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Nitrogen Transformation in Rock Valley and Adjacent Areas of the Mohave Desert

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FINAL REPORT

NITROGEN TRANSFORMATIONS IN ROCK VALLEY AND ADJACENT AREAS OF THE MOHAVE DESERT

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ABSTRACT

This is the final report of investigations of nitrogen transformations in the northern Mohave Desert areas adjacent to Rock Valley. Harvests and tissue analyses of *Ambrosia dumosa* showed that within measurement limits all nitrogen required for growth of leaves and new stems during 1975 was derived from soil pools. Although nitrogen in leaves ranged from 0 to 40% of N in live above-ground tissues, it was not depleted from stems or large roots in spring, nor accumulated in them as dormancy approached. Variations in *Ambrosia* leaf and stem concentrations of other elements during 1975 were also measured. A buildup of soluble salts in leaves suggested that they act as wicks after capillary flow of water to roots ceased. Nitrogen in ^{15}N-tagged plant material added to Rock Valley soils was more available to plants than endogenous soil nitrogen. A half-life of three to four years for this added nitrogen was indicated by soil analysis and plant uptake. Loss solely through harvest would result in a half-life of seven to eight years under glasshouse conditions. Treatment of selected shrub clumps with ^{15}N fertilizer allowed estimates of root zone radii varying from less than one to more than 7 m for common Mohave Desert shrubs. Labeling of plant tissues occurred primarily in new leaves, stems and fruit, and all soil analyses showed $^{15}NO_3^-$ remained in the nitrate form 70 days after application. Extensive measurements of acetylene reduction indicated a near absence of nitrogen fixation associated with random samples of soils, litter or roots of major shrub species. A seasonal trend of ethylene production by roots was found. Evolution of ethylene from litter and adsorption of ethylene and acetylene by dry soils were indicated. Soils amended with fertilizers and incubated under the field under three watering regimes showed ammonia volatilization, nitrification, denitrification and organic matter decomposition to be slow processes under Mohave Desert conditions. Input of ammonium and nitrate by rainfall amounted to approximately 2 kg N/ha in 1976. Three samples of cemented gravel from the undersides of buried rocks contained 306, 398 and 621 μg NO_3^- N/g of acid-soluble "cement."

INTRODUCTION

Nitrogen is the most commonly limiting plant nutrient and plays an important role in uptake of other essential elements (Hiatt and Legget 1974; Raven and Smith 1976). Although water is more commonly limiting in the Mohave Desert, nitrogen fertilization has been shown to increase yield and N content of both annuals and shrubs (Romney et al. 1974; Hunter et al. 1975a, 1976a). The size of nitrogen pools in the Mohave Desert, additions to them from the atmosphere and transformations between pools have been investigated under this project for the last four years (Wallace et al. 1974b; Hunter et al. 1975b, 1976b), following some previous work under other fundings (Wallace et al. 1972; Romney et al. 1973) and by other researchers (Wells 1967; Garcia-Moya and McKell 1970). It has become increasingly clear that nitrogen dynamics in the Mohave are different from those in the cool deserts (Rychert and Skujins 1974; Reichle 1975), especially in the relative importance of lichen and algae crusts.

In this final report we present results relating to plant storage of nitrogen, mineralization of plant litter and soil organic matter, denitrification, nitrogen fixation by lichen-algae crust, rhizosphere microorganisms and decomposing microorganisms, input of nitrogen in rainfall, volatilization losses of soil ammonia and the half-life of N in a natural shrub community.

METHODS

Ambrosia Mineral Turnover

Three small-to-medium *Ambrosia dumosa* plants were harvested at intervals throughout 1975. They were separated into tissues and analyzed for N and minerals by Kjeldahl digestion and emission spectrography (Wallace et al. 1974a), respectively.

Litter Decomposition

Ground samples of ^{15}N-tagged desert plant species were added to pots of Rock Valley soil (from several locations, sieved and mixed) in January 1975. Crops of native annuals have been grown in these pots several times a year since. Nitrogen-15 enrichment was measured by emission spectrography directly in plant tissues, and in soils after Kjeldahl extraction and precipitation as $(NH_4)_2PtCl_6$.

Uptake of ^{15}N Fertilizers

Application of $^{15}NO_3^-$ and $^{15}NH_4^+$ fertilizer to four 5-m^2 areas was described previously (Hunter et al. 1976b). Analyses were by emission spectrography as described above.

N-Balance in Field-Incubated Soils

One hundred kg of two different soils was collected in Mercury Valley, sieved (2 mm) and each thoroughly mixed in a cement mixer. One was from a large bare area covered by desert pavement with sparse shrub cover. The other was taken from beneath a shrub clump dominated by a large *Ephedra nevadensis* (1 m height, 1.2 m diameter). In this area *Ephedra* builds up a fairly thick litter mat. Before sampling, a surface sample from each site showed nitrate-N concentrations of < 2.5 μg/g in the bare area and ~ 20 μg/g under the shrub. Samples were taken to a depth of 30 cm.

These soils were treated in various ways (described below) and divided into 774 samples in order to determine rates of ammonia volatilization, denitrification, nitrification and ammonification.

To estimate ammonia volatilization, 8.4 kg of bare soil was steam sterilized at 15 lb for 40 min. N-Serve (2-chloro-6 [trichloromethyl] pyridine, Dow Chemical Co. lot WP10294-2) was diluted .25 ml/836 ml with distilled water,

added to and thoroughly mixed with the soil. The soil was dried for three days at 60 C in a forced draft oven. Finally 0.987 g $(NH_4)_2SO_4$ was ground to a fine powder and thoroughly mixed with half the soil.

For determination of litter N mineralization, the bare sample was amended with ground litter collected from Rock Valley. The litter included material from beneath six common shrub species, and was added at the rate of 3 g/100 gdw soil. Unamended shrub and bare soils were also used.

For the nitrification study, 0.978 g of powdered $(NH_4)_2SO_4$ was added to 2.1 kg bare and shrub soils.

To determine denitrification, N-Serve was added as previously described. Nitrate was added by dissolving 3.53 g $Ca(NO_3)_2 \cdot 4H_2O$ in water, which was then mixed with 4.2 kg bare and shrub soil.

Soils were apportioned into 774 74-ml acrylic plastic vials and set outside under a Plexiglas cover (with sides open to wind). One-third were not watered, one-third received "normal" water and one-third received two times "normal" water. Rainfall was averaged by amount and number of events for each month to determine amount and timing of watering. Actual water applied, given in Table 1, differs slightly from theoretical timing due to vacations and weekends. Prior to addition of water, 10 vials were weighed to prevent overwatering. Moisture held by soils in three thoroughly wet vials allowed to drain 48 hr averaged 25.8 $\pm$ 0.3 g (se). Field-incubated vials never approached this quantity of water, indicating average rainfall conditions in the Mohave are not suitable for thorough wetting of the soil.

Twenty-four vials of bare soil with added litter were wet with 25.5 g water and incubated in a lab cupboard (~ 21 C) and refrigerator (~ 5 C). A small piece of tape was applied to the rim to prevent total sealing by the plastic caps. No water was applied throughout the year, as incubation conditions did not allow an approximation of field moisture conditions. These soils were still thoroughly wet at the end of the one-yr incubation.

Three vials from each treatment were removed immediately after placement in the field April 7, 1976, and also one week, one, three and six months, and one year after the start of incubation. The ammonia volatilization experiment was duplicated starting July 7 with a new bare soil, as rainwater dripping from the supporting structure for the Plexiglas cover flooded a number of vials from the experiment.

Analyses for NO_3^-, exchangeable NH_4^+ and total N were made with selective ion electrodes (Orion). Nitrate was extracted with 0.01 M sodium citrate (2:1, V/soil dw). Ammonium was extracted with 2N KCl (10:1) and total N by Kjeldahl digestion.

Acetylene Reduction

The gas chromatograph was moved from UCLA to the CETO lab in Mercury for work done in 1976, hence samples were run within hours of removal from the field. For root samples, serum bottles were incubated in the field and buried in the hole from which they were taken. Soils were incubated in the CETO glasshouse, and microorganisms in 35-ml bottles in the lab.

Table 1. Water added to N-balance soils, field-incubated in 74-ml vials

Date	Water added per vial (ml)	
	"Normal"	"2 x normal"
4-10-76	---	6.0
4-15-76	6.0	---
4-20-76	---	6.0
5-20-76	---	6.6
6-01-76	6.6	---
6-10-76	---	6.6
7-10-76	---	7.5
7-15-76	7.5	---
7-20-76	---	7.5
9-13-76	13.3	20.6
10-05-76	4.6	15.2
11-10-76	---	9.2
11-16-76	9.2	---
11-23-76	---	9.2
12-05-76	---	7.1
12-13-76	7.1	7.1
12-21-76	8.4	8.4
12-27-76	---	8.4
1-10-77	---	10.3
1-17-77	10.3	---
1-20-77	---	10.3
2-14-77	8.0	16.0
2-18-77	---	6.9
2-22-77	6.9	---
2-25-77	---	6.9
3-04-77	---	4.6
3-10-77	5.2	---
3-15-77	---	10.7
3-21-77	4.6	4.6

Nitrogen-free agar used for culturing litter isolates contained in g/liter, 1.0 K_2HPO_4, 0.2 $MgSO_4$, .01 NaCl, .01 $FeSO_4$, .01 $MnSO_4$, 20.0 glucose, 30.0 $CaCO_3$ and 0.41 KOH. Ten ml of hot agar was added per 35-ml bottle before sealing and sterilization (15 lb, 30 min). Antibiotics and inoculant were injected through the serum bottle cap after sterilization.

Nitrate and Ammonium in Rain

A standard funnel-type rain gauge with the funnel neck lightly plugged with glass wool was used to collect rainfall for nitrogen analysis. Nitrate and ammonium content were measured when enough sample was available using Orion selective ion electrodes.

Caliche Nitrate

Three samples of cemented gravel and deposits on the underside of large rocks were partially dissolved in 50% H_2SO_4. Nitrate was determined by the known addition method using an Orion nitrate electrode.

RESULTS

Ambrosia Mineral Turnover

Allocation of nitrogen to leaves and stems of *Ambrosia dumosa*, adjusted to 100 g live shoot weight, is shown in Figure 1. Over a period of 70 days, leaf N increased from 4 to 40% of total N in the live above-ground parts. As the season progressed, new stem growth accounted for up to 13% of

Table 2. Concentration of N in live tissues of *Ambrosia dumosa* during 1975

Date	Live Stem	Leaves	New Stem	Large Root	Fine Root
			% ± se		
Jan 17	0.83 ± 0.09	-	-	1.27 ± 0.09	1.26 ± 0.23
Feb 3	0.67 ± 0.08	-	-	1.03 ± 0.21	1.34 ± 0.13
Feb 18	0.82 ± 0.08	-	-	1.22 ± 0.10	1.41 ± 0.05
Mar 3	0.80 ± 0.10	1.85	-	1.02 ± 0.11	1.27 ± 0.22
Mar 17	0.84 ± 0.11	5.85 ± 0.29	-	1.17 ± 0.05	1.40
Apr 1	0.83 ± 0.08	4.28 ± 0.17	-	1.03 ± 0.05	1.32 ± 0.02
Apr 14	0.96 ± 0.07	4.59 ± 0.25	-	1.11 ± 0.09	1.33 ± 0.33
Apr 28	0.75 ± 0.04	4.14 ± 0.49	3.12 ± 0.52	0.93 ± 0.16	1.18 ± 0.26
May 12	0.76 ± 0.04	3.38 ± 0.09	1.95 ± 0.08	1.15 ± 0.21	-
May 27	0.66 ± 0.02	2.69 ± 0.29	1.18 ± 0.04	0.74 ± 0.05	1.06 ± 0.05
Jun 12	0.70 ± 0.05	2.08 ± 0.25	0.96 ± 0.05	0.92 ± 0.04	0.74 ± 0.16
Jun 30	0.82 ± 0.07	1.75 ± 0.04	1.07 ± 0.07	1.21 ± 0.03	1.01
Jul 21	0.89 ± 0.15	1.30 ± 0.05	1.02 ± 0.19	1.20 ± 0.11	1.26
Aug 18	0.70 ± 0.05	1.59 ± 0.37	0.93 ± 0.11	0.89 ± 0.15	-
Sep 17	0.81 ± 0.01	1.17 ± 0.05	0.95 ± 0.04	-	1.33 ± 0.04
Oct 21	0.73 ± 0.08	1.23	-	0.99	-
Nov 20	0.81 ± 0.10	1.64 ± 0.69	2.57	0.83 ± 0.22	-
Dec 16	0.62 ± 0.02	1.18	-	0.90 ± 0.10	0.75 ± 0.1

total N. Gain and loss of N in the shoot generally parallels growth and loss of leaf dry weight (see Hunter et al. 1976b; Fig. 1).

Though N concentration from plant to plant is quite variable, there is no indication of a significant decrease in stem N during the spring leaf flush, nor of an increase as the plants become dormant. Hence, stems do not act as a storage site for nitrogen.

Changes in N concentration of leaves, live stem, new stem, large roots and fine roots are shown in Table 2. When first large enough to sample, new leaves contained four to seven percent N, while young stems contained two to four percent. When dormant in September, leaves contained about 1.2% and stems near 1 % N. At this time most of the leaf surface was dead, with just the midribs and youngest leaves being green. Dormancy was not sudden, as with deciduous trees, but rather occurred as a slow death of leaves, from older to younger and from outer edge to the midribs. *Ambrosia* leaves do not abscise as many species, but remain attached to the stem for several months after dying. Figure 1 and Table 2 do not differentiate live from dead leaves because of this pattern.

There are significant ($p = .05$) negative correlations of N concentration with time in new stem, leaves, large and fine roots, and dead stem (Tables 2 and 3). Large root tissue includes the crown, which after stem tissue is the only likely place for nitrogen storage during the dormant period. Hence we find no evidence that *Ambrosia* stores nitrogen, implying N for the spring growth flush is taken up from the soil.

Figure 2 shows changes in the ratios of leaf concentration to live shoot concentration of several elements. For leaf N the decrease to late May (day 147) can be largely explained by carbohydrate dilution, but after that date it indicates a minor "withdrawal" of N from the leaves. As noted above, however, we have no indication the withdrawn N is stored in any given tissue.

The variability in N concentration in old live stem is partially explained by percentage of dead wood. There is a positive correlation ($r = +.33$, $p < .025$) of percent dead wood to stem N, and also a significant correlation ($r = -.52$, $p = .05$) between the ratio of live to dead stem weights and the leaf:live stem ratios between April 28 and June 30 (i.e. while fully leafed out). These data suggest the live stem competes with leaves for nutrients, and that death of some stems allowed for increased leaf:stem ratios and stem N concentrations in remaining branches.

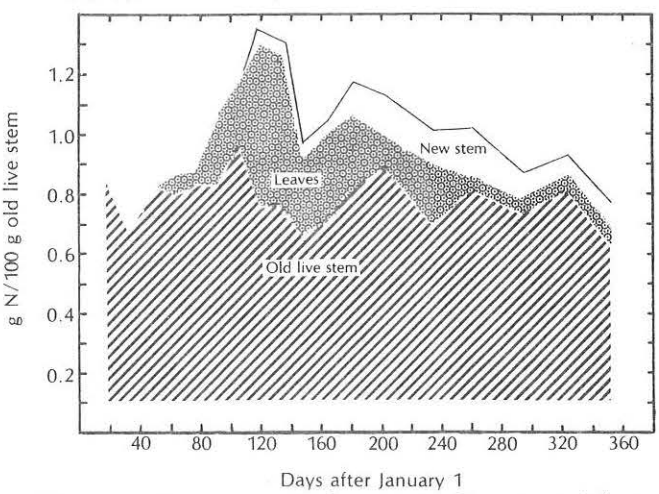


Figure 1. Above-ground nitrogen fractions in *Ambrosia dumosa* during 1975 in Mercury, Nevada.

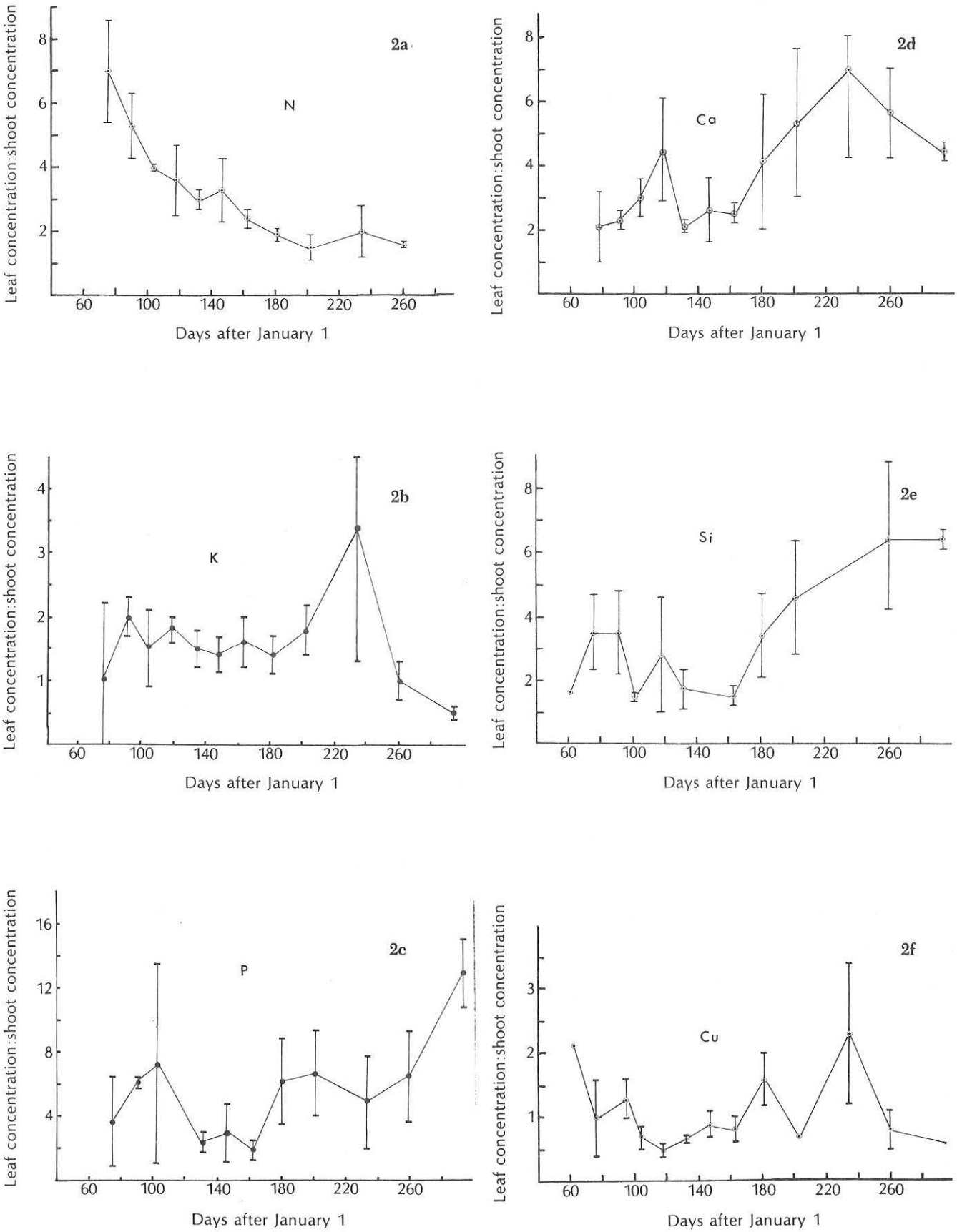


Figure 2. Ratios of leaf concentrations to average concentrations in live above-ground portions of *Ambrosia dumosa* during 1975 for several elements. Error bars are 95% confidence limits, 1-3 samples at each date

Table 3. Tissue mineral concentrations in *Ambrosia dumosa* correlating significantly with time between January and December, 1976

	Stem	New Stem	Dead Stem	Leaves	Dead Leaves	Large Root	Fine Root
$\|r\| > 0$, p = .05[a]	.29	.53	.28	.34	.50	.27	.29
Element	r						
N		-.69	-.29	-.79		-.54	-.53
P	-.46		-.33	+.34		-.28	-.38
Na	+.49	+.58	+.33	+.77		+.42	
K				-.41	+.86		
Ca	-.38			+.51			-.31
Mg				+.69	+.64		-.37
Fe	-.37		-.40			-.48	-.37
Zn	-.36		-.53	+.34			
Cu	-.33		-.32		-.61		
Mn				+.50			
B		-.54		+.57	+.74		
Al	-.43			+.55			-.31
Si				+.60			

[a] Significant |r| was determined using the relationship:
$F(1, n-2)\ .95 = r^2\ (n-2)/(1-r^2)$.

Soil nitrate concentrations under the harvested shrub ranged from 0.1 ± 0.1 to 6.2 ± 1.4 ppm (avg ± se, n = 3 per sample period) for the 17 sampling dates. There was no seasonal pattern, and no correlation of soil N with stem N. These low concentrations are typical of the open areas where these plants were harvested. (Plants growing in clumps were not harvested.)

DSCODE A3UTJ3 contains tissue analyses for 12 elements other than N. They are P, Na, K, Ca, Mg, Zn, Cu, Fe, Mn, B, Al and Si. Figure 2b, c and d shows variations in ratios of leaf concentration to average shoot concentrations for Ca, K and P. It appears that as leaves die (after day 181) there is a concentration of Ca and P in them, with some indication of a late drop in K.

In 1975 there was very little rainfall in Mercury after May 21, and soil water potentials were lower than —30 bars at 15, 30 and 60 cm from June through December (Fig. 3e). During that period there would have been negligible capillary flow of water to roots, and essentially no uptake of mineral ions from soil. It appears from the correlations given in Table 3 that most elements moved from large roots and stems into leaves with time, which may indicate leaves act as a wick, collecting salts while they play a major role in transpiration. Sodium, however, did not fit this pattern, increasing in concentration in all tissues with time. The particularly significant increase in leaf and dead leaf concentrations of Na, B, Mg and K (dead leaves only) suggest the wick effect. Increases in Si, Al and Mn are often due to dust contamination, but may also be due to uptake of these elements through roots and their concentration in dying leaf tissue with the above salts.

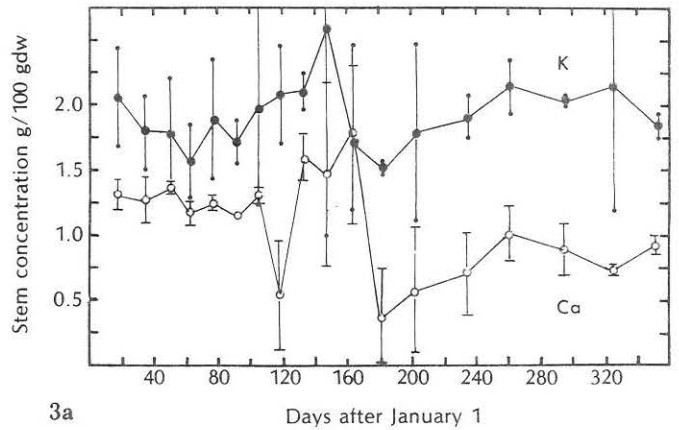
There is a high correlation between Si and Al in leaves (r = .96), but not in stems (r = .29). We believe the best explanation for this involves dust contamination of leaves. Data of Romney et al. (1974) bear on this question. In stems there is a strong correlation between Fe and Al (r = .89), which may indicate similarity in uptake mechanisms, or a single uptake process for trivalent cations.

Figure 3 plots stem concentrations of several elements and water potential against time. We consider stem tissue to be least affected by developmental changes and to be the most stable in its mineral relations. Minerals changing significantly over the year are listed in Table 3. It appears from Figure 3 that several changes occur near mid-year, when soil water capillary flow ceased. In particular there was a loss of stem P and Ca and a gradual increase in stem Na after June. The strong correlation between Al and Fe concentrations is apparent in Figure 3.

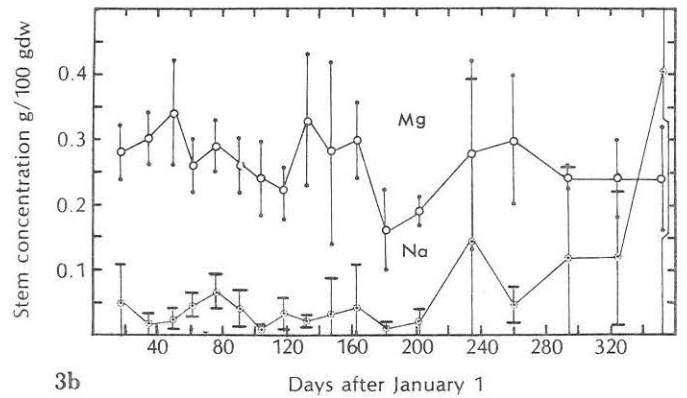
Litter Decomposition

Harvest of plant tissue and N from pots amended with ground ^{15}N-tagged plant material is reported in Table 4. Both dry matter and nitrogen harvested were considerably enhanced by the addition of all types of litter. There are significant correlations between weight and N harvested and N added, and weaker correlations between those yields and dry weight added. In several cases the weight of plant material harvested to January 7, 1977 exceeded the weight added to soils, but N harvested has not exceeded two-thirds of that added. Yields in amended soils are two to three times control yields.

The availability of N from ground litter is greater than that of endogenous soil nitrogen (Table 5). Although the amendments made up 20 to 60 percent of total nitrogen, they contributed 56 to 99 percent of initial harvest N (excepting *Larrea* leaves), and two years later still generally provided a disproportionately high percentage of harvest N. This indicates endogenous soil N is considerably reduced in availability in comparison to litter N. This is reflected in the A-values reported earlier (Hunter et al. 1976b) of 55 to 218 mg N/kg soil, whereas Kjeldahl digests average initial N values of 450 mg N/kg. Hence it appears just 10-50 % of Rock Valley soil nitrogen was available over the 6 months during which A-values were determined.



3a



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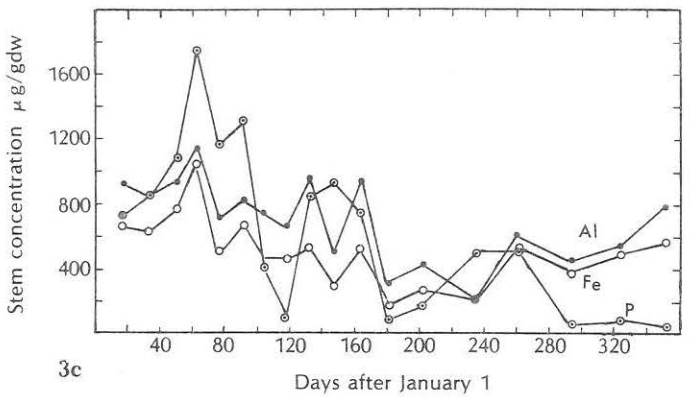

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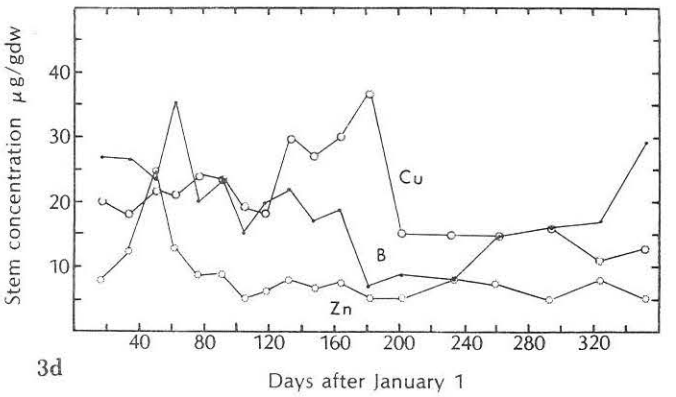

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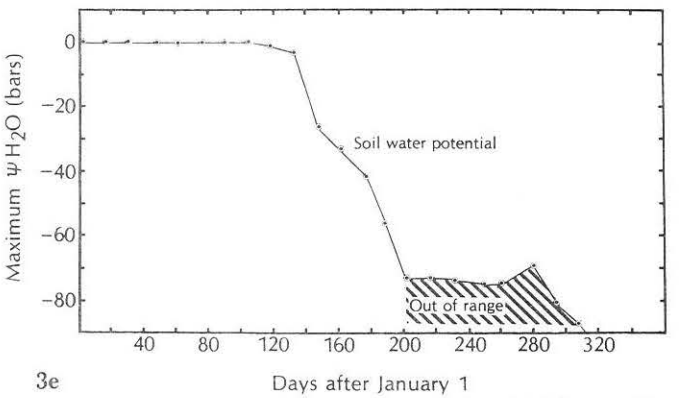

3e

Figure 3. Concentration fluctuations of several elements in old live stem of *Ambrosia dumosa* and maximum soil water potentials measured at 15, 30 or 60 cm during 1975. Error bars are 95% confidence limits, n = 1-3.

Table 4. Nitrogen and dry weight harvested from Rock Valley soils treated with ground tissues of several desert plant species. Harvested weight and nitrogen correlate significantly at p = .05 with nitrogen added (r = .58 and .72, respectively). They correlate less well with dry weight added (r = .49 and .58, the latter significant at .05)

Organic Matter Added	Jan. 24, 1975		Harvest To Jan. 7, 1977	
Species and Tissue	Dry Wt, g	N, mg	Dry Wt, g	N, mg
Atriplex hymenelytra				
root	54.0	912	19.5	279
stem	55.5	732	17.8	212
leaves	77.8	2121	14.8	354
Lycium andersonii				
root	81.3	1950	26.6	347
stem	109.4	2345	28.6	497
leaves	17.9	802	27.9	519
Larrea tridentata				
root	27.6	547	15.2	205
stem	35.9	708	25.5	288
leaves	27.8	655	23.1	262
Ambrosia dumosa				
root	19.5	386	20.0	256
stem	28.4	452	21.0	260
leaves	29.2	1180	31.5	531
Controls				
1	0	0	8.0	96
2	0	0	9.2	103
3	0	0	8.5	90

Table 5. Proportion of added nitrogen harvested in plant material from pots of Rock Valley soil which was amended with ground tissues of ^{15}N-tagged desert plants

Litter Added - Species And Tissue	Litter N Added Jan 24, 1975	Litter N In Harvest Mar 4, 1975	Jan 7, 1977
	% of Total N		
Atriplex hymenelytra			
root	37	72	3
stem	32	72	40
leaves	57	--	65
Lycium andersonii			
root	55	87	48
stem	60	99	68
leaves	34	63	49
Larrea tridentata			
root	26	63	35
stem	31	66	43
leaves	29	11	46
Ambrosia dumosa			
root	20	69	24
stem	22	59	31
leaves	43	56	36

Soil analyses were erratic, due to the involved analytical procedures. Nevertheless, the loss of ^{15}N indicated by soil analysis was greater than can be accounted for by harvested ^{15}N (Table 6). Loss of added N was greater than loss of endogenous N. These soil data would indicate loss by denitrification or ammonia volatilization. It is supported somewhat by the decrease in labeled N as a percent of harvest N (Table 7). This decrease is on the order of that indicated by the soil analysis, with average half-lives of 3.3 yr for soil ^{15}N decrease and 3.7 yr for decrease in ^{15}N uptake. In contrast, if all N had been lost by harvest the average half-life would be 7.5 yr. Perhaps we should note here that the half-life discussed is for residence time and plant availability in soil, as ^{15}N is not radioactive.

The decomposition of all tissues other than *Larrea* leaves appears to be similar, with half-lives (measured by plant uptake) of 1.3 to 5.7 yr. *Larrea* leaves show a much longer half-life of 38 yr, in agreement with the low initial N availability noted last year. The 5.7-yr half-life of nitrogen in *Atriplex hymenelytra* leaves also suggests delayed availability. It was very difficult to establish plants in the pot with ground *A. hymenelytra* leaves. Mineral analysis of *Bromus rubens* tissue from the harvest of April 28, 1975 showed the plants growing in this soil to be higher in Na, K, Zn, Cu, Sr and Li and lower in Si, Mn and Ti than those from any other pot. However, the three plants were established on the third seeding, and hence were less mature than the other plants. Their N content of 2.6% reflects this fact. N contents of other pots ranged from .72 to 1.36%, representative of *Bromus* in late seed production stages.

Uptake of Fertilizer $^{15}NO_3^-$ and $^{15}NH_4^+$

Enrichment in ^{15}N in plants adjacent to $^{15}NO_3^-$- and $^{15}NH_4^+$-fertilized plots is reported in Table 8. Results are generally consistent with root zone estimates based on ^{15}N uptake reported previously (Hunter et al. 1976b). *Acamptopappus shockleyi* and *Ambrosia dumosa* picked up no ^{15}N outside the plot boundaries, indicating root spread of less than 2 m. Two *Ceratoides lanata* picked up some ^{15}N from within one m of NH_4^+-treated plots, but none from farther than 3 m. Two *Ephedra*, one 4 m and one 22 m from the plots showed enrichment. Four *Larrea tridentata*, all within 7 m of $^{15}NO_3^-$-treated plots, showed significant enrichment. Three *Lycium andersonii*, the farthest 7 m from a plot, and one *Yucca schidigera* at 15 m were enriched in ^{15}N. These distances compare with the 1- to 6-m radii calculated from plants situated inside the plots.

The *Ephedra nevadensis* and *Yucca schidigera* showing uptake from 22 and 15 m, respectively indicate either unusual analytical error or distorted distribution of roots.

Plant samples from within the plot areas showed a concentration of ^{15}N in new structures (Table 9). Nevertheless, old stems and dead wood showed significant dilution with ^{15}N, indicating presence of a mobile N fraction of significant size. In all species but *Ambrosia*, live leaves showed the greatest enrichment, closely followed by fruit, flowers and new stem. Old live stem showed the least enrichment of live tissue, no doubt due to dilution with non-labile ^{14}N. In *Ambrosia*, fruits rather than live leaves were most enriched.

Dead leaves were considerably enriched, reflecting their short life span. Essentially all dead leaves were produced after ^{15}N fertilizer was applied. Enrichment of dead wood was of a low level, but generally higher than in 1975. It is not likely that such a high percentage of dead twigs was alive

Table 6. Loss of N between Jan 24 and Oct 29 from soils amended with ^{15}N-tagged desert plant tissues. Inconsistencies suggestive of nitrogen fixation are most likely due to errors in the rather involved soil assay procedure

	Change In Total N %	Total N Harvested %	Change In Labeled N %	Labeled N Harvested %
Amended Soil				
1	- 15	7	- 78	12
2	- 13	6	- 27	12
3	- 3	8	- 47	11
4	- 32	19	-	36
5	- 5	7	- 30	9
6	- 10	7	- 5	8
7	- 17	8	- 12	14
8	-	7	+ 8	11
9	- 8	5	- 11	10
10	- 23	10	-	29
11	- 5	13	- 63	19
12	- 31	8	- 19	12
Control				
1	- 3	5	-	-
2	- 8	4	-	-
3	+ 2	5	-	-

Table 7. Enrichment of ^{15}N in successive harvests of plants grown in Rock Valley soils which were amended with ground ^{15}N-tagged tissues of desert plants

Soil	Original Litter	Harvest Date 4-4-75	5-5-75	6-17-75	10-21-75	4-9-76	4-28-76	9-03-76	1-07-77
		^{15}N Atom % Excess							
1	.60	.44	.48	.37	.32	.22	.27	.28	.02
2	.95	.69	.69	.53	.46	.37	.41	-	.38
3	2.19	-	-	-	1.37	1.50	1.34	-	1.19
4	2.78	1.77	1.68	1.77	1.24	1.05	0.84	0.86	0.89
5	.90	0.79	0.78	0.69	.49	.50	.47	.32	.43
6	.99	0.99	.89	.89	.68	.75	.75	.68	.67
7	1.72	1.14	1.05	1.00	.84	.82	.76	.66	.74
8	2.91	.33	1.39	1.37	1.29	1.47	1.38	1.39	1.35
9	.89	.57	.63	.34	.37	.31	.44	.22	.31
10	1.72	1.19	1.20	1.01	.44	.41	.52	.09	.42
11	2.73	1.55	1.91	1.78	1.51	1.23	1.23	.80	.99
12	1.98	1.17	.82	1.00	.84	.73	.77	.45	.61
Avg.		.97	1.05	.98	.82	.78	.77	.58	.67
Controls									
1	-	.13	.06	- .02	.00	- .02	.14	-	.07
2	-	.24	.01	- .02	- .03	.06	.09	-	.12
3	-	.04	.02	.03	- .16	.02	.11	-	-
Avg.		.14	.03	.00	- .06	.02	.11		.10

after treatment and it is possible that some enrichment occurs by nitrate movement from adjacent living tissues.

On nitrate-treated plots *Bromus rubens* showed less uptake than many shrub leaves. This may be due to growth of *Bromus* in shrub clumps higher in original NO_3^- content, diluting the ^{15}N. There may be significant dilution of *Bromus* nitrogen with seed N, as the plants were quite small. The fact that shrub leaves do show higher enrichment than *Bromus* suggests shrubs' labile N pools are not much larger than *Bromus* seed pools. This is in agreement with the *Ambrosia* data reported above, which showed little storage of N.

Enrichment was lower on plots treated with $^{15}NH_4^+$ than on $^{15}NO_3^-$ plots, and lowest on the plot treated with N-Serve to inhibit nitrification. *Acamptopappus*, *Ambrosia* and *Ceratoides* were the most strongly enriched species, reflecting their smaller root zones. (Roots extending outside the 5-m^2 treated area cause reduced enrichment.)

Table 8. Percent ^{15}N in tissues of plants near the four ^{15}N-treated plots. Enrichment above background (0.27-0.43%) indicates distances over which nitrogen uptake can occur

SPECIES*	PLOT 1 Distance m	PLOT 1 %^{15}N	PLOT 2 Distance m	PLOT 2 %^{15}N	PLOT 3 Distance m	PLOT 3 %^{15}N	PLOT 4 Distance m	PLOT 4 %^{15}N
Aca sho	2	0.38	2.5	0.38	4	0.34	1	0.35
	15	0.34	3	0.37	17	0.32	6	0.33
			4.5	0.28			6	0.29
			6	0.40				
Amb dum	2	0.31	5	0.36	5	0.37	4.5	0.35
	3	0.29	9	0.34	6	0.30	6	0.35
Cer lan	3	0.40	4	0.39	1	0.48	1	0.48
	7	0.40	9	0.32	6	0.35	3	0.35
							4	0.30
Eph nev	4	0.48	12	0.38	9	0.32	16	0.41
	13	0.37	15	0.34	46	0.36	22	0.67
	13	0.41	22	0.26			26	0.38
	24	0.35					34	0.38
Eph fun	-	-	-	-	8	0.35	6	0.41
					13	0.34	12	0.33
					20	0.33	14	0.33
					22	0.34	20	0.36
Lar tri	3	0.45	3	0.36	5	0.37	3	0.29
	5	0.52	5	0.44	9	0.42	5	0.32
	7	0.53	9	0.41	13	0.36	8	0.37
	9	0.34					12	0.36
Lyc and	3	0.33	3	0.54	1	0.46	3	0.43
	7	0.36	6	0.38	5	0.29	6	0.40
	12	0.34	7	0.45	11	0.37	8	0.38
	15	0.37	11	0.39	14	0.33	12	0.33
Yuc sch	4	0.37	6	0.37	9	0.36	4	0.35
	12	0.41	15	0.46	12	0.39	4	0.37
	18	0.40						
	26	0.29						

* Aca sho = *Acamptopappus shockleyi*, Amb dum = *Ambrosia dumosa*, Cer lan = *Ceratoides lanata*, Eph nev = *Ephedra nevadensis*, Eph fun = *Ephedra funera*, Lar tri = *Larrea tridentata*, Lyc and = *Lycium andersonii*, Yuc sch = *Yucca schidigera*.

As indicated in Table 10, levels of ^{15}N in many plants or tissues have decreased, allowing a calculation of biological half-lives of N in desert shrubs. (Since half-lives below zero were not calculated, these values should not be used to approximate an average half-life.) The indicated values of 2-4 yr are shorter than we would have predicted, but as N is recycled through litter we expect an increase in half-life. Almost all plants on the plots treated with $^{15}NH_4^+$ have not reached a maximum enrichment, reflecting both later application and slower uptake due to soil adsorption and nitrification problems. Calculation of half-lives from the few samples which decreased in ^{15}N enrichment is questionable, and we would expect significant changes at subsequent sampling times.

Soil analyses (Table 11) indicate that the majority of ^{15}N present in the NO_3^--fertilized plots remained in the NO_3^- form 70 days later. The involved multiple soil assay and lack of precision in the newly instituted emission spectrographic ^{15}N assay were particularly troublesome in these data. A direct spectrographic assay for soil ^{15}N has been reported (Kanazawa and Yoneyama 1976) and is being investigated.

N Balance in Field-Incubated Soils

Changes in nitrogen fractions in field-incubated soils are recorded in Table 12. Some analyses have not yet been completed. Initial indications from these data are that soil nitrogen transformations in the Mohave Desert are quite slow and difficult to measure with our standard analyses.

Table 9. Partition of ^{15}N by tissue in Mohave Desert vegetation growing on plots treated Jan 29, 1975 (NO_3^-) and Mar 21, 1975 (NH_4^+) as of Jun 2, 1976. Background ^{15}N (.27 to .43%) has not been subtracted

9a. $^{15}NO_3^-$-treated plots

Species	Plant[A]	Live Leaves	Live Stem	New Stem	Flowers	Fruit	Dead Leaves	Dead Wood	Whole Shoot
					% ^{15}N in Tissue				
Aca sho	1	2.46	1.97	1.88	-	2.60	-	1.77	-
Amb dum	1	2.44	2.60	1.75	-	3.02	2.43	0.61	-
	2	1.59	0.74	1.46	-	1.80	-	0.36	-
Bro rub	1	-	-	-	-	-	-	-	1.19
	2	-	-	-	-	-	-	-	1.09
Cer lan	1	1.02	0.70	1.88	1.04	-	-	0.74	-
	2	1.96	1.54	2.01	1.78	-	-	0.51	-
	3	2.41	2.02	2.18	2.35	-	-	0.59	-
	4	1.22	1.26	1.68	-	1.07	1.12	0.37	-
Eph fun	1	-	1.28	-	-	-	-	0.64	-
Gra spi	1	1.21	0.68	1.27	-	1.20	-	0.46	-
	2	1.41	1.13	1.79	-	1.57	-	0.38	-
	3	1.88	0.76	1.79	-	-	-	0.50	-
	4	1.89	1.99	1.58	-	-	-	-	-
Kra par	1	-	0.82	1.04	-	-	-	0.50	-
Lar tri	1	0.78	0.64	0.75	-	-	-	0.36	-
	2	0.72	0.42	0.71	-	-	-	-	-
	3	1.19	0.71	1.24	1.10	1.09	-	-	-

9b. $^{15}NH_4^+$ + ammonia treated

Species	Plant	Live Leaves	Live Stem	New Stem	Flowers	Fruit	Dead Leaves	Dead Wood	Whole Shoot
					% ^{15}N in Tissue				
Aca sho	1	2.25	1.10	-	-	1.33	-	0.71	-
	2	2.04	1.39	1.90	-	1.61	1.81	1.68	-
	3	2.21	1.52	1.90	-	-	-	0.80	-
	4	2.59	1.90	2.43	-	2.29	-	1.15	-
Amb dum	1	0.94	0.65	-	0.90	0.92	0.63	0.58	-
	2	0.73	0.50	0.72	-	0.74	-	0.52	-
Bro rub	1	-	-	-	-	-	-	-	1.47
Cer lan	1	1.01	0.77	0.89	0.98	-	-	0.52	-
Eph fun	1	-	0.75	0.69	-	-	-	0.63	-
Kra par	1	0.73	0.51	0.66	-	-	-	0.42	-
	2	0.81	0.40	-	-	-	-	-	-
Lar tri	1	0.49	0.45	0.42	-	0.68	-	0.44	-
Lyc and	1	0.95	0.70	-	-	-	-	0.46	-

9c. $^{15}NH_4^+$ + N-Serve-treated plot

Species	Plant	Live Leaves	Live Stem	New Stem	Flowers	Fruit	Dead Leaves	Dead Wood	Whole Shoot
					% ^{15}N in Tissue				
C. $^{15}NH_4^+$ + NSERVE									
Aca sho	1	1.03	0.72	0.92	-	0.88	-	0.52	-
Amb dum	1	0.72	0.66	0.69	-	0.83	-	0.59	-
	2	0.66	0.58	0.58	0.60	0.79	-	0.50	-
	3	0.97	0.72	0.96	0.97	1.18	0.74	0.65	-
	4	0.74	0.67	0.74	-	0.74	-	0.53	-
Bro rub	1	-	-	-	-	-	-	-	0.81
Cer lan	1	0.79	0.61	0.68	-	0.83	-	0.43	-
	2	0.52	0.51	0.49	0.58	0.69	-	0.44	-
	3	0.64	0.59	-	-	-	-	-	-
Eph fun	1	-	0.57	0.58	-	-	-	-	-
Kra par	1	0.57	0.41	0.49	-	-	-	0.42	-
Lar tri	1	0.46	0.43	0.46	-	-	-	0.54	-
	2	0.45	0.35	0.47	-	-	-	0.35	-

* See footnote, Table 8; also, Bro rub = *Bromus rubens*, Gra spi = *Grayia spinosa*, Kra par = *Krameria parvifolia*.

Table 10. Preliminary indications of biological half-lives of availability of nitrogen in Mohave Desert vegetation

			1975-1976	1976-1977
A. $^{15}NO_3^-$ treatment - Plots 1 and 2				
Number of cases showing increasing	^{15}N%		12	3
Number of cases showing decreasing	^{15}N%		9	9
Half-lives of cases showing decreasing label				
			Half-life (yrs)	
Species	Tissues[a]	Plot	1975-1976	1976-1977
Aca sho	live leaves	1	4.6	-
	shoot	1	<0	1.4
Amb dum	shoot	1	<0	0.5
	live leaves	2	17.3	14.3
Bro rub	shoot	1	-	1.0
Cer lan	live leaves	2	0.9	1.7
Eph fun	live stem	2	2.6	4.8
Gra spi	live stem	1	1.0	-
	live leaves	1	1.5	-
	shoot	1	1.3	2.4
	live stem	2	1.2	-
	live leaves	2	1.6	-
	shoot	2	1.0	<0
Lar tri	shoot	1	-	1.4
	live stem	2	3.6	-
	shoot	2	6.0	-
B. $^{15}NH_4^+$ Treatment				
Number of cases showing increasingly	^{15}N%		19	7
Number of cases showing decreasing	^{15}N%		3	4
Half-lives of cases showing decreasing label				
Amb dum	shoot	4	<0	1.-
Bro rub	shoot	4	-	0.8
Cer lan	live leaves	3	1.3	<0
Cer lan	shoot	4	<0	4.4
Lar tri	shoot	4	-	3.7

[a] "Shoot" for 1976 is the average of stem and live leaf values for 1977. It is a determination on leaf and stem ground together before analysis.

Table 11. Enrichment of ^{15}N in soil fractions on $^{15}NO_3^-$-treated plots in Mercury Valley. Treatment on Plot 1 was 4 kg/ha NO_3^--N, 33.6% enrichment, and on Plot 2, 1.76 kg/ha NO_3^--N, 94.6% enrichment. Treated Jan 29, 1975 and sampled Apr 8, 1975

Plot	Site	Depth	Kjeldahl digest to exclude NO_3^-		Kjeldahl digest to include NO_3^- and NO_2^-		Soluble NO_3^-	Indicated ^{15}N in NO_3^-
		cm	%N	%^{15}N[a]	%N	%^{15}N	ppm	%^{15}N
1	1	0-15	0.117	0.37	0.110	0.472	50	12
	2	0-15	0.055	0.45	0.056	0.580	8	61
	3	0-15	0.056	0.32	0.058	0.493	5	343
		15-30	0.059	0.39	0.062	0.519	5	78
		30-45	0.057	0.41	0.062	0.466	5	64
	4	0-15	0.033	0.42	0.032	0.645	5	61
		15-30	0.038	0.41	0.038	0.586	8	131
		30-45	0.035	0.44	0.037	0.414	3	35
Controls	1	0-15	0.030	0.32	0.032	0.384	5	17
		15-30	0.031	0.37	0.035	0.393	3	43
	2	0-15	0.027	0.35	0.028	0.398	3	35
		15-30	0.031	0.38	0.034	0.412	5	43
2	1	0-15	0.045	0.43	0.048	0.464	5	58
	2	0-15	0.105	0.48	0.097	0.557	60	13
	3	0-15	0.031	0.44	0.035	0.472	5	26
		15-30	0.029	0.39	0.026	0.363	5	11
	4	0-15	0.030	0.86	0.030	lost	10	-
		15-30	0.025	0.53	0.024	0.710	8	37
		30-45	0.019	0.50	0.020	0.527	5	24
Controls	1	0-15	0.020	0.33	0.022	0.434	25	3
		15-30	0.021	0.31	0.023	0.400	148	1
	2	0-15	0.022	0.36	0.022	0.398	8	23
		15-30	0.021	0.34	0.020	0.451	3	26

[a] Averages of 2 analyses run at adifferent time from other samples. These are somewhat higher than the values used to calculate ^{15}N% in the NO_3^- fraction.

There was essentially no loss of ammonia in the ammonia volatilization experiment after six months (Table 12a, b and c). However, with 2 x normal water there was a decrease in total N and NO_3^- during the six months from October through March. It appears that some NO_3^- was generated in dry and 1 x normal NH_4^+-enriched soils during that same period, but it is difficult to explain any changes in the dry soils during that period. Skujins (1975) suggested N-Serve is lost by volatilization from dry soil. Its effectiveness in preventing nitrification would thus have been very transient.

Two of the three samples stored wet in lab and refrigerator and harvested April 7, 1977 were flooded. There was apparent denitrification in them. However, negligible change in total nitrogen indicates only nitrate was lost, not ammonia or organic nitrogen.

There was a gradual increase in exchangeable NH_4^+ in all soils which initially contained <5 ppm. Data are available for the first six months only. This increase was not related to water treatment. In cases where considerable ammonia was added there is little evidence for loss by volatilization from April through September (Tables 12b, h and k).

The denitrification experiment (Table 12j, k and l) suggests there was considerable loss of NO_3^- and total nitrogen from watered soils from October through March, but no change from April to October. This is in contrast to increases in nitrate found in shrub soils which appeared to be related to mineralization of organic nitrogen and occurred throughout the year.

It should be emphasized that these results are preliminary and subject to change upon reanalysis of some samples and a closer examination of the data.

Acetylene Reduction

Acetylene Reduction by Roots

Ethylene production by roots of five small *Yucca schidigera* harvested January 27, 1976 is reported in Table 13. There is a strong association of ethylene production with the presence of acetylene, suggesting nitrogen fixation associated with *Yucca* roots. In three of the five plants, ethylene produced from 72-141 hr exceeded our rule of thumb for maximum endogenous production (100 ng/gdw/hr; Hunter et al., 1976b). However, the lag in production seen from 0-71 hr suggests the ethylene produced is a result of incubation conditions rather than nitrogen fixation in the field. Lichen crust taken at the same time showed essentially no acetylene reduction.

The above sample developed a considerable mold population as incubation continued. We repeated the experiment as reported in Table 14. Before incubation a subsample was split into stele and epidermis and these portions incubated separately.

The form of basal roots differed between small and large *Yucca*. In the small *Yucca* the root stele is enlarged for several inches from the base, while large *Yucca* did not exhibit this swelling. The relative proportions of stele and epidermis are thus different, indicated by weights reported in Table 14.

In this experiment, started March 10, there is no convincing evidence for nitrogen fixation. The lag in ethylene production is still present, but a production rate greater than 100 ng/gdw/hr was not found in any of the 20 whole root samples. Incubation for the final 15 days without acetylene did not reduce ethylene production in the whole roots.

Table 15 reports ethylene production by roots of nine Mohave Desert species. Each value is an average of five, one incubated without acetylene. There was great variability among roots, but acetylene appeared to have no effect on ethylene production rates. On a scale of 5 (highest), the ethylene production by roots without acetylene varied from 2.08 (*Ambrosia dumosa* and *Lycium andersonii*) to 3.56 (*Krameria parvifolia*). If all ethylene were produced by reduction of acetylene these roots would all have ranked 5.

Rates of ethylene production increased approximately tenfold between February and May. Since these were incubated in the field this is likely due to a combination of factors, including temperature and physiological state of the root. Some species differences are also apparent.

Only one sample exceeded 100 ng/gdw/hr (*Yucca*, April 27). Hence we feel these results cannot be construed to indicate fixation of nitrogen. They represent endogenous production of ethylene by shrub roots.

Soil and Litter Acetylene Reduction

Ethylene production by soil and litter samples taken February 3 is reported in Table 16. There is a tendency toward increasing ethylene production with time, except in lichen crust and litter. However, production rates are well below values indicative of significant fixation, except for the later incubation period in the single algal sample from the glasshouse.

The small amount of ethylene present in most vials led us to suspect ethylene contamination in one of the reagents. Table 17 shows there is a small amount of ethylene produced by wet litter with and without acetylene. Dry soil and dry litter adsorbed a small amount of ethylene.

With use of the high concentrations of acetylene it is easy to get a trace of contamination from poorly flushed syringes. However, a careful check of the gas chromatograph charts shows a trace of acetylene in all but one serum bottle, even where nothing was added to the bottle, and where there was no chance of syringe contamination. Hence we believe the serum bottle stoppers produce a trace of acetylene. Larger traces were associated with litter and soils.

In several experiments a loss of acetylene from bottles containing dry soils, especially those from bare areas, was noticed (Table 18). Water (15%) was added to two such samples. Over the next half hour, acetylene peak heights increased 48 and 42%, indicating dry soils adsorb acetylene and release it upon wetting.

Table 12. Nitrate, exchangeable ammonium and Kjeldahl nitrogen concentrations in field-incubated soils, and changes in these fractions during a one-yr incubation

12a. Soil nitrate concentrations during the ammonia volatilization experiment

Treatment				NITRATE-N, µg/g ± sd					
				0	1 wk	1 mo	3 mo	6 mo	1 yr
Water	Fertilizer	Soil	Other	Apr 7	Apr 14	May 7	Jul 7	Oct 12	Apr 7
0	$-NH_4$	Bare	Sterile + N-Serve	36 ± 6	25 ± 14	18 ± 11	43 ± 2	39 ± 5	33 ± 16
	$+NH_4$	Bare		18 ± 2	20 ± 1	29 ± 1	33 ± 1	26 ± 1	50 ± 5
1X	$-NH_4$	Bare		27 ± 2	28 ± 2	40 ± 3	34 ± 3	43 ± 4	15 ± 8
	$+NH_4$	Bare		24 ± 2	7 ± 9	30 ± 1	20 ± 1	27 ± 2	54 ± 37
2X	$-NH_4$	Bare		19 ± 2	22 ± 2	26 ± 5	29 ± 3	32 ± 4	6 ± 6
	$+NH_4$	Bare		22 ± 1	14 ± 8	31 ± 4	25 ± 3	30 ± 1	3 ± 2
	(rerun)			Jul 7	Jul 14	Aug 7	Oct 12	Feb 18	Jul 21
0	$-NH_4$	Bare	Sterile + N-Serve	3.0 ± 1.7	1.2 ± 0.1	1.2 ± 0.5	2.4 ± 0.2	-	-
	$+NH_4$	Bare		1.1 ± 0.1	2.0 ± 1.0	1.8 ± 1.7	2.8 ± 1.3	-	-
1X	$-NH_4$	Bare		0.4 ± 0.3	2.3 ± 1.2	1.6 ± 0.7	2.2 ± 0.8	-	-
	$+NH_4$	Bare		1.3 ± 1.0	1.2 ± 0.2	2.0 ± 0.6	5.4 ± 2.0	-	-
2X	$-NH_4$	Bare		0.4 ± 0.1	1.1 ± 0.3	1.3 ± 0.1	2.1 ± 0.3	-	-
	$+NH_4$	Bare		1.3 ± 0.5	0.6 ± 0.1	2.0 ± 0.4	3.5 ± 0.6	-	-

12b. Soil exchangeable ammonium concentrations during the ammonia volatilization experiment

Treatment				AMMONIUM-N, µg/g ± sd					
				0	1 wk	1 mo	3 mo	6 mo	1 yr
Water	Fertilizer	Soil	Other	Apr 7	Apr 14	May 7	Jul 7	Oct 12	Apr 7
0	$-NH_4$	Bare	Sterile + N-Serve	2.0 ± 0.6		8.3 ± 1.1	1.9 ± 0.2	6.0 ± 0.1	-
	$+NH_4$	Bare		62 ± 16	44 ± 7	42 ± 7	57 ± 8	64 ± 7	-
1X	$-NH_4$	Bare		1.0 ± 0.0	1.2 ± 0.3	1.5 ± 0.1	2.1 ± 0.1	6.8 ± 2.4	-
	$+NH_4$	Bare		40 ± 4	38 ± 4	47 ± 6	44 ± 5	64 ± 7	-
2X	$-NH_4$	Bare		3.6 ± 1.2	3.5 ± 1.4	2.8 ± 0.5	2.4 ± 0.3	6.5 ± 1.2	-
	$+NH_4$	Bare		79 ± 14	35 ± 5	50 ± 3	49 ± 3	68 ± 5	-
	(rerun)			Jul 7	Jul 14	Aug 7	Oct 12	Feb 18	Jul 21
0	$-NH_4$	Bare	Sterile + N-Serve	2.7 ± 0.1	3.5 ± 0.3	4.4 ± 0.8	3.2 ± 1.7	-	-
	$+NH_4$	Bare		57 ± 20	50 ± 1	53 ± 7	67 ± 3	-	-
1X	$-NH_4$	Bare		4.0 ± 1.0	3.4 ± 0.2	4.5 ± 1.5	2.4 ± 0.6	-	-
	$+NH_4$	Bare		70 ± 1	57 ± 7	60 ± 5	60 ± 2	-	-
2X	$-NH_4$	Bare		3.8 ± 0.5	4.2 ± 0.8	3.9 ± 1.1	2.8 ± 1.4	-	-
	$+NH_4$	Bare		73 ± 8	52 ± 2	56 ± 6	53 ± 8	-	-

12f. Total soil N during the litter decomposition experiment

Treatment				TOTAL N, µg/g ± sd					
				0	1 wk	1 mo	3 mo	6 mo	1 yr
Water	Fertilizer	Soil	Other	Apr 7	Apr 14	May 7	Jul 7	Oct 12	Apr 7
0		Bare		270	260	270	270	277 ± 12	293 ± 6
		Shrub		770	770	800 ± 20	770	790 ± 17	880 ± 44
		Bare + litter		610	590	590	580	613 ± 215	673 ± 12
1X		Bare		270	330 ± 26	270	270	400 ± 26	303 ± 20
		Shrub		770	780	870	760	753 ± 40	817 ± 46
		Bare + litter		580	590	640	610	803 ± 67	653 ± 25
2X		Bare		300	290	310	310	267 ± 32	280 ± 20
		Shrub		830	830	840	900	945 ± 64	867 ± 91
		Bare + litter		370	650	630	640	577 ± 25	400 ± 141
		Shrub (Lab)			680			667 ± 32	567 ± 150
		Shrub (Refrig.)		630	670	700	640	673 ± 12	633 ± 90

12g. Soil nitrate during the nitrification experiment

Treatment				NITRATE-N, µg/g ± sd					
				0	1 wk	1 mo	3 mo	6 mo	1 yr
Water	Fertilizer	Soil	Other	Apr 7	Apr 14	May 7	Jul 7	Oct 12	Apr 7
0									
	$+NH_4$	Bare		30 ± 1	21 ± 1	36 ± 3	23 ± 5	31 ± 3	44 ± 12
1X	$+NH_4$	Shrub		9 ± 3	11 ± 2	17 ± 3	7 ± 0	14 ± 2	12 ± 3
	$+NH_4$	Bare		31 ± 2	33 ± 2	40 ± 1	20 ± 1	33 ± 1	36 ± 10
2X	$+NH_4$	Shrub		6 ± 7	11 ± 2	15 ± 1	8 ± 1	17 ± 1	26 ± 4
	$+NH_4$	Bare		26 ± 2	26 ± 5	38 ± 1	15 ± 3	35 ± 1	17 ± 15
	$+NH_4$	Shrub		9 ± 2	11 ± 2	16 ± 1	7 ± 1	19 ± 3	14 ± 5

12h. Soil exchangeable ammonium during the nitrification experiment

Treatment				AMMONIUM-N, µg/g ± sd					
				0	1 wk	1 mo	3 mo	6 mo	1 yr
Water	Fertilizer	Soil	Other	Apr 7	Apr 14	May 7	Jul 7	Oct 12	Apr 7
0									
	$+NH_4$	Bare		130 ± 41	108 ± 0	153 ± 24	132 ± 25	159 ± 8	-
1X	$+NH_4$	Shrub		176 ± 43	77 ± 13	120 ± 14	116 ± 21	76 ± 58	-
	$+NH_4$	Bare		119 ± 10	103 ± 24	176 ± 25	93 ± 14	112 ± 6	-
2X	$+NH_4$	Shrub		131 ± 11	120 ± 13	159 ± 24	110 ± 15	110 ± 11	-
	$+NH_4$	Bare		135 ± 10	86 ± 11	115 ± 21	95 ± 10	116 ± 3	-
	$+NH_4$	Shrub		140 ± 29	131 ± 14	151 ± 17	101 ± 14	125 ± 47	-

12c. Total soil N during the ammonia volatilization experiment

Treatment				TOTAL N, µg/g ± sd					
				0	1 wk	1 mo	3 mo	6 mo	1 yr
Water	Fertilizer	Soil	Other	Apr 7	Apr 14	May 7	Jul 7	Oct 12	Apr 7
0	-NH_4	Bare	Sterile	270	250	270	260	297 ± 15	313 ± 40
	+NH_4	Bare		330	300	310	240	323 ± 6	410 ± 20
1X	-NH_4	Bare	+	210	280	270	270	290 ± 10	307 ± 31
	+NH_4	Bare		260	300	277 ± 38	280	317 ± 23	370 ± 0
2X	-NH_4	Bare	N-Serve	260	260	270	280	243 ± 6	153 ± 31
	+NH_4	Bare		320	310	360	330	297 ± 31	200 ± 118
	(rerun)			Jul 7	Jul 14	Aug 7	Oct 12	Feb 18	Jul 21
0	-NH_4	Bare	Sterile	257 ± 38	160	180	227 ± 2	270 ± 50	-
	+NH_4	Bare		250	260 ± 20	240	253 ± 15	273 ± 40	-
1X	-NH_4	Bare	+	210	220	220	233 ± 15	220 ± 0	-
	+NH_4	Bare		250	210	220	263 ± 6	250 ± 10	-
2X	-NH_4	Bare	N-Serve	270	200	210	197 ± 12	243 ± 15	-
	+NH_4	Bare		-	270	260	277 ± 25	273 ± 12	-

12d. Soil nitrate concentrations during the litter decomposition experiment

Treatment				NITRATE-N, µg/g ± sd					
				0	1 wk	1 mo	3 mo	6 mo	1 yr
Water	Fertilizer	Soil	Other	Apr 7	Apr 15	May 7	Jul 7	Oct 12	Apr 7
0		Bare		29 ± 1	27 ± 5	30 ± 0	33 ± 1	29 ± 4	28 ± 2
		Shrub		7.0 ± 0.3	11.9 ± 1.1	11.2 ± 0.6	10.6 ± 0.4	16.5 ± 4.0	32 ± 14
		Bare + litter		29.1 ± 0.8	27.9 ± 0.7	37.1 ± 1.9	29.7 ± 4.6	23.6 ± 15.7	41 ± 25
1X		Bare		29 ± 2	33 ± 0	36 ± 2	32 ± 1	30 ± 1	57 ± 32
		Shrub		10.5 ± 1.4	9.5 ± 0.6	13.1 ± 0.3	10.8 ± 0.8	14.6 ± 3.5	20 ± 6
		Bare + litter		29 ± 2	32 ± 1	26 ± 1	35 ± 1	29 ± 4	72 ± 3
2X		Bare		23 ± 4	32 ± 1	37 ± 2	26 ± 1	33 ± 2	17 ± 15
		Shrub		8.0 ± 0.9	10.4 ± 1.4	13.9 ± 1.3	12.7 ± 0.8	21.7 ± 4.0	11 ± 8
		Bare + litter		17 ± 2	27 ± 2	40 ± 1	29 ± 2	25 ± 3	0 ± 0
		Shrub (Lab.)		2.9 ± 1	2.2 ± 0.3	1.0 ± 0.5	3.2 ± 0.2	4.4 ± 0.5	0 ± 0
		Shrub (Refrig.)		29 ± 1	5.5 ± 1.4	2.2 ± 1.7	3.0 ± 0.2	3.2 ± 0.3	0 ± 0

12e. Soil exchangeable ammonium concentrations during the litter decomposition experiment

Treatment				AMMONIUM-N, µg/g ± sd					
				0	1 wk	1 mo	3 mo	6 mo	1 yr
Water	Fertilizer	Soil	Other	Apr 7	Apr 14	May 7	Jul 7	Oct 12	Apr 7
0		Bare		1.0 ± 0.0	1.0 ± 0.0	3.2 ± 0.8	1.6 ± 0.3	5.8 ± 1.1	-
		Shrub		1.8 ± 0.9	1.0 ± 0.0	6.3 ± 0.3	3.3 ± 0.3	9.7 ± 1.1	-
		Bare + litter		3.7 ± 0.5	1.9 ± 0.0	5.1 ± 0.8	4.9 ± 0.9	8.3 ± 4.5	-
1X		Bare		1.0 ± 0.0	1.0 ± 0.0	1.7 ± 0.5	2.3 ± 1.4	6.6 ± 1.9	-
		Shrub		1.1 ± 0.2	1.1 ± 0.1	2.9 ± 0.5	3.7 ± 0.4	10.8 ± 6.6	-
		Bare + litter		1.6 ± 0.0	4.2 ± 4.2	5.4 ± 1.3	6.1 ± 1.0	11.8 ± 0.9	-
2X		Bare		4.0 ± 1.4	1.7 ± 0.6	1.7 ± 0.3	3.6 ± 0.4	5.2 ± 1.1	-
		Shrub		9.5 ± 0.7	2.0 ± 0.5	2.9 ± 0.1	5.0 ± 1.3	11.0 ± 2.5	-
		Bare + litter		10.1 ± 2.5	4.5 ± 1.7	4.7 ± 0.3	6.2 ± 1.0	6.4 ± 1.7	-
		Shrub (Lab)		2.3 ± 0.1	1.0 ± 0.0	1.0 ± 0.0	3.2 ± 1.5	5.2 ± 0.6	-
		Shrub (Refrig.)		2.0 ± 0.1	1.1 ± 0.2	1.0 ± 0.0	2.9 ± 0.4	4.8 ± 0.8	-

12i. Total soil N during the nitrification experiment

Treatment				TOTAL N, µg/g ± sd					
				0	1 wk	1 mo	3 mo	6 mo	1 yr
Water	Fertilizer	Soil	Other	Apr 7	Apr 14	May 7	Jul 7	Oct 12	Apr 7
0									
	+NH_4	Bare		410	380	417 ± 25	390	363 ± 15	410 ± 17
	+NH_4	Shrub		923 ± 15	950	940	990	920 ± 61	980 ± 46
1X	+NH_4	Bare		390	453 ± 21	430	390	467 ± 25	380 ± 26
	+NH_4	Shrub		930	950	940	910	987 ± 91	843 ± 32
2X	+NH_4	Bare		460	460	400	400	497 ± 6	353 ± 35
	+NH_4	Shrub		890	910	963 ± 81	910	1013 ± 59	877 ± 42

12j. Soil nitrate during the denitrification experiment

Treatment				Nitrate-N, µg/g ± sd					
				0	1 wk	1 mo	3 mo	6 mo	1 yr
Water	Fertilizer	Soil	Other	Apr 7	Apr 14	May 7	Jul 7	Oct 12	Apr 7
0	+NO_3	Bare	N-Serve	88 ± 9	89 ± 12	64 ± 22	33 ± 28	97 ± 27	146 ± 92
	+NO_3	Shrub	"	86 ± 26	93 ± 36	72 ± 2	50 ± 8	125 ± 54	56 ± 37
1X	+NO_3	Bare	"	122 ± 31	96 ± 7	290 ± 113	127 ± 31	155 ± 60	22 ± 15
	+NO_3	Shrub	"	72 ± 25	68 ± 14	81 ± 35	38 ± 1	77 ± 5	40 ± 9
2X	+NO_3	Bare	"	58 ± 13	70 ± 14	107 ± 19	42 ± 6	71 ± 20	41 ± 13
	+NO_3	Shrub	"	112 ± 35	118 ± 47	137 ± 12	78 ± 7	150 ± 10	70 ± 23
0	-NO_3	Bare	"	34 ± 4	28 ± 5	31 ± 4	17 ± 1	31 ± 4	38 ± 5
	-NO_3	Shrub	"	13	9 ± 3	9 ± 1	10 ± 1	14 ± 5	8 ± 3
1X	-NO_3	Bare	"	29 ± 2	28 ± 15	41 ± 10	27 ± 5	32 ± 3	22 ± 39
	-NO_3	Shrub	"	12 ± 1	9 ± 1	12 ± 1	10 ± 1	15 ± 0	33 ± 6
2X	-NO_3	Bare	"	26 ± 4	16 ± 4	20 ± 1	20 ± 3	29 ± 3	22 ± 9
	-NO_3	Shrub	"	13 ± 1	11 ± 0	13 ± 0	11 ± 1	15 ± 1	9 ± 3

12k. Soil exchangeable ammonium during the denitrification experiment

Treatment				Ammonium-N, µg/g ± sd					
				0	1 wk	1 mo	3 mo	6 mo	1 yr
Water	Fertilizer	Soil	Other	Apr 7	Apr 14	May 7	Jul 7	Oct 12	Apr 7
0	+NO_3	Bare	N-Serve	3.6 ± 2.9	2.0 ± 0.8	7.7 ± 0.8	4.6 ± 0.3	7.7 ± 1.8	-
	+NO_3	Shrub	"	45 ± 1	49 ± 4	52 ± 4	52 ± 3	54 ± 7	-
1X	+NO_3	Bare	"	3.4 ± 1.2	1.4 ± 0.1	3.6 ± 0.5	4.7 ± 0.2	8.8 ± 4.1	-
	+NO_3	Shrub	"	56 ± 4	44 ± 3	61 ± 4	53 ± 4	56 ± 1	-
2X	+NO_3	Bare	"	3.7 ± 1.3	3.6 ± 0.0	3.4 ± 0.3	4.3 ± 0.1	10.3 ± 1.8	-
	+NO_3	Shrub	"	35 ± 6	17 ± 5	42 ± 15	45 ± 7	60 ± 6	-
0	-NO_3	Bare	"	3.4 ± .6	2.7 ± 1.2	2.9 ± .2	5.7 ± 1.2	10.5 ± 1.6	-
	-NO_3	Shrub	"	38 ± 5	32 ± 7	39 ± 3	45 ± 4	47 ± 6	-
1X	-NO_3	Bare	"	1.9 ± 0.6	1.0 ± 0.0	2.9 ± 0.2	4.8 ± 0.4	8.8 ± 2.8	-
	-NO_3	Shrub	"	16 ± 1	22 ± 2	25 ± 1	32 ± 4	38 ± 2	-
2X	-NO_3	Bare	"	2.8 ± 1.1	1.0 ± 0.0	2.8 ± 0.8	5.6 ± 0.8	5.5 ± 0.8	-
	-NO_3	Shrub	"	26 ± 3	21 ± 1	30 ± 5	40 ± 3	45 ± 6	-

12l. Total soil N during the denitrification experiment

Treatment				TOTAL N, µg/g ± sd					
				0	1 wk	1 mo	3 mo	6 mo	1 yr
Water	Fertilizer	Soil	Other	Apr 7	Apr 14	May 7	Jul 7	Oct 12	Apr 7
0	+NO_3	Bare	N-Serve	320	330	330	360	540 ± 35	320 ± 10
	+NO_3	Shrub	"	840	820	860	920	1003 ± 67	643 ± 172
1X	+NO_3	Bare	"	340	340	350	360	347 ± 38	307 ± 40
	+NO_3	Shrub	"	900	880 ± 26	890	830	807 ± 59	817 ± 83
2X	+NO_3	Bare	"	290	290	300	360	310 ± 0	263 ± 15
	+NO_3	Shrub	"	900	920	850	870	893 ± 561	767 ± 137
0	-NO_3	Bare	"	260	280 ± 26	260	250	380 ± 36	280 ± 17
	-NO_3	Shrub	"	610	840	810 ± 113	750	907 ± 15	847 ± 21
1X	-NO_3	Bare	"	290	270	290	280	287 ± 12	267 ± 29
	-NO_3	Shrub	"	790	780	790	810	780 ± 10	730 ± 36
2X	-NO_3	Bare	"	270	260	260	270	270 ± 10	223 ± 21
	-NO_3	Shrub	"	833 ± 35	800	750	820	783 ± 38	437 ± 224

Table 13. Acetylene-associated ethylene production by roots of *Yucca schidigera* harvested Jan 27, 1976. Roots were incubated in an argon-O_2-CO_2 atmosphere with and without acetylene

	Acetylene	0-71 hrs	72-141 hrs	142-420 hrs
		Ethylene production rate, ng/gdw/hr		
Yucca # 1 roots	+	1.7	180.2	37.1
roots	0	-	-	0.1
soil	+	0.1	<0	0
Yucca # 2 roots	+	3.8	163.7	10.3
roots	0	0.4	<0	<0
soil	+	0.1	0	0
Yucca # 3 roots	+	1.7	18.2	9.8
roots	0	1.8	<0	0
soil	+	T	0.1	0
Yucca # 4 roots	+	1.8	525.0	57.8
roots	0	1.8	<0	0
soil	+	T	T	0
Yucca # 5 roots	+	1.3	<0	0
roots	0	0.9	<0	0
soil	+	T	T	0
Lichen crust	+	0	0.9	
	+	0	0	
	+	0	0	
	+	T	T	
	+	T	0.1	

Table 14. Ethylene production rates of *Yucca schidigera* roots incubated in an argon-O_2-CO_2-acetylene atmosphere starting Mar 10, 1977. For all values N = 10

	Days After Harvest 0-4	1-8	5-16	13-22	21-36	Weight
	ng/hr/gdw ± se					g
Large Yucca						
Whole root	2 ± 1	8 ± 2	6 ± 1	11 ± 2	10 ± 3[a]	1.19 ± .12
Stele	3 ± 2	25 ± 11	39 ± 27			0.30 ± .05
Epidermis	0 ± 0	0.3 ± 0.3	0.0 ± 0.2			0.89 ± .09
Small Yucca						
Whole roots	0.7 ± 0.4	4 ± 1	0.2 ± 0.4	11 ± 3	5 ± 3[a]	1.67 ± .07
Stele	4 ± 1	4 ± 2	-2 ± 1			1.22 ± .11
Epidermis	0 ± 0	0.7 ± 0.4	0.0 ± .3			0.43 ± .05

[a]During the final incubation period for whole roots, half the samples were incubated without acetylene. There was no significant difference in ethylene production by these samples.

Table 15. Ethylene production by shrub roots incubated in soil in the field for 7 days under argon-CO_2-O_2-acetylene atmospheres

Date started	Ace sho	Amb dum	Atr con	Eph nev	Kra par	Lar tri	Lep fre	Lyc and	Yuc sch
	ng/gdw/hr[a]								
Feb 16	.22 ± .09	.24 ± .14			0 ± 0	.38 ± .23		0.6 ± 0.6	
23			.21 ± .09	.04 ± .03			1.3 ± .4		1.0 ± 1.0
Mar 2	.16 ± .06	.15 ± .15			0.09 ± .04	1.6 ± 1.2		0.20 ± 0.09	
10			5.9 ± 1.4	.61 ± .61			1.9 ± 0.5		.24 ± .08
15	.82 ± .58	.61 ± .26			0 ± 0	3.9 ± 1.3		.09 ± .09	
22			2.7 ± 1.4	1.2 ± 0.5			0.6 ± 0.3		.74 ± .36
Apr 5	2.6 ± 1.6	2.4 ± 0.9			0.9 ± 0.6	110. ± 3.		6.1 ± 4.9	
14			4.9 ± 1.8	0.6 ± 0.6			0.4 ± 0.4		.17 ± .12
20	2.6 ± 1.5	2.0 ± 0.6			0.4 ± 0.3	15. ± 7.		0.5 ± 0.5	
27			4.4 ± 2.0	0.3 ± 0.2			2.3 ± 1.7		33. ± 33.
May 3	8.9 ± 3.7	9.6 ± 4.0			2.0 ± 0.8	20. ± 6.		0.6 ± 0.5	
10			11.0 ± 5.2	0.5 ± 0.3			28. ± 14.		1.9 ± 1.5
17	5.0 ± 5.0	16.9 ± 3.5			1.3 ± 1.0	1.1 ± 0.7		4.5 ± 3.2	
24			10.3 ± 2.2	1.4 ± 0.7			6.8 ± 2.5		3.6 ± 1.5
31	0.4 ± 0.4	12.5 ± 5.1	10.1 ± 3.7	2.3 ± 0.8	19. ± 11	30. ± 18.	6.1 ± 0.6	1.1 ± 0.7	5.3 ± 1.3
Jun 14		7.9 ± 7.9			6.8 ± 3.3	1.9 ± 1.9			

[a]Each value represents five replicates, one without acetylene.

Table 16. Ethylene production under acetylene-argon-O_2-CO_2 atmosphere by surface soils from beneath shrubs in Rock Valley. Samples were taken Feb 3, 1976

Sample Site	n	Ethylene production 0-13 days	13-26 days
		ng ethylene/gdw/hr ± se	
Intershrub open areas	33	0 ± 0	.002 ± .002
Lichen crust, Mercury Valley	5	3.5 ± 1.8	.06 ± .04
Beneath Lycium andersonii	10	.02 ± .01	.09 ± .02
Beneath Larrea tridentata	10	.02 ± .01	.07 ± .01
Beneath Ambrosia dumosa	10	.08 ± .03	.10 ± .02
Beneath Ephedra nevadensis	10	.03 ± .01	.07 ± .02
Beneath Krameria parvifolia	10	.02 ± .01	.05 ± .01
Beneath Lycium pallidum	10	.03 ± .02	.04 ± .01
Beneath Grayia spinosa	10	.03 ± .01	.06 ± .02
Beneath Salazaria mexicana	10	0 ± 0	.04 ± .02
Litter samples, 2 per species	17	21. ± 12[a]	19. ± 11.
Algal crust from glasshouse	1	0	81.

[a]Rate for litter samples averaged 3.7 ± 2.0 for the first 5 days, hence 33.5 for the next 8 days.

Table 17. Ethylene concentration in serum bottles as affected by our standard acetylene reduction assay procedures. Each treatment was replicated three times

TREATMENT Argon	Water cc	Litter g ± se	Acetylene ml/125 ml	Ethylene µ/l	Soil	ETHYLENE 168 hr	336 hr Integrator units ± se[a]	ACETYLENE 168 hr	336 hr mm[b]
+	0.5	2.8 ± 1.5	0	0	0	T	0.5 ± 0.5	T	1.1 ± .7
+	0	2.1 ± 0.4	0	0	0	0	0	T	T
0	0.5	2.7 ± .5	0	0	0	0.4 ± 0.4	4.1 ± 0.1	T	T
+	0	2.3 ± 0.2	0.2	0	0	0	0	7.7 ± .2	8.4 ± .7
+	0.5	2.5 ± 0.1	0.2	0	0	0.3 ± 0.2	3.1 ± 1.4	7.7 ± .2	7.7 ± .2
+	0.5	2.4 ± 0.5	0.2	5	0	1.5 ± 0.6	2.9 ± 1.1	7.9 ± .1	8.0 ± .0
+	0.5	2.5 ± 0.6	0	5	0	1.8 ± 0.6	2.3 ± 1.2	T	T
+	0	2.2 ± 0.3	0	5	0	0.7 ± 0.7	1.4 ± 1.4	T	T
0	0	0	0	0	0	0	0	T	T
+	0	0	0	0	0	0	0	T	T
+	0.5	0	0	0	0	0	0	T	T
+	0.5	0	0	0	+	0	0	T	T
+	0	0	0	0	+	0	0	T	T
+	0.5	0	0.2	0	+	0	0	8.1 ± .1	7.8 ± .2
+	0	0	0	5	+	T	T	T	T

[a]One unit ≈ 2ppm in the 125-ml serum bottles.

[b]Peak width at middle of chart.

Table 18. Ethylene production by Mohave Desert soils following one week's incubation in a glasshouse. Soils were incubated (with water) from Jul 2 to Jul 9, 1977 and flushed with argon-O_2-CO_2 and acetylene (.2 ml, 10% acetylene). Desert soils from Mercury Valley, sagebrush interspaces soil from Shoshone Mountain

Soil Site	% Water	Acetylene Peaks[a]			Ethylene Units[b]		
Rodent mound	0	2.8	3.5	3.3	0	0	0
	5	5.7	5.3	5.5	0	0	0
	15	5.7	5.7	5.8	T	0	1.3
Desert pavement	0	3.5	4.0	4.3	0	0	0
	5	5.4	5.3	5.5	0	0	0
	15	5.5	5.7	5.5	0	0	0
Wash soil with lichen crust	0	5.5	3.3	3.0	0	0	0
	5	3.3	5.0	5.5	0	0	0.3
	15	5.5	5.3	3.3	0.6	0.9	1.3
Mountain soil, sagebrush community	15	5.3	5.3	5.7	6.5	6.2	12.8

[a]Acetylene peak width at 50 units on gas chromatograph charts.

[b]One unit is approximately 2 ppm, 125-ml serum bottles.

Table 19. Soil nitrogen concentrations and ethylene production by Mohave Desert surface soils. Five soils of each type were incubated from Nov 23 to Dec 2 in a glasshouse under argon-CO_2-O_2-acetylene atmosphere

Soil Type	Exch. NH_4^+-N µg/g ± se	Soluble NO_3-N µg/g ± se	Total-N µg/g ± se	Ethylene Units[a] Units ± se
Rodent mound	8 ± 3	10 ± 2	750 ± 200	0
Under *Lycium* shrub	15 ± 1	87 ± 18	2840 ± 90	1.1 ± 0.3
Lichen crust	15 ± 5	6.0 ± 1.4	1130 ± 230	17 ± 5
Vesiculated desert pavement	6 ± 1	4.6 ± 0.7	360 ± 70	0
Desert pavement	9 ± 1	6.2 ± 0.3	420 ± 50	0
Sagebrush interspaces	11 ± 1	3.8 ± 1.1	1190 ± 80	0

[a]One unit is approximately 2ppm in 125-ml serum bottle.

Table 18 also shows soils from Shoshone Mountain sagebrush interspaces produced much more ethylene (near 1 ng/gdw/hr) than do Mohave Desert shrub community interspaces. The Shoshone soil was much darker in color, indicating greater organic matter content.

Table 19 reports results from a similar experiment performed between November 23 and December 2. In this case lichen crust was much more active, while soil from sagebrush interspaces (from Mine Mountain) showed no activity. Soil nitrogen fractions are also reported for the same samples. Inorganic nitrogen fractions for the February 3 soil samples (Table 16) are reported in Table 20. In both cases ammonium was enriched, but quite variable, under lichen crust. In fact, the highest exchangeable ammonium was found in samples adhering to lichen crust. Total nitrogen under lichen crust was also higher than would be expected for the bare desert pavement areas where it occurs.

Table 20. Nitrate and ammonia concentrations in surface soils (0-2 cm) under shrubs in Rock Valley

	n	Soluble NO_3^--N µg/g ± se	Exchangeable NH_4^+-N µg/g ± se
Bare areas	33	1.9 ± 0.6	2.6 ± 0.4
Adherent to lichen crust	5	0.0 ± 0.0	± 9
Ambrosia dumosa	10	8 ± 2	3.5 ± 0.6
Ephedra nevadensis	10	10 ± 4	2.9 ± 0.4
Gravia spinosa	10	10 ± 3	2.5 ± 0.6
Krameria parvifolia	9	3.9 ± 0.8	4.8 ± 1.1
Larrea tridentata	9	7 ± 3	2.9 ± 0.5
Lycium andersonii	10	31 ± 4	4.2 ± 0.9
Lycium pallidum	10	8 ± 3	2.3 ± 0.6
Salazaria mexicana[a]	9	10 ± 3	5.6 ± 1.0

[a]Mercury Valley

Table 21. Ethylene production by Mohave Desert (Mercury Valley) soils over the course of a single day. Soils were sampled and injected between 0500 and 0600 Jun 30, 1976, and analyzed throughout that day and the morning of Jul 1. Units are ethylene peak integrator units, approximately equal to 2 ppm ethylene

Treatment	Soil 10% C_2H_2 15% H_2O		Soil 10% C_2H_2		Air Only		Soil 10% C_2H_2				Soil Only	
Replicate	1	2	1	2	1	2	1	2	3	4	1	2
Time												
6/30 AM	1.8	1.8	2.6	1.0	0.0	0.0	1.5	1.6	1.8	2.3	0.0	0.0
				0.9	0.0	0.0				1.3	0.0	
PM	1.7	1.3	1.8	1.5	0.0	0.0	1.6	1.6	0.8	1.2	0.0	0.0
		1.0						1.8				0.0
7/1 AM	1.6		1.0	1.3	0.0	0.0	1.0	1.4	1.4	1.3	0.0	0.0
	1.7											
Average + se	1.5 ± .1		1.4 ± .2		0.0 ± 0.0		1.5 ± 0.1				0.0 + 0.0	

Table 21 shows results of an attempt to duplicate Skujins' (1976) data which showed diurnal fluctuation in Rock Valley acetylene reduction. The use of 10% C_2H_2 in air, rather than in Ar-CO_2-O_2 was an attempt to duplicate his techniques, although a larger serum bottle (125-ml) was used. We were not able to detect any ethylene production by soils, although Table 21 shows a significant level of contaminating ethylene in the acetylene.

Microorganisms

In February 1976, rinse water from litter samples was used to inoculate N-free agar plates in an attempt to isolate N-fixing bacteria. The plates were left too long, and were overgrown by a fungus, tentatively identified as a *Pullularia* species. Several experiments were run on the *Pullularia* isolates and further isolates from litter (Tables 22 and 23). All organisms positive for N fixation in Table 22 were tested in agar containing streptomycin and tetracycline, in an attempt to eliminate bacterial fixation. It is apparent that tetracycline severely inhibited most acetylene-reducing isolates, while streptomycin did not.

Table 22. Ethylene production (acetylene reduction) associated with organisms growing on Mohave Desert plant litter mixed with N-free agar, and with "fungi" isolated from such litter

	Treatment[a]		April 9		April 16		April 19		May 15	
	Acetylene	Argon	Acetylene	Ethylene	Acetylene	Ethylene	Acetylene	Ethylene	Acetylene	Ethylene
Aca sho litter	-	-	0	0	0	T				
Aca sho litter	+	+	8.0	T	7.5	0.25	-	-	7.0	1.0
Yuc sch litter	-	-	0	0			-	T	0	T
Yuc sch litter	+	+	8.0	T	T	56	-	-	T	1.0
Fungus from Atr con	-	-	0	0.4	-	-	T	0.2	0	T
	+	+	5.5	T	-	-	6.0	0.1	3.5	T
Fungus from Aca sho	-	-	0	0	0	T	0	0	0	0
	+	+	8.0	0.5			7.0	276	3.5	293
Fungus from Amb dum	-	-	0	0	0	0	T	0	-	-
	+	+	6.0	0	6.5	0	3.5	0	4.5	0
Fungus from Cer lan	-	-	0	0	0	0	T	2.8	0	0
	+	+	6.0	25.5	5.5	185	T	138	-	-
"Red mold" from Yuc sch	-	-	0	0	0	0	-	-	-	T
	+	+	7.5	1.8	-	-	-	-	-	-
Pullularia sp.	-	-	0	0	0	0	0	0	0	0
	+	+	5.0	0	0	246	T	223	0	30
Control agar	-	-	0	0	-	-	0	0	-	-
	+	+	7.8	0	-	-	5.5	0	6.0	

[a]Units for acetylene are width of acetylene peak (mm) at 50 units on gas chromatograph chart, and for ethylene the integrator units on the same chart. One unit of ethylene is approximately 2 ppm in the 125-ml serum bottles used. Bottles were inoculated and injected with acetylene April 5.

Table 23. Sensitivity of acetylene reduction associated with fungi isolated from Mohave Desert plant litter to the antibiotics streptomycin and tetracycline

Antibiotic	None		Streptomycin + Tetracycline		Streptomycin		Tetracycline	
Source of fungus isolate	July 9	July 14	July 9	July 14	July 9	July 14	July 9	July 14
	Ethylene Units[a]							
Cer lan litter	5	-	10	78	15	56	1	4
Aca sho litter	5	14	0	0	5	30	0	0
Amb dum litter	4	4	T	T	0	0	-	0
Atr con litter	120	270	T	T	4	121	T	T
Yuc sch root	4	8	0	0	12	53	0	0
Yuc sch root	112	217	0	0	114	206	T	T
[illegible] sp	63	178	-	-	88	80	T	T
Pullularia sp	27	167	0	T	T	T	0	0

[a]Fungi incubated from June 12 to July 8 in 35-ml serum bottles on N-free agar in air. On July 8, .2 ml 10% acetylene was injected, without first flushing with Argon-O_2-CO_2. One ethylene unit represents ~ 2 ppm in the 25-ml air volume.

Table 24. Nitrate and ammonia in rain at Mercury, Nevada, during 1976

Date	Precipitation, mm	NH_4^+ µg-N/ml	NH_4^+ kg/ha	NO_3^- µg-N/ml	NO_3^- kg/ha
Feb 6-9	52.4	0.1 ± 0.3	.157	-	-
Mar-April	14.7	-	-	-	-
May 7-8	27.0	<0.1	<.027	2.2	.594
July 16	10.7	0.3	.034	.75	.080
July 26-27	19.0	0.4	.068	.25	.048
July 30	5.2	0.6	.030	1.76	.092
Sept 5	0.5	-	-	-	-
Sept 10	21.6	0.1	.026	.60	.130
Sept 27	3.3	2.7*	.089	.51	.017
Oct 1	30.5	0.1	.037	.54	.165
Dec 30	2.0	-	-	-	-
	Sum 184.9	Weighted Average .245	Sum .415	Weighted Average .958	Sum 1.126
Sums corrected for missing data			.452		1.770

*Not filtered - contained insects.

The lag phase in these cultures is a common finding in growth of microbial colonies. Disappearance of acetylene in the most active cultures confirms the reality of acetylene reduction, but acetylene in the most active cultures confirms the reality of acetylene reduction, but acetylene reduction in less active cultures is not differentiated from endogenous ethylene production. These studies were not continued. Attempts to transfer *Pullularia* to agar containing nitrogen failed, with a number of other fungal contaminates overgrowing the medium.

Nitrate and Ammonium in Rain

Table 24 shows nitrate and ammonium concentrations in rainwater. Although some contamination from dust was unavoidable, the calculated nitrogen input of 2.3 kg/ha is a reasonable upper limit.

Caliche Nitrate

The three dissolved "caliche" samples contained 306, 398 and 621 µg NO_3^--N/g dissolved rock.

DISCUSSION

None of the data reported above are inconsistent with the nitrogen cycle model presented in Figure 4 (Wallace et al., in press). Minor changes might be indicated by the short half-lives found with ^{15}N, e.g. a greater potential mineralization rate or nitrification rate. Similarly the low indicated rate of atmospheric N_2 fixation might be further decreased. Indications of the nitrogen balance experiment reported above are that denitrification and ammonia volatilization losses are small.

The Mohave Desert appears to have a total reserve of N on the order of 100 x annual plant uptake, with immediately available N sufficient for several years' uptake. Input in rain can supply about 10% of annual needs, with fixation of N_2 supplying perhaps 1% of the needs. Although a gradual net loss of N from the desert cannot be ruled out, an equilibrium state or net gain (as NO_3^-) seems most likely. The Chilean nitrate deposits and data of Boyce et al. (1976) suggest deserts may accumulate NO_3^-.

It appears from *Ambrosia* harvest data and enrichment of new tissues by $^{15}NO_3^-$ uptake that N for new growth is supplied by soil reserves, rather than plant reserves. This simplifies consideration of annual needs, which we have estimated from annual production on the basis that new growth depends on soil uptake of nitrogen.

The data indicating root zones with radii of up to 7 m for *Larrea* are consistent with findings that plants several meters distant from irrigated plots tended to be affected by irrigation (Hunter et al. 1976a). The alternative explanation was that horizontal water flow occurred over those distances in the vapor phase. Vollmer et al. (1975) have excavated *Larrea tridentata* roots for distances up to 1.1 m, and one *Krameria parvifolia* root was followed to 3 m. A photograph of a *Larrea* plant with a root several meters long is shown by Wallace and Romney (1972;123). Determining these root lengths by excavation is a formidable task in the very rocky soils of the northern Mohave Desert, and the ^{15}N data, if expanded, would be quite useful.

The short half-lives of 3-4 yr indicated those both in pots in the glasshouse and in the field need clarification. The greenhouse pots received much more water, at average temperatures warmer in winter and cooler in summer than in the field. Under such conditions denitrification, volatilization and plant uptake are unrelated to the field situation. Nevertheless, the non-harvest loss of ^{15}N appears evidence for loss either by denitrification or ammonia volatilization, or immobilization as organic N. In the field the half-life is essentially a half-life for availability, not residence time. As the ^{15}N is bound up in plant tissues, lost as litter or equilibrated with other soil fractions, it is temporarily lost from the available N pool, and these transformations reduce the apparent half-life as measured by falling plant tissue concentrations. We feel after equilibration in the system the apparent half-life will show a considerable increase.

Our acetylene reduction assays show very consistently low or zero fixation of atmospheric ammonia. Almost all ethylene produced, except by microorganisms cultured on N-free agar, can be explained by reactions other than acetylene reduction or by contamination of the acetylene supply. For the few root samples in which a positive acetylene reduction result was found, the lag before significant ethylene production suggests the rates measured are not representative of field conditions. Indeed, given the long incubation periods, the results may be due to attack by decomposing organisms rather than normal rhizosphere microbes.

Nitrogen in rain is the largest apparent input of N to the Mohave Desert. However, there is some evidence that the source of this N is the desert itself. Yaalon (1964) found NH_4^+ concentration in rain increased with soil temperature over calcareous soils, and suggested volatilization was the source. In a study of ammonia in rain in the United States, Junge (1958) attributed increases over the western states to calcareous soil.

Woodmansee (1976) considers rain and dust and direct absorption of NH_3 by plants to be the principal sources of nitrogen input to the short grass prairie.

Table 12 suggests NH_3 volatilization is insignificant. This is similar to results of Skujins (1975, 1976) who found NH_3 volatilization losses of less than 1% of soil NH_4^+ in three weeks, both with and without NH_4^+ fertilizer.

There are several indications that NO_3^- builds up to high levels in Mohave Desert soils. Results presented by Romney et al. (1973), Hunter et al. (1975b) and the caliche studies above have found concentrations from 100 to 1000 $\mu g/NO_3^-$-N/g. In these cases NO_3^- behaves as any other salt. Such concentrations would be unlikely if denitrification occurred to a significant degree, or if NO_3^- were leached below the

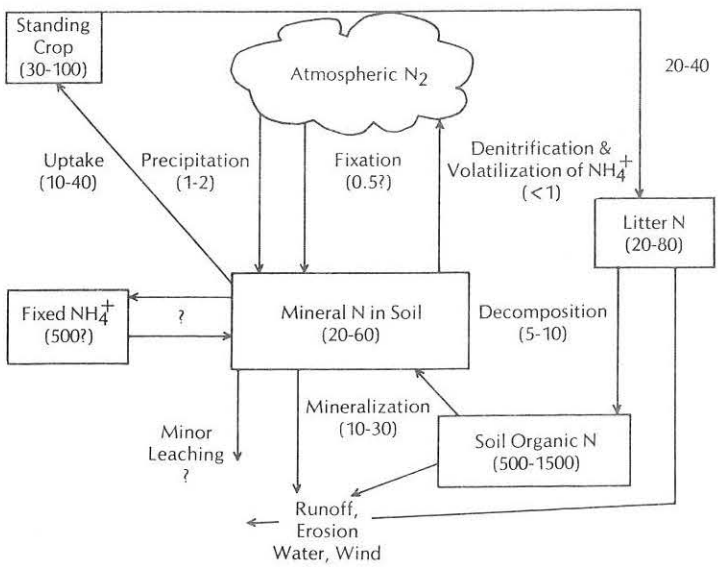

Figure 4. Nitrogen cycle model—northern Mohave Desert. Units are kg N/ha for compartments (boxes) and kg N/ha-yr for fluxes (arrows).

depth sampled. The association with caliche and the presence of high concentration levels of NO_3^- between 30-90 cm suggest to us a concentration at the lower drying front of Mohave Desert soils.

It is possible that over geological time periods nitrate may replace $CO_3^=$ in the carbonate-silicate "caliche" deposits, leading to nitrate deposits or high nitrate levels in ground water.

Concentration of NO_3^- and other salts under shrubs may be related both to water movement toward the drier soils under shrubs and collection of litter and its associated salts (Romney et al., in press). Hanawalt and Whittaker (1977) found mass flow of ions to roots greater than uptake for most salts in the Mohave Desert. If that situation holds for NO_3^- as well, the concentration under shrubs and depletion of nitrogen in bare areas might be partially explained by mass flow of water toward roots. Validation site studies (Turner et al. 1975; Maza and Turner 1976) consistently show a gradient of water potential between open and shrub areas which would cause flow of water (and salts) toward the shrubs.

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