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1973 PROGRESS REPORT

RESPONSES AND INTERACTIONS IN DESERT PLANTS AS INFLUENCED BY IRRIGATION AND NITROGEN APPLICATIONS

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ABSTRACT

Some examples are reported of responses and interactions of Mohave Desert vegetation to soil surface applications of supplemental nitrogen and sprinkler irrigation. Results of preliminary studies agree with findings reported for grasslands in that surface applications of nitrogen generally were ineffective for increasing primary productivity when soil moisture was limiting. When followed by natural precipitation or sprinkler irrigation, broadcast fertilization of nitrogen was most beneficial to the annual plant species, increasing both herbage yield and nitrogen content of plant tissue. Shrubs responded in like manner when the nitrogen and moisture had penetrated into the root zone; those having the highest natural grazing potential, viz. *Ambrosia dumosa, Ceratoides lanata* and *Lycium andersonii*, consistently showed the most favorable response. There was marked establishment of new seedlings of *Acamptopappus shockleyi, Ambrosia dumosa, Ceratoides lanata*, and *Sphaeralcea ambigua* from sustained moisture treatments. Also, there appeared to be a growth-response plateau for most species above which further additions of either supplement would be ineffective. Two species, *Ephedra funerea* and *Larrea divaricata*, showed some evidence of new shoot damage from prolonged sprinkler irrigation. Growth of annual species on bare soil between shrub clumps also was inhibited in sprinkler-irrigated plots, presumably from mechanical impact damage and sun scald. Inasmuch as soil moisture is the most limiting factor affecting primary productivity in the Mohave Desert, its enhancement generally masked any growth response that might have been attributable to supplemental nitrogen. Additions of supplemental moisture markedly increased the productivity of native grasses indicating that sustained treatment should increase the grassland grazing potential of Mohave Desert areas.

INTRODUCTION

Preliminary field and laboratory experiments that should contribute information for this process study were initiated in 1967 (supplementary to another research program) on the basis of anticipated funding which eventually started in 1973. Certain aspects of the work could not be fully covered during this interim period; however, sufficient data were obtained to help establish guidelines for continuing studies now underway to investigate the responses and interactions in desert vegetation as influenced by irrigation and nitrogen applications. In some respects the continuing studies are refinements and amplifications of these preliminary experiments.

Inasmuch as studies of nitrogen fertilization of rangelands indicate that added nitrogen was ineffective when soil moisture was limiting (Rogler and Lorenz, 1957; Klipple and Retzer, 1959; Dahl, 1963; Stroehlein et al., 1968; Owensby et al., 1970), it was presumed that any beneficial response that might be practical in the Mohave Desert would have to involve both supplemental nitrogen and moisture, or at least some timing of nitrogen applications relative to seasonal precipitation. Preliminary field studies based upon this premise were established in Rock Valley near the IBP validation site and in Mercury Valley near a source of reclaimed water impounded from the sewage processing system from the town of Mercury, Nevada. Subsequent findings showed need for a better source of water; therefore, another field plot area was developed for the continuing studies utilizing water from the city water supply.

OBJECTIVES

The general objectives of this process study are to investigate responses and interactions of Mohave Desert vegetation as influenced by irrigation and nitrogen applications. For the continuing process studies, a trickle-irrigation system has been established in which the amounts and timing of irrigation can be controlled. Nitrogen fertilization is superimposed upon this system at various levels of application and in various forms and placements in the soil.

The specific objectives for preliminary experiments were to:

1. Determine the growth response of vegetation to supplemental nitrogen broadcast onto the surface of soils with and without an underlying, restrictive hardpan.
2. Investigate shrub response to surface applications of nitrogen with and without supplemental moisture applied by sprinkler irrigation.
3. Analyze plant samples for nitrogen and other element contents.
4. Measure changes in the nitrogn content of soil samples from the test plots.
5. Conduct glasshouse pot experiments to determine the response of selected shrub species to nitrogen fertilization.

METHODS

Field plots 30 x 30 m in size were established in Rock Valley on soils with and without an underlying, restrictive hardpan. Commercial nitrogen fertilizer (NH_4NO_3) was broadcast onto the soil surface in an amount equivalent to 100 kg N/ha in April, 1967. Observations were made of treatment response each year thereafter. Samples of annual plants and shrubs were collected for nitrogen analysis during the peak of the growth season in 1969 (Wallace and Romney, 1972, p. 350) and 1970, and for yield and nitrogen analysis in 1973 (DSCODE A3URM01). Physical and chemical properties of the soil underlain with hardpan were determined from samples collected in 1969 and processed as described by Romney et al. (1973; A3URM04). Soluble nitrate and ammonium forms of nitrogen at 3, 15 and 30 cm depths were determined again in the fall of 1973 by the method of Bremner et al. (1968). Nitrogen analyses of plant samples were by conventional methods using the Coleman Nitrogen Analyzer and Kjeldahl-ammonium ion electrode system (Bremner and Tabatabai, 1972).

Preliminary studies in Mercury Valley were conducted at paired experimental plots, 30.5 m in diameter, treated with supplemental nitrogen at levels of 0, 100 and 200 kg N/ha (NH_4NO_3) broadcast uniformly onto the soil surface in March, 1968, and again in October, 1970. Supplemental moisture was applied by overhead sprinkler irrigation, starting in April, 1968, in amounts sufficient to maintain the soil moisture level above 5% by weight until treatment was discontinued in October, 1970. Inasmuch as the seasonal precipitation occurred mainly during the late fall and winter months, the sprinkler irrigation was applied after the soil moisture was depleted from about mid-April through October. The dry plots received annual precipitation measured by rain gauge for the period of September 1 to August 31 (see below). The watered plots received natural precipitation plus sprinkler irrigation in the amounts listed below. Due to losses from evaporation, we estimate that about one half of the irrigation water penetrated into the root zone.

The natural precipitation and sprinkler irrigation treatments for Rock Valley and Mercury Valley plots were as follows:

ROCK VALLEY		MERCURY VALLEY	
Year	Precip. (cm)	Precip. (cm)	Irrigation (cm)
1968	18.09	17.98	23
1969	25.07	22.16	20
1970	9.98	7.39	34
1971	10.33	7.81	--
1972	14.88	9.35	--
1973	26.08	22.04	--

The irrigation water available from the sewage processing system was of marginal quality as indicated by the following analyses. It served the purpose, however, for other research project needs of which these preliminary nitrogen studies were supplementary.

Element	1967	1969
Ca, ppm	18.4	12.5
Mg, ppm	3.1	2.8
K, ppm	16.0	16.5
Na, ppm	263.0	266.3
Cl^-, ppm	132.3	108.4
$SO_4^=$, ppm	8.3	7.4
Sodium adsorption ratio	21.1	23.6

The total nitrogen content, including that contributed by algae and other organic forms, varied from 5 to 7 ppm. During the three-year period of sprinkler irrigation, the watered plots could have received additional nitrogen equivalent to from 40 to 60 kg/ha. We do not know how rapidly this source of nitrogen became available as fertilizer, but we continued to sample vegetaton for residual effects after irrigation was discontinued in October, 1970. Because of this, and other reasons discussed later on, a clean source of city water was obtained for the continuing nitrogen response experiments.

The physical and chemical properties for soil at the Mercury plots were determined from samples collected in 1969 (A3URM04). Soluble nitrate and ammonium forms of nitrogen at three depths in the soil were again measured in the fall of 1973. Samples were collected from shrubs at peak of growth season for nitrogen and other element analysis and for determining new growth response. Annual plant species were collected for yield and chemical analyses only in 1973 from the Mercury plots; however, phenological observations were made weekly in the spring and summer months and every two to four weeks during the rest of the year. Nitrogen contents were determined on dry plant tissue by methods indicated above; the other elements were analyzed by optical emission spectroscopy (Wallace and Romney, 1972; Romney et al., 1973; A3URM02).

The nature of our major research project would not permit harvesting whole shrubs; therefore, three indirect methods were used for measuring the shrub growth response to treatments. Inasmuch as natural precipitation was adequate for new shoot production in both dry and watered plots in 1968, 1969 and 1973, samples consisting of either 50 or 100 new shoots were collected at random from five different shrubs of each of eight indicator species for the determination of new shoot productivity during these favorable years. Natural precipitation was inadequate for new shoot production on shrubs in the dry plots in 1970, 1971 and 1972; therefore, several branches were clipped randomly from the indicator shrubs for determining only the leaf/stem ratios (A3URM01). The third method of determining growth response involved non-destructive, dimensional measurement techniques developed for our major research programs at the Nevada Test Site and for the perennial vegetation studies at the IBP validation site in Rock Valley. Descriptions of this method and some of its applications have been reported (Wallace and Romney, 1972; Turner, 1972, 1973; Romney et al., 1973). Baseline dimensional measurements were made before the sprinkler irrigation started in April, 1968. Another set of measurements to check on shrub response to supplemental moisture were made in April, 1970, on the dry and watered control plots only (A3URM03). The early effects of supplemental moisture so overshadowed any growth response from the nitrogen treatments that the decision was made to wait until the termination of the major research project for further measurements on the nitrogen-treated plots. Syntheses of these final results are in progress.

Soil pot culture tests were conducted under glasshouse conditions at Mercury, Nevada, to determine yield and nitrogen uptake responses for *Atriplex canescens*, *Artemisia tridentata* and *Ceratoides lanata*. The *A. tridentata* was included because of our interest in testing the response to nitrogen of higher-elevation, Great Basin Desert species. New plants of each species were propagated from rooted cuttings and transplanted (*C. lanata* on April 23, 1970; *A. canescens* and *A. tridentata* on May 14, 1970), three per pot to soil fertilized with NH_4NO_3 at levels equivalent to 0, 100 and 300 kg N/ha. In these tests the nitrogen fertilizer was thoroughly blended with soil collected from the Mercury Valley field plot area. The soil moisture level was maintained above 5% by weight during the plant growth period which was terminated on December 9, 1972. This minimum level of soil moisture was important for both the field plot and glasshouse pot culture experiments because many of the Mohave Desert shrub species drop their leaves and go into summer dormancy when the soil moisture content is depleted below 5% by weight. Harvested plant material was oven-dried at 70 C, weighed, ground, and analyzed for nitrogen and other elements as indicated above (A3URM06).

RESULTS

Soil Properties of Study Sites

Descriptions of the soil profiles characterized for the study plots in Rock Valley and Mercury Valley (A3URM04) are given in Tables 1 and 2. The chemical and physical properties of profile horizons developed underneath shrub clump and bare areas are given in Tables 3 and 4. In both study areas the soils are derived from heterogeneous alluvium composed primarily of Cambrian limestone with some basalt and tuff. Much of the surface between shrub clumps is a well-developed desert pavement. The soils have developed under conditions of high temperature and low rainfall on alluvium deposits containing unconsolidated parent materials low in clay content. Through the processes of alkaline hydrolysis, they are now underlain with a massive and strongly cemented hardpan at depths ranging from 30 to 70 cm. In the Rock Valley area, pairs of test plots were located on one site which had restrictive hardpan and on an adjacent site, near a stream bed, which had no hardpan.

Aeolian deposits have formed at the base of shrubs, particularly those grouped together in clumps, and they generally have developed A horizons which are not characteristic of the bare soil between shrub clumps. Significant differences also have occurred within the root zone underneath shrub clumps where higher concentrations of $EC_{25°}$, soluble cations, available phosphorus, and organic carbon and nitrogen are present in comparison to that in bare soil. Decomposition and mineralization of litter deposited underneath shrubs can account for these differences in soil properties which, collectively, increase the fertility of the soil underneath shrub clumps. Salt concentrations in these soils are relatively low.

Table 1. Soil profile description in Rock Valley nitrogen study site

Area: Rock Valley, Nye County, Nevada
Perennial Vegetation: *Ambrosia dumosa* (Gray) Payne, *Atriplex confertifolia* (Torr. & Frem.) Wats., *Ephedra nevadensis* Wats., *Ceratoides lanata* (Pursh) Moq., *Grayia spinosa* (Hood) Moq., *Krameria parvifolia* Benth., *Larrea divaricata* Ses. & Moq., *Lycium andersonii* Gray, *Lycium pallidum* Miers.
Parent Material: Alluvium from limestone - tuff.
Topography: Two percent northwest slope, smooth relief; well-drained to pan; moderate permeability; moderate erosion; surface about 30 percent rock and gravel; elevation 1015 meters.
Profile Under Shrub Clump: *G. spinosa, L. divaricata, K. parvifolia*

A11	0-10 cm	Pale brown (10YR6/3) sand, dark grayish brown (10YR4/2) moist; weak fine subangular blocky structure; soft, friable non-sticky; violently effervescent; few micro roots; pH 8.0; wavy boundary.
A12	10-20 cm	Pale brown (10YR6/3) loamy sand, brown (10YR4/3) moist; weak medium subangular blocky structure; slightly hard, friable, non-sticky; violently effervescent; few medium, fine and micro roots; pH 8.5; abrupt wavy boundary.
A2	20-28 cm	Light gray (10YR7/2) sandy loam, brown (10YR5/3) moist; weak fine platy; slightly hard; slightly friable, slightly sticky; violently effervescent; few fine and micro roots; pH 8.3; abrupt wavy boundary.
C1	28-49 cm	Very pale brown (10YR7/3) loamy sand, brown (10 YR5/3) moist; weak fine subangular blocky structure; soft, friable, non-sticky; violently effervescent; few medium, fine and micro roots; pH 8.5; abrupt wavy boundary.
C2sica	49+ cm	Cemented pan.

Profile in Bare Area

A2	0-8 cm	Horizon descriptions are the same as under shrub.
C1	8-36 cm	
C2sica	36+ cm	

Table 2. Soil profile description in Mercury Valley nitrogen study site

Area: Mercury Valley, Nye County, Nevada
Perennial Vegetation: *Acamptopappus shockleyi* Gray, *Ambrosia dumosa* (Gray) Payne, *Ephedra funerea* Cov. & Mort., *Ephedra nevadensis* Wats., *Ceratoides lanata* (Pursh) Moq., *Grayia spinosa* (Hook) Moq., *Larrea divaricata* Ses. & Moq., *Lycium andersonii* Gray, *Yucca schidigera* Roezl ex Ortgies.
Parent Material: Alluvium from limestone and quartz.
Topography: Three percent south slope; excessively drained; smooth relief; moderate erosion; slow permeability; surface about 30 percent rock and gravel; elevation 1103 meters.
Profile Under Shrub Clump: *L. divaricata, L. andersonii*

A1	0-9 cm	Light grayish brown (10YR6/2) loamy very fine sand, brown to dark brown (10YR4/3) moist; weak fine platy structure; soft, friable, non-sticky; violently effervescent; abundant micro roots; pH 8.2; clear smooth boundary.
C1	9-27 cm	Very pale brown (10YR7/3) fine sandy loam, brown (7.5YR5/4) moist; moderate medium subangular blocky structure; slightly hard, friable, slightly sticky; violently effervescent; abundant coarse, medium, fine and micro roots; pH 8.5; clear wavy boundary.
C2ca	27-81 cm	Very pale brown (10YR7/3) gravelly cobbly sand, dark yellowish brown (10YR4/4) moist; single grain structure; loose, friable, non-sticky; violently effervescent; few coarse and medium, abundant fine and micro roots; 35% cobbles and 25% gravel; pH 8.5.

Profile in Bare Area

A2	0-10 cm	Light gray (10YR7/2) silty clay loam, brown (10YR5/3) moist; hard, friable, sticky; violently effervescent; pH 8.5.
C1	10-31 cm	Other horizon descriptions are the same as under shrub.
Csca	31-80 cm	

Plant Response to Nitrogen Fertilization in Rock Valley

Plant samples were taken for nitrogen analysis in 1969 (A3URM01), two years following a soil surface application of nitrogen (100 kg/ha). Precipitation was above normal during 1968 and 1969 and there was an increased productivity, especially of annuals, on plots receiving supplemental nitrogen. Yield measurements were not taken until 1973 primarily because of the lack of any noticeable response during subsequent growth seasons following low annual precipitation in 1970, 1971 and 1972. Above-normal precipitation again occurred during the late fall and winter months of 1972-1973, and the response of annual plant species at the peak of growth season in 1973 is indicated from an example of data for yield and nitrogen contents in Table 5. Several of the annual plant species continued to respond to the nitrogen fertilization six years earlier. Analytical efforts were concentrated on the more prominent species listed; however, many more species of annuals were present in the study plots during the growth season of 1973. Except for species of the legume family, the annual plants had much lower nitrogen contents than did new foliage of most woody shrub species. We have consistently noticed this to be the case for the annual plants and also perennial grasses wherever sampled on the Nevada Test Site.

Table 3. Physical and chemical properties of soil profile horizons under shrub and bare areas in Rock Valley nitrogen study site

Profile Horizons	Shrub Clump				Bare Area	
Properties	A11	A12	A2	C1	A2	C1
Horizon depth, cm	0-10	10-20	20-28	28-49	0-8	8-36
Particle size distribution (% < 2 mm)						
coarse sand (2.0-0.25)	34.4	30.8	49.0	34.4	53.4	40.6
fine sand (0.25-0.05)	54.9	53.5	24.0	49.0	21.3	34.3
silt (0.05-0.002)	5.9	9.2	14.8	9.3	13.6	12.6
clay (< 0.002)	4.8	6.5	12.2	7.3	11.7	12.5
Percent moisture retention						
saturation	33.3	22.5	23.1	33.8	21.8	33.6
1/3 bar	11.3	14.0	18.7	17.3	16.0	17.2
1 bar	8.6	10.2	14.4	12.0	12.6	12.6
15 bar	5.2	5.0	8.3	7.3	6.9	9.3
pH (saturated paste)	8.0	8.5	8.3	8.5	8.3	8.5
EC (mmhos per cm. 25°C)	1.07	0.66	0.47	0.57	0.44	0.27
Saturation extract soluble cations and anions						
Na, meq/l	0.97	0.65	0.97	1.95	0.97	0.52
K, meq/l	2.38	2.34	1.65	1.86	1.13	0.96
Ca, meq/l	10.56	5.69	3.96	2.64	3.96	3.96
SO_4, meq/l	0.23	0.15	0.08	0.08	0.10	0.08
B, ppm	2.10	2.40	3.20	1.50	0.10	2.30
Exchangeable cations (NH_4OAc-extraction)						
Na, meq/100g	0.35	0.34	0.43	0.68	0.43	0.48
Na, %	2.6	2.5	2.3	5.2	2.5	2.4
K, meq/100g	4.10	6.38	6.26	6.87	4.56	6.00
Ca + Mg, meq/100g	9.05	6.78	11.81	5.45	12.01	13.27
C.E.C. meq/100g	13.5	13.5	18.5	13.0	17.0	19.8
Percent lime (< 2mm)	4.0	5.6	5.6	6.4	3.8	3.0
P, ($NaHCO_3$-ext.) ppm	5.20	0.00	0.00	0.00	0.00	0.00
Organic carbon, %	0.64	0.35	0.21	0.30	0.13	0.16
Organic nitrogen, %	0.138	0.039	0.024	0.033	0.026	0.025
DTPA - extractable micronutrients						
Fe, ppm	0.3	0.2	0.3	0.2	0.3	0.2
Zn, ppm	0.55	0.40	0.30	0.35	0.42	0.30
Cu, ppm	0.15	0.20	0.25	0.10	0.30	0.15
Mn, ppm	3.55	1.15	1.05	0.90	0.65	0.65

New productivity based upon the leaf/stem ratio and nitrogen content of shrub species sampled in 1973 is indicated from the data in Table 6 which were obtained from test plots on soil with and without restrictive hardpan. The leaf/stem ratio was not the best indicator that perhaps could have been used to indicate new productivity, but we did not wish to destroy whole shrubs. Nevertheless, this ratio gave indications of new leaf growth response attributable to the earlier application of nitrogen fertilizer.

Nitrogen contents in leaves of desert shrubs were much higher than those of annual plant species and, in many cases, exceeded the range commonly found in cultivated pasture crops. Nitrogen applications on the soil surface generally increased nitrogen concentrations in leaf tissue, but not until the precipitation was sufficient to transport the fertilizer down into the root zone.

Initially we had been curious about the possible influence of an underlying, restrictive hardpan on shrub response to nitrogen fertilization, but no indicative effects became apparent during the 6-year period of observation.

Plant Response to Supplemental Moisture and Nitrogen in Mercury Valley

Data are given in Table 7 for the yield and nitrogen content of several prominent annual plant species harvested in 1973 from test plots which previously had received applications of supplemental moisture and nitrogen (A3URM01). Tissue concentrations of some 12 additional mineral elements also were determined for these species and data have been submitted to the data bank (A3URM02). Some yield increases were obtained in 1973 for certain species in the unwatered nitrogen-treated plots, but this response was inconsistent. Some pronounced residual growth responses also were apparent in the watered plots even though the sprinkler irrigation had been discontinued during the two previous years. Some of this response might be attributable to an increased seed pressure resulting from some of the marked yield responses which previously had occurred when the plots were being irrigated. Some reductions in foliage nitrogen concentration occurred as the result of carbohydrate dilution in those species showing marked growth response to treatment. Available time and manpower did not permit sampling and analysis of the many other annual plant species which were less prominent on these test plots in 1973.

One of the more consistent observations of annual plant response to treatment was the abundance of *Bromus rubens* introduced on the irrigated plots. Many of the annual plant species did not grow on the bare soil between shrub clumps in the irrigated plots, presumably as the result of damage from mechanical impact and sun-scald during the prolonged periods of overhead sprinkling. The introduced

Table 4. Physical and chemical properties of soil profile horizons under shrub and bare areas in Mercury Valley nitrogen study area

Profile Horizon Properties	Shrub Clump A1	Shrub Clump C1	Shrub Clump C2ca	Bare Area A2	Bare Area C1	Bare Area C2ca
Horizon depth, cm	0-9	9-27	27-81	0-10	10-31	31-80
Particle size distribution (% < 2 mm)						
coarse sand (2.0-0.25)	25.1	24.1	49.4	16.8	21.4	41.9
fine sand (0.25-0.05)	61.1	51.6	41.2	51.0	59.0	39.2
silt (0.05-0.002)	8.8	17.0	6.2	24.0	14.9	11.8
clay (< 0.002)	5.0	7.3	3.2	8.2	4.7	7.1
Percent moisture retention						
saturation	42.6	34.3	32.8	39.2	43.0	29.9
1/3 bar	14.2	18.4	12.8	14.8	19.4	16.2
1 bar	11.0	14.6	10.8	12.4	13.6	12.2
15 bars	8.3	8.0	6.1	7.2	7.5	6.6
pH (saturated paste)	8.2	8.5	8.5	8.5	8.6	8.4
EC (mmhos per cm, 25°C	2.74	0.80	0.75	0.46	0.31	4.01
Saturation extract soluble cations and anions						
Na, meq/l	0.98	0.42	2.80	1.36	1.45	40.00
K, meq/l	4.50	2.05	1.00	0.78	0.20	0.34
Ca, meq/l	5.64	2.95	4.03	2.15	3.64	4.48
SO_4, meq/l	0.57	0.15	0.05	0.07	0.05	1.50
B, ppm	8.30	3.50	5.20	2.70	0.00	16.20
Exchangeable cations (NH_4OAc-extraction)						
Na, meq/100g	0.41	0.44	0.84	0.62	0.72	2.93
Na, %	5.0	2.6	8.4	4.0	5.0	23.4
K, meq/100g	2.31	2.98	1.92	2.04	1.24	0.70
Ca + Mg, meq/100g	13.53	13.46	7.24	12.97	12.42	8.87
C.E.C., meq/100g	16.3	16.9	10.0	15.6	14.4	12.5
Percent lime (< 2mm)	15.0	17.0	25.0	17.0	22.0	30.0
P, ($NaHCO_3$-ext.) ppm	3.16	0.32	0.04	0.20	0.04	0.04
Organic carbon, %	2.12	0.68	0.22	0.22	0.30	0.23
Organic nitrogen, %	0.191	0.068	0.021	0.025	0.029	0.021
DTPA - extractable micronutrients						
Fe, ppm	1.0	0.3	0.5	0.3	0.3	0.5
Zn, ppm	1.03	0.82	2.00	2.53	1.20	3.40
Cu, ppm	0.15	0.15	0.10	0.20	0.10	0.10
Mn, ppm	5.30	0.95	0.95	0.70	1.10	0.95

summer annual *Salsola* species (*S. paulsenii* and *S. iberica*) also became prominent on the irrigated plots as compared to the dry plots. For example, the number of plants on the dry control plot in September, 1969, was five plants (126 g) compared to 1,143 plants (17,456 g) counted and harvested from the watered control plot.

Response of annual plant species to sprinkler irrigation was measured by Turner et al. (1973) in nearby study plots designed to investigate survival and reproduction of the iguanid lizard *Uta stansburiana*, in response to artificial augmentation of normal winter precipitation by the addition of 5 cm of water during November. In both 1969 and 1971 the additional water applied had obvious effects on germination and growth of winter annuals. In 1970 about 75% of the plant material collected was the introduced grass, *Bromus rubens*. This species continued to dominate in 1972 (ca. 37% of total) along with three other important contributors, *Cryptantha recurvata*, *Festuca octoflora* and *Phacelia fremontii*. The vast majority of annuals occurred underneath shrubs rather than in bare areas between shrubs. The combined weight of annuals produced during 1969-70, estimated from 60 quadrats (20 x 50 cm), was 7.98 g/m^2 with irrigation compared to 0.48 g/m^2 without irrigation. During 1971-72 the combined dry weight of annuals from the same plots was 5.66 g/m^2 compared to 0.11 g/m^2.

As mentioned earlier, three different methods were used to measure shrub growth response to supplemental nitrogen and moisture. Table 8

Table 5. Influence of nitrogen fertilizer on yield and nitrogen content of annual plants in Rock Valley, 1973 (A3URM01)

Plant Species	Plant Yield Control	Plant Yield +N*	N - Content Control	N - Content +N*
	gm/m^2	gm/m^2	%	%
Amsinckia tessellata	0.18	1.29	0.87	1.35
Astragalus didymocarpus	0.47	0.24	2.07	2.70
Bromus rubens	1.18	1.01	0.80	0.97
Caulanthus cooperi	0.69	0.40	1.00	1.38
Chaenactis fremonti	7.00	9.08	0.87	0.81
Cryptantha nevadensis	0.30	2.13	0.75	0.85
Cryptantha pterocarya	0.72	2.26	0.72	0.72
Festuca octoflora	0.16	0.05	0.79	0.82
Gilia cana	0.23	0.86	-	0.72
Malacothrix glabrata	0.59	2.73	0.74	1.00
Mentzelia obscura	1.79	2.60	0.98	1.32
Phacelia vallis-mortae	0.24	0.65	0.78	0.98
Streptanthella longirostis	2.16	4.07	0.43	0.80

* Nitrogen application of 100 kg. N/ha. (NH_4NO_3) were made in April 1967.

Table 6. Influence of Nitrogen Fertilization on the leaf/stem ratios and nitrogen contents of shrub leaves grown on Rock Valley soil with and without restrictive hardpan (A3URM01)

Plant Species	Leaf/Stem Ratio Control	Leaf/Stem Ratio +N*	N - Content Control	N - Content +N*
NO UNDERLYING HARD PAN				
Ambrosia dumosa	1.78	1.66	3.81	4.18
Ceratoides lanata	1.29	2.10	2.18	2.56
Grayia spinosa	1.19	2.37	1.45	2.64
Larrea divaricata	3.37	5.00	2.10	2.35
Lycium pallidum	0.94	1.17	2.54	3.19
RESTRICTIVE HARD PAN AT 50 cm. DEPTH				
Ambrosia dumosa	0.77	1.51	3.85	3.96
Ceratoides lanata	1.52	2.97	1.98	2.49
Grayia spinosa	1.54	3.10	1.56	2.09
Larrea divaricata	3.54	3.70	2.22	2.70
Lycium andersonii	2.00	2.50	3.15	3.83
Lycium pallidum	1.00	1.17	2.87	3.64

* Nitrogen equivalent to 100 kg. N/ha. (NH_4NO_3) applied in April 1967.

Table 7. Influence of supplemental nitrogen and moisture on yield and nitrogen content of annual plant species in Mercury Valley, May 1973 (A3URM01)

Plant Species	Plant Yield		N - Content	
	Control	+N*	Control	+N*
	gm/m^2	gm/m^2	%	%
NATURAL DESERT CONDITIONS				
Bromus rubens	-	-	-	-
Caulanthus cooperi	7.96	3.54	1.42	1.72
Crypthantha nevadensis	1.26	0.48	0.93	1.08
Descurainia pinnata	4.24	7.63	1.12	1.05
Festuca octoflora	8.11	***	0.85	0.55
Phacelia fremontii	6.68	3.00	0.95	0.89
Streptanthella longirostris	9.65	36.21	1.24	1.20
SUPPLEMENTAL MOISTURE**				
Bromus rubens	9.66	44.81	0.55	0.42
Caulanthus cooperi	-	7.70	-	1.43
Cryptantha nevadensis	1.12	1.67	1.64	2.11
Descurainia pinnata	3.45	8.00	0.61	0.58
Festuca octoflora	6.91	17.1	0.50	0.55
Phacelia fremontii	***	4.67	0.75	0.81
Streptanthella longirostris	6.99	19.52	1.07	0.97

* Nitrogen fertilizer (NH_4NO_3) equivalent to 200 kg. N/ha. applied in October 1970.

**Data for 1973 indicate residual effects of supplemental moisture applied by sprinkler irrigation during period from April 1968 to November 1970.

***Species present but sample values lost.

Table 8. Influence of supplemental nitrogen and moisture on new shoot growth of shrubs in Mercury Valley (A3URM01)

Plant Species	1968		1969		1973	
	Control	+N*	Control	+N*	Control	+N*
	gms dry plant tissue***					
NATURAL DESERT CONDITIONS						
Acamptopappus shockleyi	1.87	1.26	6.58	5.41	3.25	2.75
Ambrosia dumosa	3.31	3.49	8.00	7.37	6.53	5.15
Ceratoides lanata	4.76	4.96	9.59	10.23	13.80	15.70
Grayia spinosa	-	-	7.20	7.62	7.60	7.50
Krameria parvifolia	1.08	1.32	1.03	1.07	-	-
Larrea divaricata	3.45	2.16	2.95	2.86	4.20	4.30
Lycium andersonii	2.78	3.90	3.65	3.35	4.97	4.77
SUPPLEMENTAL MOISTURE**						
Acamptopappus shockleyi	4.90	6.80	7.68	8.05	5.50	5.40
Ambrosia dumosa	8.82	11.00	9.02	8.29	5.65	6.65
Ceratoides lanata	9.73	9.55	13.85	14.65	14.60	11.20
Grayia spinosa	-	-	11.75	10.27	9.55	7.50
Krameria parvifolia	4.76	3.52	1.05	0.95	-	-
Larrea divaricata	3.85	3.93	3.21	2.94	5.25	4.85
Lycium andersonii	4.84	8.50	4.03	4.12	7.83	10.00

* Nitrogen application of 200 kg. N/ha. as NH_4NO_3 in March 1968 and October 1970.

** Sprinkler irrigations of 23 cm in 1968, 20 cm in 1969, and 34 cm in 1970. No supplemental moisture in 1972-1973; data for 1973 indicate residual treatment effects.

***Weight of 50 new shoots picked at random from shrub species in each plot.

contains an example of data for new shoot growth on indicator shrub species. The samples were a composite of either 50 or 100 new shoots picked at random from five shrubs of each species in a given plot in order to obtain what was considered to be an adequate biomass for analysis. All data reported were normalized on a 50 shoot basis, however, to indicate the relative new productivity among different species. *C. lanata* was the only shrub species that consistently responded to nitrogen fertilization of the dry plots. Responses to sprinkler irrigation generally masked any influence of added nitrogen in the watered plots. However, the differences in new shoot growth response between watered and dry plots were not as apparent in 1969 and 1973, which were years of very favorable new productivity under natural desert conditions because of above-normal precipitation. Note that the data for 1973 from the watered plot indicate some residual growth responses of certain shrubs to previously-applied sprinkler irrigation treatments.

Some examples are shown in Table 9 of data for the second method of measuring leaf/stem ratios to indicate growth response during the years of low natural precipitation when there was very little new shoot production on shrubs in dry plots. This method, based on the production of new leaf tissue on old stems, indicated an increased growth response to nitrogen, particularly for *Ceratoides lanata* and *Grayia spinosa*, under the natural desert conditions. For the irrigated plots this ratio method also indicated an increased growth response, but it did not disclose the marked new

Table 9. Influence of supplemental nitrogen and moisture on leaf/stem ratios of shrubs in Mercury Valley (A3URM01)

Plant Species	1970		1971	
	Control	+N*	Control	+N*
	L/S ratio of dry plant tissue			
NATURAL DESERT CONDITIONS				
Acamptopappus shockleyi	0.16	0.25	0.21	0.14
Ambrosia dumosa	0.21	0.27	0.32	0.34
Ceratoides lanata	0.17	0.45	0.72	0.92
Grayia spinosa	0.18	0.31	0.31	0.42
Krameria parvifolia	0.24	0.19	0.27	0.28
Larrea divaricata	0.40	0.77	1.33	1.21
Lycium andersonii	0.06	0.10	0.10	0.19
SUPPLEMENTAL MOISTURE**				
Acamptopappus shockleyi	0.39	0.37	1.02	0.59
Ambrosia dumosa	0.52	0.44	1.23	1.18
Ceratoides lanata	0.49	0.36	2.41	2.50
Grayia spinosa	0.29	0.30	0.66	0.55
Krameria parvifolia	0.29	0.50	0.75	0.57
Larrea divaricata	0.46	0.57	2.29	2.39
Lycium andersonnii	0.11	0.12	0.29	0.23

* Nitrogen application of 200 kg. N/ha. as NH_4NO_3 in March 1968 and Oct. 1970.

**Sprinkler irrigations of 26 cm applied during period of April - August, 1970; and 8 cm applied in November 1970.

Table 10. Influence of sprinkler irrigation on changes in shrub population and biomass in Mercury Valley (A3URM03)

Shrub Species	Before Irrigation (1968) Number	Density	Biomass	After Irrigation (1970) Number	Density	Biomass
		No./ha	kg/ha		No./ha	kg/ha
NATURAL DESERT CONDITIONS (Plot 8)						
Acamptopappus shockleyi	76	1041	9.8	88	1205	11.6
Ambrosia dumosa	103	1411	265.7	105	1438	309.8
Ephedra funerea	5	69	31.9	5	69	38.1
Ceratoides lanata	328	4493	448.3	340	4657	509.7
Grayia spinosa	30	411	97.0	44	603	141.7
Krameria parvifolia	29	397	81.8	29	397	86.9
Larrea divaricata	50	684	559.2	52	712	590.2
Lycium andersonii	46	630	344.3	45	616	330.6
Sphaeralcea ambigua	49	671	2.2	45	616	1.6
Yucca schidigera	3	41	346.6	4	55	463.5
Total	719	9848	2,186.8	757	10,368	2,483.7
SUPPLEMENTAL MOISTURE (Plot 4)*						
Acamptopappus shockleyi	265	3630	27.6	351	4808	36.1
Ambrosia dumosa	148	2027	241.6	171	2342	345.5
Ephedra funerea	24	329	400.6	24	329	418.3
Eurotia lanata	138	1890	91.4	202	2767	205.3
Grayia spinosa	17	233	32.2	21	288	79.6
Krameria parvifolia	78	1068	83.7	80	1096	140.2
Larrea divaricata	32	438	167.0	33	452	197.8
Lycium andersonii	52	712	294.6	54	740	331.8
Sphaeralcea ambigua	90	1233	3.4	140	1918	15.0
Yucca schidigera	5	68	579.4	6	82	695.3
Total	849	11,628	1,921.5	1,082	14,822	2,464.9

*Supplemental moisture was 38 cm and 20 cm during the two years of irrigation before measurements in April, 1970.

shoot production on shrubs that resulted from the supplemental moisture treatments.

The third method of measuring growth response from sprinkler irrigation involved the determination of increased biomass of shrub species from non-destructive dimensional measurements. Since this method was costly in time and manpower, repeated measurements were made only for 1970 on the watered and dry control plots. Results of the biomass status and composition of shrubs at the beginning of the test in 1968, and after 2 years of sprinkler irrigation in 1970, are given in Table 10 (A3URM03). A few new seedlings were found under natural desert conditions in 1970, probably as the result of the above-normal seasonal precipitation during the early spring of 1969. In the sprinkler irrigated plot many new seedlings were recorded, especially among the species of *Acamptopappus shockleyi*, *Ambrosia dumosa*, *Ceratoides lanata*, and *Sphaeralcea ambigua*. It should be noted here that data for the shrub species listed in Table 10 account for more than 95% of the total plot standing biomass. The number of perennial plants increased by 233 after two seasons of irrigation compared to 36 under natural conditions. The increase in biomass from sprinkler irrigation was nearly twice that which occurred under natural conditions. Many of the 36 new seedlings on the dry plot did not survive the very dry years of 1970 and 1971, whereas most of the 233 new seedlings became firmly established on the irrigated plot.

Many new clumps of perennial grasses were established on the sprinkler-irrigated plots, but no biomass measurements were made on them during these preliminary studies. We did not wish to disturb the grasses because of other interests in determining succession under natural seed pressure. The observed effects, however, were most convincing that grassland conditions would develop from continuing irrigation treatments. Another interesting observation was the influx of small mammals to the irrigated plots from surrounding areas. Biomass losses to grazing rabbits were significant, especially during those years of low natural precipitation.

The influence of supplemental nitrogen and moisture on nitrogen composition of shrub foliage is indicated from sample data in Table 11. Applications of nitrogen fertilizer onto the soil surface generally increased leaf tissue concentrations under natural desert conditions. Although this generally was the case for shrubs receiving additional moisture, there also were some indications of reduced nitrogen contents from carbohydrate dilution. It seemed apparent from these preliminary studies that most of the desert vegetation under investigation should respond favorably to broadcast applications of nitrogen when timed to precede natural precipitation. There appears, however, to be a beneficial treatment plateau above which any additional applications would produce no further response regardless of the soil moisture supply. The economics of application and management coupled with the grazing potential probably will determine the feasibility of nitrogen fertilization in shrub-desert areas.

Examples of data for other mineral element concentrations in shrub leaves harvested in 1969 are given in Tables 12 and 13 for the watered and dry control plots (A3URM02). In general, these element contents appeared to be unaltered by nitrogen or irrigation treatments except for some carbohydrate dilution effects on phosphorus and zinc concentrations.

Influence of Supplemental Nitrogen and Moisture on the Distribution of Nitrogen in Treated Soils

Tests were made in 1973 to determine the nitrogen distribution in soils treated with surface applications of nitrogen fertilizer and sprinkler irrigation. The findings (Table 14; A3URM05) represent the relative concentrations of soluble nitrate and ammonium forms of nitrogen extracted by water from soil samples collected at depths of 3, 15 and 30 cm in the profile underneath shrub clumps and bare areas. It is not known how much of the surface application of nitrogen fertilizer was lost through

Table 11. Influence of supplemental nitrogen and moisture on nitrogen contents of shrub leaves in Mercury Valley (A3URM01)

Plant Species	1968 Control	1968 +N*	1969 Control	1969 +N*	1970 Control	1970 +N*	1973 Control	1973 +N*
	% of dry leaf tissue							
NATURAL DESERT CONDITIONS								
Aaamptopappus shockleyi	1.17	1.11	1.91	2.48	1.68	1.78	2.08	2.24
Ambrosia dumosa	1.96	2.67	3.59	3.90	1.74	1.79	2.48	3.03
Ephedra nevadensis	-	-	2.34	2.86	-	-	2.00	2.04
Ceratoides lanata	2.23	2.82	2.63	3.06	1.92	1.64	2.56	2.81
Grayia spinosa	-	-	2.15	2.37	1.58	1.34	2.54	2.92
Krameria parvifolia	2.03	2.92	-	-	1.84	1.88	-	-
Larrea divaricata	1.83	2.08	2.19	2.42	1.77	1.83	2.22	2.26
Lycium andersonii	4.85	6.00	2.80	4.28	2.31	3.44	2.55	3.39
SUPPLEMENTAL MOISTURE**								
Acamptopappus shockleyi	1.53	1.46	1.82	2.25	2.37	2.14	2.22	2.22
Ambrosia dumosa	2.08	1.08	3.79	4.07	3.12	2.86	3.45	3.50
Ephedra nevadensis	-	-	1.84	2.63	-	-	2.94	2.34
Ceratoides lanata	1.35	1.87	2.90	3.13	2.47	2.27	2.05	2.63
Grayia spinosa	-	-	2.31	2.57	2.49	2.31	2.03	3.21
Krameria parvifolia	1.87	2.50	-	-	2.61	2.35	-	-
Larrea divaricata	2.00	2.04	3.18	2.52	2.50	2.38	2.23	2.34
Lycium andersonii	3.53	4.52	2.71	3.08	1.93	2.18	3.13	3.55

* Nitrogen application of 200 kg. N/ha. as NH_4NO_3 in March 1968 and Oct. 1970.

**Sprinkler irrigations of 23 cm in 1968, 20 cm in 1969, and 34 cm in 1970. No supplemental moisture in 1972-1973; data for 1973 indicate residual treatment effects.

volatilization of ammonia, nor was this of particular concern in these preliminary experiments. Some of it understandably was lost from dry soil before rainfall occurred, but we were more interested in the practicality of supplemental irrigation water moving the ammonium source down through the soil profile in order to enhance nitrification within the root zone. Placement of nitrogen fertilizer at any depth in the soil profile by mechanical means is just not practical in most Mohave Desert areas. Fuller (1963) reported that nitrates formed readily in calcareous soil up to pH 9.0 if the ammonium concentration was favorable and the pO_2 conditions were not limiting. Romney et al. (1973) and Nishita and Haug (1973) found highest levels of organic nitrogen concentrated in surface horizons of Mohave Desert soils, especially in the *A* horizons underneath shrubs. Soluble nitrate concentrations generally were low except at lower depths in profiles of soils formed on the playas of closed drainage basins. Nishita and Haug (1973) accounted for the lower fixation of ammonium nitrogen observed underneath desert shrubs compared to its fixation in bare soil under natural conditions as the result of higher concentrations of exchangeable potassium and organic matter present in the root zone.

The results in Table 14 indicate that very little of the applied fertilizer had remained in

Table 12. Mineral composition of perennial vegetation from irrigated control plot in Mercury Valley nitrogen study site; Mercury pond plots, woody shrubs, 1969 (A3URM02)

Plant Species	Part	P	Na	K	Ca	Mg	Zn	Cu	Fe	Mn	B	Sr	Ba
				%						ppm			
Acamptopappus shockleyi	leaf	.20 ±.03	.192	2.97 ±.22	.46 ±.08	.33 ±.03	24	6.2 ±.5	127.0 ±14.6	38.8 ±7.0	46.3 ±11.0	55.8 ±10.5	5.3 ±1.4
	stem	.10 ±.01	.183	2.64 ±.29	1.05 ±.16	.27 ±.03	13	7.2 ±1.2	94.1 ±43.0	17.5 ±3.1	27.3 ±8.9	111.2 ±2.9	16.6 ±1.0
Ambrosia dumosa	leaf	.41 ±.01	.222 ±.045	4.53 ±.24	1.94 ±.65	.35 ±.01	29	4.5 ±.1	163.2 ±42.6	21.9 ±1.3	130.0 ±27.2	110.1 ±.8	10.3 ±1.3
	stem	.14 ±.02	.218 ±.025	2.83 ±.32	1.08 ±.29	.32 ±.04	18	3.1 ±1.1	52.8 ±15.0	14.8 ±2.3	32.0 ±5.2	110.0 ±10.4	21.0 ±4.2
Ephedra nevadensis	shoot	.26 ±.04	.052 ±.016	2.82 ±.01	.67 ±.09	.22 ±.01	18	4.4 ±.5	126.7 ±1.0	25.3 ±2.9	21.4 ±5.1	115.7 ±14.8	17.3 ±1.4
Ceratoides lanata	leaf	.23 ±.04	.123 ±.041	3.10 ±.27	1.21 ±.05	.42 ±.06	36	3.9 ±1.3	198.0 ±36.1	78.6 ±5.9	64.1 ±8.5	109.9 ±12.2	12.7 ±2.9
	stem	.08 ±.01	.015 ±.008	2.77 ±.24	.41 ±.08	.21 ±.04	9	11.3 ±2.9	81.3 ±23.5	31.4 ±6.8	12.3 ±3.9	93.9 ±10.9	11.8 ±2.8
Grayia spinosa	leaf	.19 ±.03	.699 ±.139	8.43 ±1.08	5.19 ±.21	.75 ±.00	37	3.4 ±.3	89.6 ±7.5	73.3 ±17.8	27.4 ±3.4	68.1 ±10.7	8.4 ±.3
	stem	.13 ±.01	.017 ±.004	3.15 ±.06	.59 ±.12	.21 ±.02	16	2.8 ±.2	28.9 ±9.1	12.8 ±1.9	10.0 ±3.0	69.4 ±5.2	11.3 ±1.1
Krameria parvifolia	leaf	.30 ±.03	.317	2.05 ±.09	1.29 ±.18	.34 ±.02	10	5.0 ±.9	200.3 ±55.9	38.1 ±4.0	37.3 ±10.9	103.7 ±7.4	18.2 ±1.8
	stem	.24 ±.08	.187 ±.084	2.06 ±.05	.81 ±.09	.26 ±.03	10	4.4 ±.4	243.5 ±106.5	13.8 ±.9	27.7 ±5.5	101.6 ±3.0	20.1 ±.3
Larrea divaricata	leaf	.26 ±.03	.091 ±.035	2.07 ±.06	1.02 ±.08	.13 ±.02	13	4.0 ±1.4	227.9 ±60.7	32.2 ±3.6	74.1 ±14.3	75.5 ±6.6	10.5 ±4.2
	stem	.21 ±.04	.075 ±.027	1.90 ±.21	.69 ±.07	.17 ±.00	12	2.7 ±.6	216.1 ±88.0	23.0 ±4.3	28.0 ±4.9	84.9 ±7.4	11.9 ±2.1
Lycium andersonii	leaf	.16 ±.02	.028 ±.012	3.13 ±.49	8.75 ±.50	.71 ±.07	38	3.2 ±.4	114.0 ±17.4	38.8 ±12.8	47.0 ±1.2	219.6 ±12.1	17.6 ±2.2
	stem	.14 ±.02	.022 ±.011	1.66 ±.09	1.51 ±.21	.23 ±.05	19	4.2 ±.5	60.9 ±33.9	9.1 ±2.1	13.6 ±2.5	133.8 ±12.5	8.6 ±1.3

Table 13. Mineral composition of perennial vegetation from dry control plot in Mercury Valley nitrogen study site; Mercury pond plots, woody shrubs, 1969 (A3URM02)

Plant Species	Part	P	Na	K	Ca	Mg	Zn	Cu	Fe	Mn	B	Sr	Ba
				%						ppm			
Acamptopappus shockleyi	leaf	.26	.134	3.29	.77	.23	26	3.7	144.0	45.8	21.3	49.8	4.1
		±.02	±.021	±.09	±.12	±.03		±.7	±52.3	±10.2	±8.1	±5.2	
	stem	.15	.098	2.68	1.35	.19	13	5.0	94.4	22.2	10.1	103.2	9.5
		±.01	±.009	±.80	±.23	±.02		±1.6	±19.3	±1.4	±3.7	±11.6	±1.3
Ambrosia dumosa	leaf	.46	.136	4.42	1.82	.43	36	3.7	191.7	35.9	127.7	116.6	7.6
		±.07	±.034	±.67	±.39	±.01		±1.0	±47.4	±3.7	±36.1	±6.8	±1.4
	stem	.16	.114	3.12	1.28	.39	57	2.8	60.3	23.2	26.2	115.8	13.9
		±.02	±.052	±.20	±.20	±.05		±1.1	±3.2	±1.6	±3.8	±13.1	±2.0
Ephedra nevadensis	shoot	.30	.007	2.57	.68	.19	23	3.5	107.3	22.8	10.9	96.0	10.6
		±.03	±.002	±.32	±.07	±.02		±1.0	±25.8	±2.1	±4.3	±8.0	±2.2
Ceratoides lanata	leaf	.22	.050	3.24	1.43	.49	39	5.8	273.5	110.3	40.4	110.0	11.9
		±.02	±.012	±.58	±.09	±.04		±.3	±51.0	±20.6	±4.2	±8.1	±1.7
	stem	.09	.009	2.87	.71	.23	11	9.4	116.3	57.4	10.2	103.0	10.6
		±.01	±.003	±.03	±.06	±.02		±2.8	±27.9	±4.2	±5.5	±8.6	±.9
Grayia spinosa	leaf	.15	.231	8.33	1.95	.91	12	3.6	45.3	121.5	29.9	65.0	8.0
		±.01	±.042	±.86	±.26	±.06		±.4	±5.6	±11.8	±1.1	±4.5	±1.0
	stem	.11	.015	3.37	1.01	.32	17	4.3	128.6	30.6	12.6	66.7	10.0
		±.01	±.005	±.25	±.18	±.02		±.4	±12.0	±2.1	±4.1	±6.9	±1.8
Krameria parvifolia	leaf	.30	.040	2.14	.96	.35	17	5.3	195.0	68.1	37.1	78.5	14.3
		±.03	±.011	±.13	±.13	±.01		±.6	±45.2	±12.5	±6.0	±8.2	±2.8
	stem	.22	.019	2.21	.80	.28	5	3.9	184.9	23.2	22.3	92.1	19.2
		±.02	±.006	±.10	±.13	±.02		±.5	±55.9	±4.0	±1.2	±4.5	±2.1
Larrea divaricata	leaf	.16	.040	2.06	.94	.21	14	3.4	348.7	49.1	50.7	84.3	12.8
		±.02	±.020	±.10	±.15	±.00		±.8	±88.5	±3.6	±23.3	±7.3	±1.3
	stem	.11	.044	2.00	.83	.23	25	3.4	371.8	30.2	21.2	113.6	18.0
		±.01	±.014	±.05	±.02	±.01		±.6	±38.9	±2.3	±3.3	±1.7	±1.0
Lycium andersonii	leaf	.21	.012	3.78	7.44	.91	46	2.6	116.6	59.9	65.2	219.6	20.7
		±.01	±.005	±.33	±1.42	±.03		±.3	±11.1	±2.6	±6.1	±3.0	±1.8
	stem	.17	.003	1.83	1.36	.28	16	3.5	37.2	11.3	16.8	129.7	9.4
		±.03	±.001	±.76	±.51	±.05		±.4	±10.7	±2.7	±5.6	±29.9	±1.5

Table 14. Distribution of nitrate and ammonium forms of nitrogen in treated soil profiles, fall, 1973 (A3URM05).

Depth in Soil Profile	Rock Valley Field Plots*				Mercury Valley Field Plots**			
	+ Hardpan		- Hardpan		Dry		Irrigated	
	Shrub	Bare	Shrub	Bare	Shrub	Bare	Shrub	Bare
cm	mg N/100 g soil				mg N/100 g soil			
Water Soluble Nitrate-Nitrogen†								
3	.57	.10	.71	.21	1.34	.39	5.29	.17
15	.57	.31	.28	.10	1.29	.40	1.18	3.33
30	.16	.10	.15	.08	7.00	18.39	.53	16.69
Water Soluble Ammonium-Nitrogen††								
3	.057	.055	.008	.020	.132	.071	.126	.024
15	.016	.015	.019	.006	.030	.008	.025	.012
30	.018	.010	.009	.012	.032	.005	.017	.018

* Top-dressed with NH_4NO_3 equivalent to 100 kg N/ha in April 1967.

** Top-dressed with NH_4NO_3 equivalent to 200 kg N/ha in March 1968 and again in October 1970.

† Nitrate-nitrogen levels in control plots at both study sites were less than .25 mg N/100 g soil except in the A horizon underneath shrubs where it ranged from .50 to 1.25 mg N/100 g.

†† Ammonium-nitrogen levels in control plots ranged from .010 to .035 mg N/100 g soil in the profiles of both sites.

the top 30 cm of the soil profile of treated plots in Rock Valley by the sixth year following treatment. There was, however, from three to five times more nitrate-nitrogen in the root zone underneath shrubs than in the profile of bare areas. The highest levels of ammonium-nitrogen in these soil profiles were only about one-tenth of the nitrate-nitrogen levels present. Preliminary data from the Mercury Valley plots indicate that the fertilizer applied onto the soil surface was in the process of being leached downward, as a front, into the lower profile horizons of bare areas. In the root zone underneath shrub clumps, however, it was being utilized and recycled by plants. Additional sampling of these plots in more detail and at greater depth increments is underway to examine more closely the nature and depth of these vertical nitrogen profiles. It should be noted here that the irrigated Mercury plots received only about 3 cm of supplemental water after the last top-dressing of NH_4NO_3 before the sprinkler irrigation was terminated in the fall of 1970. Natural precipitation on these plots for the next 3 years was 7.81 cm, 9.35 cm and 22.04 cm, respectively.

Glasshouse Pot Culture Experiments

Some results from pot culture tests using

Table 15. Response of three shrub species to nitrogen fertilization of Mercury Valley soil under glasshouse pot culture conditions (A3URM06)

	A. canescens		*E. lanata*		*A. tridentata*	
Treatments*	Yield**	N***	Yield	N	Yield	N
	gm.	%	gm.	%	gm.	%
Control	55.6	0.60	24.9	0.52	14.3	0.88
100 kg. N/ha.	79.3	0.52	45.8	0.70	27.6	1.09
300 kg. N/ha.	79.3	0.94	51.0	1.84	33.1	2.25
F value	11.9	13.1	25.9	104.6	29.1	50.9
L.S.D. (.05)	13.7	0.21	9.4	0.24	10.8	0.36
L.S.D. (.01)	20.7	0.32	14.2	0.37	16.3	0.54

* NH_4NO_3 blended with potted soil.

** Total plant tops; mean of 3 replicates.

*** Nitrogen contents of leaf tissue.

three different species of desert shrubs (A3URM06) are given in Table 15. Significant increases in both yields and nitrogen contents of foliage were obtained for each of the shrub species investigated, supporting observations from the preliminary field plot studies. These experiments further demonstrate some beneficial effects that could be derived on desert shrubs from root zone contact with fertilizer supplements in such cases where it might be practical to achieve deep-placement of fertilizers. One must, however, recognize the agronomic principles concerning crop production and management when considering such manipulation of desert areas, because so few of the desert plant species seem to have adaptive strategies for producing competitively high forage yields.

DISCUSSION

The literature is full of reports indicating beneficial effects to be derived from nitrogen fertilization of rangelands to increase the productivity of forage grasses, but little evidence is available concerning effects on wildland shrubs. The preliminary studies reported herein produced some guidelines from which to set up some permanent field studies to examine in more detail such things as timing and placement of supplemental nitrogen and moisture, response to different forms of nitrogen fertilization, and transformations and interactions of different forms of nitrogen in desert soils with and without supplemental moisture.

Some of the more significant findings from these preliminary tests included marked responses to added moisture by overhead sprinkler irrigation during years of below-normal precipitation. This included the survival of new seedlings of several different shrub species on the watered plots. Responses were obtained from nitrogen fertilizers broadcast onto soil under natural desert conditions, but only when followed by sufficient precipitation to move the nitrogen supplement down into the root zone. The responses to supplemental moisture generally overshadowed any responses to nitrogen fertilization. We believe that it would be necessary to add nitrogen fertilizer to Mohave Desert vegetation which might be subjected to successive years of sprinkler irrigation in order to avoid adverse effects from nitrogen deficiency. The need for broadcasting fertilizer amendment onto bare soil between shrub clumps probably is questionable, but certainly it would need to be applied to the shrub clumps. Sustained, supplemental moisture probably would result in a succession of this shrub-clump type of desert rangeland to grassland vegetation.

The overhead sprinkler irrigation studies using the reclaimed sewage water of marginal quality were discontinued because of adverse effects on the foliage of some species, including *Ambrosia dumosa*, *Ephedra funerea*, *Larrea divaricata*, and *Yucca schidigera*. Flood irrigation tests showed that the marginal water source could be used as long as one might wish so long as the plant foliage did not come in contact with it. The more permanent study plots have been designed to receive water by trickle-irrigation from a clean drinking water source. Aside from the problem of water quality (salt and algal content), some adverse effects were observed on the foliage of the evergreen species from prolonged periods of being kept wet from sprinkler-irrigation in direct sunlight.

EXPECTATIONS

The following data are to be taken from the field studies in 1974 and continuing: (1) phenology, (2) nitrogen and other element contents of leaves, stems and flowers, (3) leaf-stem-root ratios, (4) new growth of perennials, (5) yield of annuals, (6) soil moisture tension, (7) leaf moisture potential, (8) soil nitrate and ammonium nitrogen forms, (9) soil organic matter, (10) dimensional analysis of shrubs, (11) C^{14} tagging to determine movement of photosynthate to plant parts, including roots, (12) rates of nitrogen uptake by plants under some of the environmental manipulations of moisture and nitrogen fertilization by N^{15}-tagging techniques.

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