with moderate temperatures in the southern desert. Number of proteolytic organisms does not appear to correlate with proteolytic activity as one would expect.

Analysis for nitrification potential of March samples showed Jornada-playa site soil as being the only one to show significant nitrification potential. Silverbell's March sample shows some nitrification with little evidence of nitrite buildup. This may be due to the tendency towards neutrality of pH values. Jornada-bajada 3 tends to show more overall activity than bajadas 1 and 2.

Our studies tend to show that ATP concentration values in soils correlate closely to microbial activity, especially to dehydrogenase values. Recovery of ATP from soil is influenced by soil texture and recovery tends to be lowest in soils with higher clay content.

From the acetylene reduction data, the potential of nitrogen fixation is greater in the wetted soils than in the soils at field moisture. This is not surprising as the maximum rates of biological activity in deserts occur during the rainy season.

Although the Jornada-bajada site has the lowest acetylene-reducing ability at field moisture, it exceeds that of the Jornada-playa and Pine Valley potentials under wet conditions, thus suggesting the real dependence of this site on water for nitrogen fixation.

The rates of nitrogen fixation at all of the desert sites appear to be similar. Dark (heterotrophic) fixation is low, followed by a sharp increase in activity between sunrise and 1000 hr. Thereafter, activity either fluctuates or decreases depending on field moisture, temperature, cloud cover, etc.

The in situ fixation rates for Curlew Valley during September 1975 demonstrate a maximum peak during the afternoon. This is in contrast to the report by Skujins and West (1973) where it was found to have a maximum around 1000 hr. It should be noted that the previously reported work was performed under cloudy skies. The data reported here were obtained under bright, sunny days with temperatures not exceeding 30 C. Thus, the temperature and the radiation variables assume significant importance.

Analysis of the soils of desert comparison study are still continuing. A complete understanding of these data will not be achieved until all of the results have been compiled and evaluated.

EXOGENOUSLY SUPPLIED $(^{15}NH_4)_2SO_4$ AMENDMENTS TO SOILS (CURLEW VALLEY)

In all cases, the loss of ^{15}N is approximately 75 to 80%, no matter how the experimental conditions are varied. This indicates then, as one applies inorganic nitrogen to these Curlew soils, a priming effect occurs, thus resulting in a probable rapid increase in the activity by *Nitrosomonas* and *Nitrobacter*. The greatest amount of ammonia volatilization (in general) occurs during the first week, followed by a rapid decrease. It suggests that during the first week of incubation the *Nitrosomonas* and *Nitrobacter* populations are undergoing a lag phase, and, therefore, their capability for oxidizing the ammonium substrate during this period is low. This view is supported by Skujins and West (1974) in which the nitrification potentials of these soils demonstrated a 10- to 12-day lag period prior to the oxidation of ammonium to nitrite-nitrogen. In addition, the pH (in general) increases during the first week followed by a decrease during the remaining 2- to 4-week incubation period (Skujins 1975). This suggests the formation of either nitrous or nitric acid, or both, due to the appearance of nitrite and nitrate ions.

The levels of nitrate-nitrogen also have another significance with respect to allelopathic inhibition. In this report, plant amended soils have a very low level of nitrate-nitrogen (0.17 to 3.1 μg NO_3^-—N/g soil) and a low atom percent excess ^{15}N (0.0012 to 0.007). A similar observation has been reported by Skujins (1975) for $(^{15}NH_4)_2SO_4$ plus plant material amended soils maintained at —1 bar water tension. Although the atom percent excesses of the *Ceratoides* (previously *Eurotia*) and *Atriplex* soils are high (0.4930 and 0.2803, respectively), they are less than the percent enrichment of nonplant material amended soils (0.5220 to 1.9465). Furthermore, the ^{15}N data in this report and in Skujins (1975) show no substantial increase in ^{15}N-labeled organic nitrogen. These data, therefore, strongly suggest that an allelopathic inhibition by the plant material on the *Nitrobacter* population occurs, as no substantial increase in ^{15}N-labeled nitrate-nitrogen occurs. In addition, these low levels of nitrate-nitrogen cannot be explained on the basis of nitrate reductions since the organic nitrogen fraction fails to incorporate large amounts of ^{15}N. Therefore, as the *Nitrosomonas* population is primed and oxidizes ammonium-nitrogen to nitrite-nitrogen, the *Nitrobacter* population is inhibited, thus allowing the nitrite to be reduced to nitrogen gas or nitrous oxide; hence, the observed 80% loss of ^{15}N. However, it should also be noted that the higher levels of nitrate-nitrogen in the *Ceratoides* and *Atriplex* plant material amended soils reported by Skujins (1975) indicate that the inhibition on *Nitrobacter* is not permanent. Thus, as the decomposition of the plant material occurs, the inhibitory material is removed, thereby allowing the *Nitrobacter* population to oxidize nitrite to nitrate.

In the $(^{15}NH_4)_2SO_4$ amended soils maintained at —1 bar, —15 bars or air-dried soils, substantial losses of the applied ^{15}N (61.51 to 84.86%) result. This suggests that even in the absence of an allelopathic inhibitor, denitrification will still occur. Thus, whether the applied ^{15}N is oxidized to nitrite and subsequently denitrified, or completely oxidized to nitrate and denitrified is not really of importance, but rather that the denitrification does occur.

The 3-week experiments with exogenously supplied

$(^{15}NH_4)_2SO_4$ appear to confirm the results of the 5-week experiments. In all of the experiment systems, ammonia volatilization was maximum after the first week of incubation followed by a decline, again indicating that the nitrifying population is undergoing a lag prior to the oxidization of ammonium-nitrogen. The amount of ammonia volatilized by the N-Serve plus ammonium sulfate amended soils was greater than the loss by the ammonium sulfate amended soils by a factor of two. Similarly, the ammonium sulfate treated soil has a twofold greater volatilization loss than that of the control or unamended soils.

Nitrate again predominates over nitrite in all of the experimental systems including the plant material amended soils. However, this does not say that allelopathic inhibition is not occurring as the ^{15}N analysis is not yet available. Furthermore, the data may implicate that the rate of denitrification may be greater than that of ammonium oxidation; hence, a buildup of nitrite would never occur. Undoubtedly, the loss of ^{15}N will be by denitrification as indicated by the previously mentioned ^{15}N data.

Surface applied N-Serve failed to prevent the oxidation of ammonium-nitrogen. In addition, these treated soils have the highest levels of nitrate in all of the 3-week experimental systems. Because the ammonia volatilization in these soils is high, and because the rate of volatilization does not drop off after the first week of incubation, it appears that, initially, the N-Serve is blocking nitrification. However, as the soil dries, the N-Serve is lost, thus making the ammonium ion available to be nitrified. This suggests, therefore, that if a soil is to be treated with a surface application of N-Serve, the soil must be maintained at a constant moisture in order to be effective.

Tables 31 and 35 summarize the nitrogen balance sheet for the 3-week, air-dry experiments. These tables, as well as Table 4 of Skujins (1975), show that a threshold value of organic nitrogen for heterotrophic nitrogen fixation exists. When the initial total nitrogen of an experimental system is below 90 μg N/g soil, nitrogen fixation occurs with an increase in organic nitrogen (Tables 30, 33, 34, 36). Furthermore, when the initial total nitrogen ranges from 90 to 110 μg N/g soil, nitrogen fixation or net denitrification may occur with low levels of nitrogen fixed or lost. When the total N values exceed 110 μ g N/g soil, net denitrification occurs, and nitrogen fixation is turned off. This suggests a dependence on the C:N ratio of the soil. Thus, if the C:N ratio is high, nitrogen is limiting and, therefore, fixation is turned on. As the level of organic nitrogen increases, the C:N ratio decreases until nitrogen no longer becomes limiting. Hence, because there is an excess of nitrogen, and assuming a loss of carbon due to respiration, the nitrogen would then be denitrified and nitrogen fixation would continue to be turned off until the level of nitrogen again becomes limiting. Thus, a higher C:N ratio will subsequently occur.

Heterotrophic fixation also is important in this context. A high C:N ratio has an importance as the carbon represents the energy source for nitrogen fixation. It is also the energy source for denitrification as well. Thus, the overall picture is one in which carbon is the driving source for the reactions of nitrogen fixation and denitrification. Allelopathy makes its contribution to the loss of nitrogen as the *Nitrobacter* population is inhibited, thus allowing the nitrite to be directly denitrified to either nitrogen gas or nitrous oxide. When nitrogen is exogenously supplied, such as ammonium sulfate, a priming of the nitrifying population occurs, thus resulting in substantial losses of the applied nitrogen.

EXPECTATIONS

The studies on nitrogen cycling in the Curlew Valley and on biological activity comparison among the western deserts will be completed in 1976. It is expected that the information developed will be of value in the construction of models for various components of the desert ecosystems.

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