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ABSTRACT

Residual effects of sprinkle irrigation on Mohave Desert shrub communities from 1968 through 1970 were observed, as were initial effects of trickle irrigation performed in 1974. The sprinkle-irrigated plots showed a residual increase in density of four species, but many others either failed to reproduce in significant numbers or lost all gains made during the dry years following treatment. Response to trickle irrigation was similarly species-dependent with just a few endemic species responding strongly to water. Invasion by short-lived perennials and summer annuals was begun, but was not massive during the initial season. Above-ground productivity, due mainly to established shrubs, varied from 52 to 560 kg/ha on dry control plots and from 1726 to 2130 kg/ha on irrigated plots. Nitrogen requirements for above-ground growth were 1 to 7 kg/ha on dry plots and 31 to 39 kg/ha on irrigated plots. Soil nitrate levels were strongly elevated by 100 kg N/ha applied as NH_4NO_3. Ammonium concentrations quickly decreased to control levels on irrigated plots, but remained high after fertilization of dry plots during the unusually dry summer of 1974. Mineral and nitrogen contents of leaves were little affected by nitrogen fertilization or irrigation during the initial season of treatment in contrast to effects on plants grown in a greenhouse. The primary phenological effect of treatment was to extend the period of growth of stems and leaves of those shrubs not normally inhibited by high soil and air temperatures.

INTRODUCTION

Our continuing program to determine the effects of irrigation and fertilizer application on Mohave Desert shrub communities has undergone considerable change in 1974. Data from a final census on sprinkle-irrigated plots described last year (Romney et al. 1974) are presented herein as are some preliminary data from new trickle-irrigated plots. Analytical data from previously reported glasshouse experiments are also included.

OBJECTIVES

The general objectives of this program are to determine responses of Mohave Desert shrubs and annuals to irrigation and nitrogen application. A basic premise supported by rangeland studies (Rogler and Lorenz 1957, Klipple and Retzer 1959, Dahl 1963, Stroehlein et al. 1968 and Owensby et al. 1970) is that, since water is normally limiting, nitrogen fertilization will be effective only when the water supply is increased.

The specific objectives of experiments reported herein were to:

1. Measure permanence of changes in biomass and shrub density when irrigation and fertilization are halted.
2. Measure changes in soil nitrogen contents caused by a single fertilizer application followed by irrigation.
3. Compare efficacy of sprinkle irrigation with that of trickle irrigation.
4. Measure changes in shrub and annual biomass, phenology, and mineral composition as affected by irrigation and nitrogen application.

METHODS

Census and Dimensional Analysis

For both sprinkle-irrigated and trickle-irrigated plots, the height and two widths of each shrub were recorded. From this information, shrub volume and biomass were calculated using a biomass-volume regression line. This technique and the regression lines used were reported by Wallace and Romney (1972). Such a census was performed on the sprinkle-irrigated plots in October and November 1974 and on the trickle-irrigated plots from February 13 to 15 and from September 27 to October 5, 1974.

Sums and means of the changes in biomass have been calculated only for the trickle-irrigated plots. Further analysis of these data and those from the sprinkle-irrigated plots is underway and will be covered in the next progress report.

Installation of Trickle-Irrigated Plots

In early 1974, thirty 20-m^2 plots were chosen near the CETO laboratory in Mercury, Nevada, in order to utilize a source of filtered, public water. This water is softened and has a high sodium content, balanced by sulfate and bicarbonate. Nitrate content is 0.4 ppm as N.

Part of the area chosen for these plots had been disturbed during construction of drainage channels in 1966, thus permitting an evaluation of treatment response on sites undergoing natural revegetation. The disturbed site includes six watered plots and one dry plot. The succession vegetation on the disturbed area is somewhat different from that on the undisturbed plots. It is predominantly *Atriplex confertifolia*. This gave us the opportunity to test transplanting procedures of several different species on these plots in conjunction with our primary objective.

Plastic pipe was installed to 24 of the plots. Shut-off valves in the feeder lines were included for each group of three plots, permitting differential watering on eight groups of three plots. There are 12 valves on each plot, each of which is set to allow a slow trickle of water on the inner 10-m^2 area of the plot.

Granular NH_4NO_3 was applied at the rates of 25 and 100 kg N/ha to the 20-m^2 area of selected plots on March 14, 1974. There was no rainfall from that date until late July, and no irrigation water was applied before April 15. Consequently, the fertilizer is presumed not to have affected growth of winter annuals.

Water was applied to saturation on all irrigated plots from April 15-19, May 13-20, June 16-July 7 and August 30-September 3. Between October 23 and October 26 an estimated 9.5 $\pm$ 0.8 cm were applied. This quantity was estimated by measuring output from three valves per plot, which averaged 35 $\pm$ 11 cm^3/min. Water was allowed to flow for 75.5 hr.

Phenology

Phenological stages of the more common perennial shrubs were recorded from March 15, 1974. Plants were observed weekly during the season of rapid growth and biweekly thereafter. The data are recorded as a subjective percentage of maximum possible flowering, fruiting, etc., rather than as percentage of plants exhibiting a given stage.

Biomass of Annuals

The biomass of winter annuals was determined as of May 5-6 by uprooting and drying (60 C for three days) all annuals within 16 randomly selected 0.1-m^2 areas on each of four plots. The dried samples were pooled by species and weighed. Roots were not processed in most cases.

Summer annuals were harvested from the whole 20-m^2 area of each plot in early September 1974. The plants were dried and weighed and an aliquot saved for nitrogen and mineral analysis. *Salsola* seed had not matured before harvest, but was approaching maturity. Summer annuals adjacent to the plots were not harvested and were expected to disperse considerable seed onto the plots.

Nitrogen and Mineral Analysis

Plant tissue nitrogen was determined with an ammonia electrode following Kjeldahl digestion of 150 to 300 mg of tissue.

Soil nitrate nitrogen was determined on 20 g of sieved soil ($<$ 2 mm) diluted with 40 ml of 0.01 M sodium citrate and 10 ppm sodium nitrate. The determination was done with an Orion nitrate electrode and an Orion 801 selective ion analyzer.

Soil ammonium nitrogen was determined on the same soil extract used for nitrate determination, following filtration, with an Orion ammonium electrode.

Mineral analysis of plant tissues was performed by emission spectrography.

Abiotic Data

Precipitation was measured with a standard rain gauge located approximately 50 m from the nearest plot and 200 m from the furthest. The dates recorded are, in most cases, the day following precipitation inasmuch as the rain gauge was read the morning after a rainfall.

In September and October, Wescor PT51-05 soil moisture-temperature sensors were installed on a number of plots at depths of 15, 30 and 60 cm. Water potential and soil temperatures were measured biweekly with a Wescor HR-33T Dewpoint Microvoltmeter.

RESULTS

Sprinkle-Irrigated Plots

A report census of some plots that previously had been treated with reclaimed sewage water showed that changes induced by supplemental sprinkler irrigation were still apparent four years after the last application of water. In particular, there remained a net gain in population on the watered plots and a net loss on the dry plots (Table 1; DSCODE A3URM07).

Population changes depended significantly on species. *Ceratoides lanata* had a much more rapid turnover than did most other species, losing 12 to 36% of its population during the course of the study on dry plots while its population increased on irrigated plots. *Sphaeralcea ambigua* lost an even higher proportion, 55 to 93% on the dry plots, and nearly as much, 47 to 79%, on watered plots.

The population of *Acamptopappus shockleyi* increased on all plots, watered or not. Gains on dry plots ranged from 6 to 55% and on watered plots from 8 to 105%.

Numbers of *Ambrosia dumosa* increased slightly on watered plots and decreased slightly on dry plots. This species, especially, showed visible increases in new biomass in response to supplemental moisture.

Other species generally showed negligible changes in populations and, for several species, this low turnover rate is considered to be significant. *Krameria parvifolia*, *Ephedra funerea*, *Ephedra nevadensis*, *Yucca schidigera* and *Salazaria mexicana* must have unusually long life spans if our data are representative. Similarly, their invasion of disturbed sites must be very slow.

It is also apparent from Table 1 that populations of major shrub species are not evenly distributed over the study area. Rather than being randomly distributed, they show local aggregations whose origins are presently unexplained. A more detailed consideration of their distribution is presented by Wallace and Romney (1972).

As mentioned before, the biomass changes by species on these plots are not yet yet complete and will be reported in the next progress report. Residual effects of nitrogen application, if any, will presumably show up following further analysis of the data.

Some subjective observations on these sprinkle-irrigated plots may be considered of value. There is a well-developed shrub clump structure, with each clump surrounded by desert pavement. Seedlings growing in the interspaces and on the edges of the clumps, though restricted in number and species, seemed to have grown larger than those growing within the clumps. Furthermore, live stems and leaves were distributed to receive the maximum sunlight, whereas one might expect shading to be advantageous in the desert.

Sprinkle irrigation led to the discoloration or burning of leaves of some species, presumably due to salt deposited on

Table 1. Population changes in sprinkle-irrigated plots over a 6-year period. Water was applied to wet plots in 1968, 1969 and 1970. Fertilizer rates were 224 kg/ha N or P, applied in 1967 and again in 1970. Area of each plot is 730 m^2 (A3URM07)

SPECIES	WET CONTROL						WET + N				WET + N + P			
	Start	New	Died	New	Died	6 yr	Start	New	Died	6 yr	Start	New	Died	6 yr
	1968	68-70	68-70	71-74	71-74	Δ	1968	68-74	68-74	Δ	1968	68-74	68-74	Δ
Aca. sho.	266	100	-14	18	-50	+54	244	53	-33	+20	83	95	- 8	+87
Amb. dum.	144	18	- 1	0	- 4	+13	241	8	- 6	+ 2	148	23	- 2	+21
Atr. con.	20	0	0	0	-16	-16	26	5	-12	- 7	0	0	0	0
Cactus	6	1	0	0	0	+ 1	3	5	0	+ 5	1	0	0	0
Cer. lan.	138	67	- 3	15	-43	+36	65	8	- 6	+ 2	185	73	-22	+51
Col. ram.	0	0	0	0	0	0	3	0	- 2	- 2	0	0	0	0
Eph. fun.	24	0	0	0	0	0	33	6	- 1	+ 5	6	0	0	0
Eph. nev.	20	1	0	1	- 1	+ 1	41	4	- 1	+ 3	19	3	- 1	+ 2
Gra. spi.	16	5	0	3	- 1	+ 7	11	2	- 2	0	36	30	- 3	+27
Kra. par.	79	0	0	0	- 6	- 6	86	3	- 1	+ 2	76	3	- 3	0
Lar. tri.	33	1	- 1	0	0	0	41	0	- 2	- 2	63	1	- 2	- 1
Lep. fre.	0	8	0	19	- 2	+25	12	50	0	+50	0	4	0	+ 4
Lyc. and.	53	1	0	1	- 1	+ 1	73	1	0	+ 1	55	0	- 1	- 1
Mac. tor.	2	6	0	0	- 4	+ 2	22	9	0	+ 9	4	15	0	+15
Man. spi.	7	0	0	0	0	0	1	0	0	0	1	15	0	0
Ory. hym.	8	1	- 6	0	- 3	- 8	21	5	-11	- 6	8	0	- 4	- 4
Sal. mex.	2	0	0	0	0	0	6	0	0	0	9	0	0	0
Sph. amb.	89	54	- 4	1	-121	-70	85	3	-58	-55	43	10	-30	-20
Ste. pau.	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sti. spe.	2	2	0	1	- 1	+ 2	0	2	0	+ 2	0	4	0	+ 4
Yuc. sch.	5	1	0	0	0	+ 1	8	1	0	+ 1	7	0	0	0

SPECIES	DRY CONTROL						Dry + N				DRY + N + P			
	Start	New	Died	New	Died	6 yr	Start	New	Died	6 yr	Start	New	Died	6 yr
	1968	68-70	68-70	71-74	68-70	Δ	1968	68-74	68-74	Δ	1968	68-74	68-74	Δ
Aca. sho.	74	17	-2	4	-10	+9	27	17	-2	+15	82	25	-20	+5
Amb. dum.	102	4	-2	3	- 6	-1	83	2	-2	0	66	1	- 4	-3
Atr. con.	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cactus	0	1	0	2	- 1	+2	2	0	0	0	2	0	- 1	-1
Cer. lan.	318	22	-9	+31	-82	-38	185	44	-83	-39	317	12	-127	-115
Col. ram.	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Eph. fun.	5	0	0	2	0	+2	6	1	0	+ 1	0	1	0	+1
Eph. nev.	10	0	0	4	0	+4	0	2	0	+2	2	1	0	+1
Gra. spi.	33	13	-1	3	-3	+12	21	10	-2	+8	25	2	0	+2
Kra. par.	28	1	0	0	0	+1	25	0	-1	-1	13	0	0	0
Lar. tri.	49	3	0	0	0	+3	32	0	-1	-1	69	0	-3	-3
Lep. fre.	2	0	0	0	0	0	0	1	0	+1	0	2	0	+2
Lyc. and.	46	0	-1	0	-1	-2	33	1	0	+1	29	0	-1	-1
Mac. tor.	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Men. spi.	1	0	0	0	0	0	1	0	0	0	0	0	0	0
Ory. hym.	14	2	-5	1	-2	-4	0	1	0	+1	6	2	-2	0
Sal. mex.	10	0	0	0	0	0	15	0	-2	-2	2	0	0	0
Sph. amb.	47	2	-4	1	-27	-28	55	3	-33	-30	30	0	-28	-28
Ste. pau.	2	0	0	0	-1	-1	0	1	0	+1	0	0	0	0
Sti. spe.	36	4	0	5	-8	+1	18	3	-8	-5	8	1	-1	0
Yuc. sch.	3	1	0	1	-2	0	3	0	-1	-1	6	0	-1	-1

them and/or sunscald from being wetted during the intense heat and sunlight of successive days of sprinkler irrigation. This may also have killed some seedlings. Such leaves generally were lost, but were quickly replaced due to the added moisture. This damage is obviated by use of trickle irrigation or furrow irrigation.

Trickle-Irrigated Plots

Abiotic Environment

Rainfall on the area covered by the newly established trickle-irrigated plots is recorded in Table 2. Soil water potentials and temperatures are recorded in Table 3. The spring and summer months of 1974 were quite dry so the natural precipitation generally had little influence on the irrigation treatments applied.

Soil-water potentials (Table 3) show the effects of early September and October irrigations as well as the effects of rainfall after mid-October. There was very little drying of the soil during the winter and spring months; nearly all moisture was stored until March. The depth of wetting from natural precipitation did not reach down to 60 cm in control plots, a depth which would probably remain "dry" during most low-rainfall years. Irrigated plots were wet below the 60-cm depth after the early fall moisture applications.

Saturation extract nitrate and ammonium concentrations were measured on a few samples taken June 11, July 30 and October 5. These samples conform to the expected increase in nitrate concentrations caused by fertilization, but elevated ammonium concentrations were found only on dry plots (Table 4).

Table 2. Rainfall on trickle-irrigated plots during the 1974 and early 1975 growing season

Date	Precipitation	Date	Precipitation
	mm		mm
8-3-73	5.8	10-3-74	9.9
8-5-73	0.5	10-8-74	1.5
10-8-73	0.5	10-28-74	9.1
10-9-73	3.8	10-29-74	2.8
11-18-73	17.0	10-30-74	1.8
11-21-73	1.8	11-1-74	1.3
12-2-73	2.3	11-3-74	4.6
		12-4-74	7.4
1-1-74	14.2	12-5-74	17.8
1-9-74	15.5	12-29-74	7.9
1-17-74	0.8		
1-21-74	5.3	1-28-75	0.3
2-19-74	0.3	2-3-75	1.0
2-28-74	0.8	2-14-75	0.5
3-3-74	0.5	2-15-75	17.5
3-8-74	1.0	3-6-75	9.4
7-21-74	0.5	3-10-75	3.9
7-22-74	10.4	3-11-75	0.3
7-30-74	0.5	3-12-75	0.8
8-3-74	5.7	3-14-75	2.0

Table 3. Soil temperatures and water potentials of trickle-irrigated and control plots in Mercury Valley

	Soil water potentials						Soil temperatures
	Irrigated plots			Control plots			wet and dry**
Depth, cm	15	30	3	15	30	60	30
# of psychrometers	3	9	3	2	4	2	13
	negative bars			negative bars			°C
Date:							
October 17, 1974	1	5	2	>72*	>71	>74	21.8
October 21, 1974	11	6	2	>69	>73	>75	21.4
November 1, 1974	0	0	0	27	>75	>75	18.7
November 15, 1974	1	0	1	6	>63	>81	19.3
November 26, 1974	1	1	1	7	>57	>70	19.7
December 6, 1974	1	0	0	0	41	>83	16.1
December 20, 1974	1	0	0	1	10	>97	13.4
January 3, 1975	3	0	1	0	4	>85	13.9
January 17, 1975	2	0	0	2	4	>96	11.2
January 31, 1975	5	1	0	2	4	>97	10.7
February 18, 1975	0	0	0	0	2	>99	9.5
March 3, 1975	1	0	0	2	2	>99	11.2

* These values represent the limits of the measurement system, which depend upon soil temperature and cooling coefficients of the psychrometers.

**Soil temperature on wet and dry plots do not differ significantly at P = 0.05 Averages differ less than 1° C.

Table 4. Soil nitrogen levels as affected by irrigation and fertilizer application (A3URM08)

	NO_3-N, ppm			NH_4-N, ppm		
Treatment	June 11	July 30	Oct. 5	June 11	July 30	Oct. 5
Days since treatment	89	138	205	89	138	205
Wet 100 N	113 ± 44*	180 ± 63		1.3 ± 0.5	0.7 ± 0.1	
Wet 25 N	24 ± .05	89 ± 25	46 ± 19	1.0 ± 0.1	0.9 ± 0.3	1.3 ± 0.3
Wet 0 N	17 ± .06	67 ± 39		0.7 ± 0.1	1.1 ± 0.4	
Dry 100 N	119 ± 40	90 ± 23		7.6 ± 3.4	21.1 ± 4.2	
Dry 25 N	42 ± .08	20 ± 1	20**	3.4 ± 0.4	4.4 ± 0.1	1.9**
Dry 0 N	8 ± .03	6 ± 1		1.0 ± 0.1	1.1 ± 0.4	

* Error estimate is standard error of mean. For June 11, n=4; July 30 n=2; October 5 n=6.

**Only one determination.

Biological Effects

Addition of supplemental water to the desert is a rather severe change in the natural environment and plant species differ considerably in their response. Table 5 shows some of the population changes after the first summer of trickle irrigation (A3URM12). Many of the slow-growing and long-lived perennials were not strongly affected. *Menodora spinescens*, *Krameria parvifolia* and *Yucca schidigera*, although relatively common in the test area, did not increase in numbers. *Lycium andersonii* and *Ephedra nevadensis* are rare in this area so seedlings were not expected. *Ephedra funerea* and *Larrea tridentata* seedlings were moderately common after the first summer of treatment.

Several other long-lived shrubs common in the area increased dramaticallly in numbers. *Acamptopappus shockleyi, Atriplex confertifolia* and *Ambrosia dumosa* are most conspicuous. *Lepidium fremontii*, occurring on nearby distrubed areas, and *Sphaeralcea ambigua* also increased considerably in numbers.

Species not common, but showing an increase which may become significant, include *Baileya multiradiata*, *Cryptantha virginensis* and *Encelia virginenesis*. *Erodium cicutarium* was present and flowering on one plot during the fall census.

There are a number of grasses in the area. *Stipa speciosa* and *Oryzopsis hymenoides* are rare but could be expected to increase in numbers. The diminutive *Tridens pulchellus* is common, but unevenly distributed. A large number of *Tridens pulchellus* seedlings were present on a small part of the study plots in the fall.

We expect to see continuing rather significant changes in species composition as trickle irrigation is continued.

Phenology

Table 6 (A3URM09) details phenological stages for five of the more common shrub species. Irrigation had a strong effect on most species; *Ambrosia dumosa* and *Larrea tridentata* both produced new stems and leaves, *Acamptopappus shockleyi* retained its leaves all summer but did not grow, *Ephedra funerea*, *E. nevadensis* and *Lycium andersonii* appeared to go dormant in spite of the added moisture.

Nitrogen effects on phenology seemed limited. The most obvious effect was the greater production of flowers and fruit by *Ambrosia dumosa* plants on the high-nitrogen plots. Other effects suggested by data in Table 6 are renewal of leaf and stem growth by *Acamptopappus shockleyi*, *Atriplex confertifolia* and the two *Ephedra* species in the early fall.

Table 5. Population change on trickle-irrigated plots between February 19 and September 20, 1974. Area counted was 20 m^2 per plot. Fertilizer rates are 100, 25 and 0 kg N/ha as NH_4NO_3. There are eight plots of each watered treatment, two of 100 N + 25 N dry, and four of 0 N dry (A3URM12)*

Species	Watered plots number/100 m^2						Unwatered plots number/100 m^2					
	100 N		25 N		0 N		100 N		25 N		0 N	
	Feb	Sep	Feb	Sep	Feb	Sep	Feb	Sep	Feb	Sep	Feb	Sep
Aca. sho.	85	174	46	126	54	111	35	35	40	40	12	12
Amb. dum.	92	198	60	141	80	356	40	40	40	40	0	0
Atr. con.	134	240	81	336	71	136	95	95	155	145	108	105
Bai. mul.	0	2	0	9	0	2	0	0	0	0	0	0
Cactus	4	5	2	2	1	1	0	0	0	0	2	2
Cry. vir.	0	31	0	64	0	22	0	0	0	0	0	0
Enc. vir.	1	2	1	4	1	6	0	0	0	0	0	0
Eph. spp.	14	18	11	14	12	14	15	15	10	10	15	15
Kra. par.	5	5	2	2	6	6	0	0	20	20	0	0
Lar. tri.	14	20	15	21	12	20	20	20	10	10	15	15
Lep. fre.	29	55	21	66	15	55	15	15	10	10	20	20
Lyc. and.	10	10	11	11	10	10	5	5	5	5	2	2
Men. spi.	25	25	32	32	34	34	51	51	10	10	48	48
Ory. hym.	1	1	0	0	0	0	5	5	0	0	0	0
Sph. amb.	15	70	19	125	26	220	20	20	10	10	15	15
Ste. pau.	0	4	1	4	0	0	0	0	0	0	0	0
Sti. spe.	2	4	1	1	2	4	0	0	0	0	0	0
Tha. mon.	0	1	1	2	2	10	0	0	15	15	2	2
Tri. pul.***	--	(45)	--	(51)	--	0	--	(0)	--	(80)	--	(0)

* Three dry control plots were selected in October. The tabulated data assumes no population change on these plots.

**Some plants were transplanted onto plots lacking them. These included 28 of 29 <u>Lycium andersonii</u>, 13 of 24 <u>Ephedra nevadensis</u>, and 17 of 203 <u>Ambrosia dumosa</u>. Native <u>Ephedras</u> are <u>E. nevadensis</u>.

***<u>Tridens pulchellus</u> was not counted in February.

Table 6. Comparative phenologies of selected shrubs during 1974 under four water and nitrogen treatments (A3URM09)

a. *Acamptopappus shockleyi*

Treatment	Number of plants (n)	First leaf buds	Leaves expanded	New stems	First flower buds	Open flowers	% of possible flowers	Flower buds dying	First fruit apparent	% of possible fruit	Fruit falling	First leaf senescence	Start of leaf fall	Dormant
Dry 0 N	2	n.d.[a]	n.d.	n.d.	Mar 15	May 2-10	<30	May 20	May 20	<30	May 28	May 2	May 20	Sep 3
		Oct 16	Nov 15											
Dry 100N	2	n.d.	n.d.	n.d.	Mar 15	Apr 25-May 20	30-70	May 20	May 10	30-70	May 20-	May 10	May 20	Sep 3
Wet 0 N	1[b]	n.d.	n.d.	n.d.	Mar 15	Apr 25-Jun 4	<30	May 20	May 10	<30	May 28-Jul 1	May 20	May 28	never
Wet 100N	2	n.d.	n.d.	n.d.	Mar 15	Apr 25-May 28	100	Jun 13	May 10	100	May 28-Jul 1	May 28	Jul 1	never
		n.d.[c]	Jul 29->	Oct 1[c]	Oct 1									

[a]n.d. means no observations made at that stage.

[b]Another plant transplanted in March.

[c]New leaves and stems produced much of summer.

Table 6, continued

b. *Ambrosia dumosa*

Treatment	Number of plants (n)	First leaf buds	Leaves expanded	New stems	First flower buds	Open flowers	% of possible flowers	Flower buds dying	First fruit apparent,	% of possible fruit	Fruit falling	First leaf senescence	Start of leaf fall	Dormant
Dry 0 N	2	n.d. Oct 16	n.d. Oct 16	Mar 15	Apr 4	May 2-	70-100	n.d.	May 10	70-100	May 28-	May 28	May 28	Jul 29[c] Sep 17
Dry 100N	2[a]	n.d. Oct 16	n.d. Oct 16	Mar 15	May 2	none	0	May 28	none	0	none	May 28	May 28	Sep 3[c] Sep 17
Wet 0 N	2	n.d.	n.d.	Mar 15[b]	Apr 4♀ May 28♂	May 2-20♀ Jun 13♂	<70	n.d.	May 10	<70	May 28- Jul 1	Jun 17	Jul 1	never
		n.d.[b]	n.d.[b]	Jun 15[b]	Jul 29	Jul 29♂	<30	n.d.	n.d.	<30				
		Sep 17[b]	n.d.[b]	Sep 17[b]	Sep 17	Sep 17	n.d.	Oct 1	Oct 16	0	Nov 8	Oct 1	Oct 16	
Wet 100N	2	n.d.	n.d.	Mar 15[b]	Apr 4	May 10- Jun 4	100	n.d.	May 20	100	May 20	Jun 13	Jun 13	never
		b	b	Jul 16[b]	Jul 1	Jul 16- Sep 3	100	n.d.	Jul 29	100	Jul 29	Dec 17	Dec 17	

[a] Both plants transplanted in March.

[b] Stems and leaves produced all summer.

[c] Two plants dormant on different dates.

c. *Atriplex confertifolia*

Treatment	n	First leaf buds	Leaves expanded	New stems	First flower buds	Open flowers	% of possible flowers	Flower buds dying	First fruit apparent,	% of possible fruit	Fruit falling	First leaf senescence	Start of leaf fall	Dormant
Dry 0 N	2	n.d.	n.d.	n.d.	n.d.	Apr 4-♀ May 10 Apr 4 - May 20♂	100	n.d.	Apr 25	100	Oct 1→	May 10	May 20	never[a]
Dry 100N	2	n.d.	n.d.	n.d.	n.d.	Apr 4-♀ Apr 10 Apr 4- May 20♂	100	n.d.	Apr 25	100	Sep 17→	May 2	May 2	never[a]
Wet 0 N	2	n.d.	n.d.	n.d.	n.d.	Apr 4-♀ May 20 Apr 4- Jun 4♂	100	n.d.	Apr 25	100	Sep 17- Dec 17	May 2	May 10	never[a]
Wet 100N	2	n.d.	n.d.	n.d.	n.d.	Apr 4-♀ Jun 4 Apr 4- Jul 1♂	100	n.d.	Apr 25	100	Sep 1- Dec 17	May 2	May 10	never[a]
			Oct 16	Nov 8										

[a] Live *A. confertifolia* always retain some leaves or bracts.

d. *Ephedra funerea* and *Ephedra nevadensis*

Treatment	n	First leaf buds	Leaves expanded	New stems	First flower buds	Open flowers	% of possible flowers	Flower buds dying	First fruit apparent,	% of possible fruit	Fruit falling	First leaf senescence	Start of leaf fall	Dormant
Dry 0 N	1[a]	none	none	none	none	none	n.a. [b]	none	none	n.a.	none	May 2	May 10	Jun 13
Dry 100N	2	Mar 15	n.a.	Mar 26	none	none	n.a.	none	none	n.a.	none	May 28	none	never? [c]
Wet 0 N	1	Mar 15 Oct 16	n.a.	Apr 5	none	none	n.a.	none	none	n.a.	none	none	none	never?
Wet 100N	1	Mar 15 Oct 16	n.a.	Apr 25 Nov 8	none	none	n.a.	none	none	n.a.	none	none	none	never?

[a] One transplanted *E. nevadensis*. All others are natural *E. funera*.

[b] Not applicable.

[c] Dormancy is difficult to determine by visual means in *Ephedra*.

Table 6, continued

e. *Larrea tridentata*

Treatment	Number of plants (n)	First leaf buds	Leaves expanded	New stems	First flower buds	Open flowers	% of possible flowers	Flower buds dying	First fruit apparent	% of possible fruit	Fruit falling	First leaf senescence	Start of leaf fall	Dormant
Dry 0 N	1	Mar 15[a]	Mar 26[a]	Mar 26[a]	Apr 2	May 10- May 28	<70	May 28	May 20	<70	Jul 1- Jul 16	May 2	May 2	never
		Jul 29	Aug 20	Aug 20								Sep 17	Oct 1	
		Oct 16	Oct 16									Dec 17	Dec 17	
Dry 100N	1	Mar 15	Mar 26	Mar 26	Mar 26	May 10- May 20	<60	May 28	May 20	<60	Jul 1- Jul 16	May 2	May 2	never
		Jul 29	Aug 20									Sep 3	Sep 3	
		Oct 16	Nov 25											
Wet 0 N	2	Mar 15	Mar 26	Mar 26	Mar 26	May 20- Jun 13	100%[b] <30%	n.d.	May 20	100[b] <30	Jul 1- Jul 29	May 10	May 20	never
												Oct 1	Oct 1	
				Nov 8								n.d.	Nov 25	
Wet 100N	1	Mar 15	Mar 26	Mar 26	Mar 26	May 20- Jun 4	100%	n.d.	May 20	<70	Jul 1- Jul 29	May 10	May 28	never
				Mar 26 Nov 8								n.d.	Oct 1	
												Nov 25	Nov 25	

[a] *Larrea* produces leaves and stems whenever moisture is adequate and weather warm.

[b] Reflects differences between the two plants observed.

Annuals

Winter annuals were slightly affected by the irrigation treatments applied two weeks prior to harvest (Table 7; A3URM10). Numbers of plants were not affected, but dry weight per plant was almost twice as high on the watered plots. Winter annuals on plots with added nitrogen were not harvested as there was no apparent effect of treatment distinguishable from moisture response.

Many winter annuals were present in low numbers. One would expect changes in population of various species as treatment progresses, but we do not as yet have data to suggest which species will benefit from added moisture and nitrogen.

It might be expected, given the available summer moisture, that some winter annuals would germinate and grow. This was not evident during the fall census. There were a number of grass seedlings of undetermined taxon, and a few maturing plants of the grass *Bouteloua barbata*.

Summer annual productivity was almost totally dependent upon water (Table 8; A3URM11). Two genera, *Salsola* and *Eriogonum*, produced nearly the total biomass. *Euphorbia micromera* produced a small proportion of the total. Two species of *Salsola*, *S. iberica* and *S. paulsenii*, and their hybrids are present in this area. The *Eriogonum* population consisted of *E. brachypodum* and *E. trichopes*.

The study area includes two areas with differing soil surfaces, separated by a man-made drainage channel. Above this channel is a well-developed desert pavement, long undisturbed. Below the channel the pavement has been disrupted by graders and other traffic and is, therefore, not as compact. Most of the *Salsola, Eriogonum brachypodum, Lepidium fremontii* and *Atriplex confertifolia* occurred in the disturbed area. *Salsola* growing in the undisturbed area was grazed by rodents which may have affected its distribution. Similarly, *Eriogonum brachypodum* predominated on the disturbed area, while above the wash only *Eriogonum trichopes* was found. *Euphorbia micromera* was present primarily on the undisturbed area. Finally, a few plants of *Halogeton glomeratus* grew on the disturbed area.

Interestingly, two of the most important annuals are introduced species; *Salsola*, common primarily along roadsides, and *Bromus rubens*, dispersed over much of the desert. *B. rubens* may play a significant role in nitrogen cycling as its roots have been associated with acetylene reduction activity (Wallace and Romney 1972).

Nitrogen requirements of annuals were less than 1 kg/ha on dry plots, but ranged from 6 to 8 kg/ha on watered plots (Table 9).

Perennial Shrubs

Growth estimates for the above-ground portions of perennial shrubs, calculated from dimensional measurements, are given in Table 10 (A3URM11).

One of the more interesting effects of the initial trickle-irrigation treatments was an unexpected response resulting in the need to abandon two of the dry, unfertilized plots and select new ones. Earlier work of excavating shrub root systems had indicated that the bulk of root distribution occurred within about 2 m of the shrub canopy. We assumed, therefore, that a buffer zone of 3 to 4 m would be sufficient between wet and dry plots. This was not so under certain conditions, as indicated by the data in Table 10. Some of the mature shrubs in these plots obviously received supplemental moisture in comparison to adjacent dry areas. *Atriplex confertifolia* and *Ambrosia dumosa* showed easily

Table 7. Density and weights of annuals on watered and unwatered plots as of May 3-6, 1974. Plots 3 and 21 were watered from April 15-20, 1974. Area sampled was 1.6 m^2 per plot, as sixteen 0.1 m^2 quadrangles (A3URM10)

Taxon	Unwatered plots				Watered plots			
	Plot 7		Plot 14		Plot 3		Plot 21	
	#/m^2	kg/ha dry wt	#/m^2	kg/ha dry wt	#/m^2	kg/ha dry wt	#/m^2	kg/ha dry wt
Bromus rubens	145.5	27.00	103.1	18.43	157.5	86.06	16.9	8.50
Caulanthus lasiophyllus	0	0	0	0	0.6	0.18	0	0
Chaenactis carphoclina	13.8	1.37	23.1	3.50	15.0	2.50	18.1	3.75
" macrantha	2.5	0.87	9.4	4.31	0	0	0.6	0.37
Chorizanthe brevicornu	0	0	0.6	<0.06	0.6	0.06	0	0
" rigida	4.4	0.81	8.1	0.50	5.0	0.37	8.8	0.12
Crypthantha circumscissa	18.8	1.18	8.1	1.06	21.9	6.50	26.9	4.12
" nevadensis	16.9	2.50	94.4	7.62	18.8	7.43	10.0	2.50
" recurvata	3.1	0.37	16.3	0.87	1.9	0.43	0.6	0.06
" virginensis*	3.1	0.50	0	0	1.2	0.06	0	0
" spp.	0	0	3.1	0.18	0	0	0	0
Descurainia pinnata	0	0	1.9	0.12	4.4	0.37	1.9	0.12
Eriogonum brachypodum*	3.1	0.25	0	0	2.5	0.31	3.1	0.25
" trichopes*	0	0	0	0	0	0	8.8	1.75
Erodium cicutarium	0	0	0	0	8.8	12.31	0	0
Festuca octoflora	262.5	9.37	294.4	8.31	33.1	3.18	616.2	22.68
Gilia cana	0.6	< 0.06	0	0	0	0	0	0
Ipomopsis polycladon	0	0	0	0	4.4	0.06	8.8	0.06
Langloisia setosissima	42.5	3.87	28.8	3.00	36.2	6.06	48.8	4.12
Linanthus demissus	3.1	0.12	1.9	0.06	0	0	11.2	0.31
Oenothera munzii	0	0	10.0	1.81	1.2	0.12	1.9	0.12
Phacelia fremontii	3.1	0.12	2.5	0.18	0.6	0.50	4.4	0.25
" vallis-mortae	0	0	0	0	0	0	5.6	16.50
Pectocarya spp.	0	0	0	0	3.1	0.75	0	0
Rafinesquia neomexicana	0	0	0.6	0.06	0	0	0	0
Sisymbrium altissimum	0.6	< 0.06	0	0	6.9	0.43	0	0
Salsola spp*	0.6	< 0.06	0	0	24.4	0.11	1.2	0.12
Schismus arabicus	0	0	0	0	17.5	3.62	0	0
Strepthanthella longirostris	3.1	0.68	0	0	0	0	0	0
Stylocline micropoides	0	0	0	0	0.6	0.06	0	0
Tridens pulchellus*	0	0	0	0	0	0	2.5	0.06
Totals	527.3	49.19	606.3	50.07	366.2	131.47	796.3	65.76

*Other data areincluded on Eriogonum and Salsola as summer annuals. C. virginesis and T. pulchellus are, respectively, a short-lived perennial and a long-lived, but diminutive, perennial.

Table 8. Above-ground dry matter production by summer annuals as affected by irrigation and fertilizer application. Determined in September by harvest (A3URM11)

Species	Treatment					
	Wet 100 N	Wet 25 N	Wet 0 N	Dry 100 N	Dry 25 N	Dry 0 N
	kg/ha ± sem*	kg/ha ± sem	kg/ha ± sem	kg/ha ± sem	kg/ha ± sem	kg/ha ± sem
Salsola spp.	273 ± 162	250 ± 93	176 ± 110	0 ± 1	0 ± 0	0 ± 0
Eriogonum spp.	165 ± 53	124 ± 47	82 ± 47	1 ± 1	0 ± 0	3 ± 1
Other spp.	12 ± 5	2 ± 1	1 ± 1	0 ± 0	0 ± 0	0 ± 0
Totals	450	376	259	1	0	3

*Standard error of mean.

Table 9. Estimated nitrogen requirements for above-ground productivity as affected by irrigation and nitrogen fertilization. Data are derived from values in Tables 7, 8, 10, 11 and 12, and leaf-to-stem ratios from Romney et al. (1974)

SPECIES	TREATMENT					
	Wet 100N kg-N/ha[a]	Wet 25N kg-N/ha	Wet 0 N kg-N/ha	Dry 100N kg-N/ha	Dry 25N kg-N/ha	Dry 0 N kg-N/ha
Aca. sho.	2.09	1.32	1.79	0.06	2.13	0.00
Amb. dum.	13.00	9.44	13.20	0.00	-0.20	1.21
Atr. con.	4.84	3.78	3.47	-1.88	-1.41	3.47
Eph. spp.	1.37	0.03	1.23	0.18	1.70	0.00
Kra. par.	0.53	0.11	0.25	-0.12	-0.06	0.00
Lar. tri.	5.00	2.48	3.28	1.48	0.91	0.30
Men. spi.	2.09	2.98	1.80	0.12	0.34	0.58
ph. amb.	0.17	0.45	0.27	0.04	0.00	0.04
Other perennials	0.50	0.00	0.13	0.04	-0.18	0.00
Seedling perennials	0.97	2.94	1.52	0.32	0.70	0.60
Eriogonum spp.	2.81	1.79	1.26	0.02	0.00	0.05
Salsola spp.	3.87	4.11	3.35	0.00	0.00	0.00
Other summer annuals	0.17	0.03	0.02	0.00	0.00	0.00
Winter annuals	1.49[b]	1.49[b]	1.49	0.74[b]	0.74[b]	0.74
Totals	38.90	30.95	33.06	1.00	4.67	6.99[c]

[a] Error estimates (sem) consistently approach 50% of the tabulated means.
[b] Winter annuals were harvested only on non-fertilized plots.
[c] Perennial plants on the two dry control plots received some subsoil moisture from adjacent watered plots.

Table 10. Above-ground dry matter production by perennial shrubs as affected by water and fertilizer application. Biomass was estimated by dimensional analysis in February and September 1974. There are eight replicates for watered treatments and two for unwatered treatments (A3URM11)

Species	Treatment					
	Wet 100 N	Wet 25 N	Wet 0 N	Dry 100 N	Dry 25 N	Dry 0 N*
	kg/ha ± sem **	kg/ha ± sem	kg/ha ± sem	kg/ha ± sem	kg/ha ± sem	kg/ha ± sem
Aca. sho.	104 ± 54	66 ± 22	90 ± 62	3 ± 3	112 ± 89	0 ± 0
Amb. dum.	711 ± 211	553 ± 170	773 ± 136	0 ± 1	-15 ± 3	113 ± 73
Atr. con.	520 ± 102	404 ± 148	380 ± 194	-193 ± 142	-139 ± 90	374 ± 86
Eph. spp.	157 ± 123	14 ± 27	80 ± 32	9 ± 9	75 ± 75	0 ± 0
Kra. par.	39 ± 26	10 ± 6	21 ± 14	0 ± 0	-5 ± 5	0 ± 0
Lar. tri.	283 ± 48	155 ± 51	214 ± 44	93 ± 64	58 ± 7	2 ± 2
Men. spi.	214 ± 59	311 ± 74	173 ± 77	10 ± 4	31 ± 31	50 ± 39
Sph. amb.	7 ± 4	17 ± 15	13 ± 7	2 ± 2	0 ± 0	2 ± 2
All others	33 ± 25	0 ± 1	9 ± 8	2 ± 2	-12 ± 12	0 ± 0
Seedlings	65 ± 26	196 ± 172	102 ± 47	22 ± 20	47 ± 34	21 ± 17
Totals	2130	1726	1855	-52	152	562

*The two dry control plots received some moisture from nearby watered plots. New dry controls were selectec in October 1974.

**Standard error of mean.

visible growth response. The initial trickle-irrigation applications were continued long enough to assure saturation of the plot area, as indicated by the wetted surface, without controlling the total amount of water supplied. The continuing irrigations are now metered to prevent oversaturation. Apparently there was enough lateral movement of moisture from the early oversaturation of irrigated plots to permit tapping of water by the roots of mature shrubs growing on the dry, 0-nitrogen plots located 3 to 4 m from the nearest outlet valve. The other dry plots were all located 10 m or more from the nearest watered plot so they were not affected. Three more dry, 0-nitrogen control plots have been selected for the continuing experiment at distances sufficient to avoid this problem.

There are large standard errors in average plot biomass, a good portion of which may be attributed to variability in original population. A means of circumventing this effect is to compare percentage increase in biomass, rather than total increase. Table 11 shows the error estimates ("sem") are reduced from near 100% to somewhat less than 30% on wet plots. Further analysis of these data will be performed this year.

The relatively large numbers of seedlings of perennial shrubs had little effect on productivity, due to their small sizes. We expect their contribution to increase considerably in subsequent years.

Nitrogen requirements for above-ground growth of both annuals and perennials are estimated in Table 9. This tabulation shows that the requirements are raised from the low range of 1 to 10 $kg \cdot ha^{-1} \cdot yr^{-1}$ on dry plots to 30 to 40 $kg \cdot ha^{-1} \cdot yr^{-1}$ on irrigated plots. In relation to these demands, we estimated nitrate reserves on unfertilized plots ranged from 36 to 400 kg/ha on unfertilized plots in the top 60 cm of soil. Thus, in some watered plots we may deplete the soil reserves in one or two years without supplemental fertilization. Without added water we would expect reserves to last much longer. Considering the low concentration of ammonium-N, we feel it would not be a major source of nitrogen to any plant capable of using nitrate.

Mineral Analysis

Mineral analyses of the more common perennial shrubs are detailed in Table 12. The significant changes ($P < .05$) in elemental content attributable to treatment are also included. In *Ambrosia dumosa* the watered plants had live leaves with high nutrient content while leaves on the unwatered plants were dead. The decrease in nitrogen in stems of *A. dumosa* and *Larrea tridentata* caused by irrigation may be attributed to large demand for nitrogen by the numerous new leaves. Similarly, the decrease in aluminum, iron and silicon in *L. tridentata* leaves and stems is likely due to age of the tissue; older tissues would carry more dust in the resinous coating on *L. tridentata*.

Table 11. Percentage change in perennial above-ground biomass during one growing season as affected by irrigation and nitrogen application. There are eight replicates for watered plots, two for dry plots

TREATMENT	PERENNIAL BIOMASS % increase ± sem
Wet 100 N	78 ± 9
25 N	64 ± 9
0 N	87 ± 12
Dry 100 N*	23 ± 12
25 N	5 ± 12
0 N	-2 ± 3

* These two plots obtained moisture from adjacent watered plots.

Table 12. Effects of nitrogen and irrigation on leaf and stem mineral contents of several Mohave Desert shrubs (dry weight basis). Control error estimates are ± sem. Changes are calculated from pooled data with smaller errors. For changes listed, P = .05 to .10, depending on number of samples

Species/part	N	P	K	Ca	Mg	Na	Cu	Fe	Mn	Al	Mo	B
	%						ppm					
Amb. dum leaf - control	1.08 ±.17	.18 ±.06	1.0 ±.1	2.5 ±1.7	.8 ±.8	.036 ±.019	7 ±2	700 ±660	50 ±40	800 ±840	1.0 ±.2	100 ±81
% change due to N	NS	NS	NS	NS	NS	+ 25	NS	NS	NS	NS	NS	NS
% change due to H_2O	+145	+135	+148	NS	+44	+194	NS	NS	NS	NS	NS	+106
Amb. dum. stem - control	1.38 ±.11	.13 ±.01	2.8 ±.9	1.2 ±.1	.70 ±.02	.070 ±.054	9 ±3	220 ±41	22 ±5	290 ±48	.7 ±.3	40 ±13
% change due to N	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
% change due to H_2O	-35	NS	NS	NS	-39	+59	NS	NS	NS	-51	NS	NS
Atr. con. leaf - control	1.48 ±.24	.13 ±.05	2.3 ±.2	2.8 ±.4	1.3 ±.1	3.00 ±.54	6 ±7	280 ±93	30 ±15	400 ±130	.9 ±.4	70 ±26
% change due to N	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
% change due to H_2O	-23	NS	NS	NS	NS	NS	NS	NS	NS	NS	+ 66	+ 67
Atr. con. - stem control	.81 ±.05	.08 ± .02	1.4 ±.2	1.9 ±.3	.61 ±.06	.190 ±.022	8 ±4	190 ±136	21 ±7	220 ±82	1.5	18 ±2
% change due to N	NS	NS	NS	-19	NS	NS	-31	NS	NS	NS	NS	NS
% change due to H_2O	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Eph. spp. stem - control	2.14 ±53	.10 ±.04	.9 ±.8	1.4 ±.4	.27 ±.04	.013 ±.011	10 ±4	250 ±180	20 ±14	300 ±250	.5 ±.2	11 ±1
% change due to N	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
% change due to H_2O	NS	NS	NS	NS	NS	+205	NS	NS	NS	NS	NS	NS
Lar. tri. leaf - control	1.73 ±.11	.23 ±.11	1.7 ±.4	1.1 ±.2	.8 ±.2	.060 ±.017	12 ±3	1.050 ±310	49 ±16	1.000 ±340	1.3 ±.5	130 ±13
% change due to N	NS	-19	NS	NS	-19	NS	-45	NS	NS	-31	NS	NS
% change due to H_2O	NS	NS	NS	NS	-32	NS	-46	-45	-24	-37	NS	NS
Lor. tri. stem - control	1.54 ±.14	.12 ±.06	1.3 ±.3	.7 ±.1	.7 ±.1	.060 ±.018	22 ±4	1.300 ±610	30 ±6	970 ±280	1.1 ±.5	30 ±13
% change due to N	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
% change due to H_2O	-16	NS	NS	NS	NS	NS	-39	-44	NS	NS	NS	NS

Table 13. Mineral analysis of pot-grown desert shrubs as affected by nitrogen and phosphorus fertilization. Three replicates per treatment. The error estimate is two times the standard error of the mean (A3URM06)

a. *Atriplex canescens*

Treatment	Part	N %	P %	K %	Ca %	Mg %	Si %	Na ppm	Zn ppm	Cu ppm	Fe ppm	Mn ppm	Al ppm	Ti ppm	Mo ppm
Control	leaf	.60 ±.07	.34 ±.03	4.4 ±1.5	3.8 ±1.1	1.16 ±.23	.08 ±.03	327 ± 75	130 ± 14	15 ± 3	37 ±48	344 ±102	69 ±80	2.6 ±3.3	3.7 ± .5
100 N	leaf	.52 ±.20	.30 ±.13	4.0 ±1.0	2.8 ± .9	.89 ±.03	.05 ±.01	283 ± 94	111 ± 18	16 ± 4	19 ±14	227 ±129	27 ±19	2.6 ±1.8	4.9 ±1.2
300 N	leaf	.94 ±.04	.12 ±.02	3.2 ± .9	3.0 ± .8	.91 ±.04	.08 ±.01	346 ± 40	69 ± 33	13 ± 2	54 ±32	190 ± 37	76 ±47	4.6 ±2.4	3.4 ± .9
100 P	leaf	.51 ±.16	.46 ±.07	3.9 ± .7	4.4 ± .2	.99 ±.06	.10 ±.02	402 ±115	88 ± 19	16 ± 1	66 ±23	396 ±141	108 ±43	4.3 ±1.5	3.4 ±1.0
300 P	leaf	.43 ±.05	.64 ±.12	4.6 ±1.2	4.4 ± .8	.91 ±.10	.06 ±.02	539 ±139	65 ± 27	18 ± 3	44 ±26	596 ±122	49 ±28	2.7 ±2.1	2.3 ± .3
Control	stem	.35 ±.05	.14 ±.01	2.5 ± .2	.8 ± .3	.48 ±.08	.02 ±.02	205 ± 46	15.8 ± 5.7	14 ± 7	32 ±23	297 ± 47	32 ±35	4.2 ±3.9	2.0 ±1.1
100 N	stem	.38 ±.02	.10 ±.05	2.0 ± .5	.8 ± .2	.40 ±.16	.02 ±.01	133 ± 87	24.5[a] ± 0.6	11 ± 2	29 ±20	195 ± 85	19 ±12	1.8[a] ± .0	2.2 ± .9
300 N	stem	.64 ±.20	.10 ±.01	1.6 ± .5	.9 ± .2	.36 ±.10	.02 ±.01	91 ± 62	11.6 ± 7.9	13 ± 3	30 ±22	214 ± 55	21 ±26	2.0[a] ±2.3	1.5 ± .2
100 P	stem	.57 ±.40	.13 ±.02	2.3 ± .1	.8 ± .0	.36 ±.03	.01 ±.01	202 ± 30	11.7 ± 4.4	15 ± 3	23 ±13	310 ± 48	17 ±12	2.1 ±2.1	.8[a] ± .1
300 P	stem	.41 ±.04	.09 ±.06	2.2 ± .3	.6 ± .1	.31 ±.08	.01 ±.00	185 ± 77	11.7 ± 4.9	12 ± 2	19 ± 4	202 ±105	6 ± 4	.0 ± .0	.2 ± .2

b. *Artemisia tridentata*

Treatment	Part	N %	P %	K %	Ca %	Mg %	Si %	Na ppm	Zn ppm	Cu ppm	Fe ppm	Mn ppm	Al ppm	Ti ppm	Mo ppm
Control	leaf	.88 ±.29	.36 ±.11	2.6 ± .6	2.0 ± .2	.45 ±.05	.16 ±.04	284 ±471	29.2 ± 1.8	46 ±10	56 ±13	276 ± 33	42 ±17	3.4 ±1.3	3.4 ± .2
100 N	leaf	1.09 ±.14	.31[a] ±.00	2.8[a] ± .1	1.2 ± .4	.38 ±.06	.14 ±.01	112[a] ± 5	37.4 ±27.7	42[a] ± 2	115[a] ±34	180[a] ± 18	96[a] ±28	8.5 ±8.6	3.5 ± .8
300 N	leaf	2.25 ±.16	.27 ±.01	1.3 ± .2	1.2 ± .3	.29 ±.02	.20 ±.06	172 ±106	22.4 ±15.3	43 ± 6	231 ±66	226 ±25	271 ±108	13.3 ±8.5	2.3 ± .7
100 P	leaf	.78 ±.10	.41 ±.14	2.6 ± .3	2.0 ± .2	.38 ±.03	.15 ±.02	94 ± 59	22.3 ±10.1	57 ± 6	95 ±36	271 ±46	122 ±89	6.0 ±1.4	2.9 ± .3
300 P	leaf	.79 ±.08	.39 ±.04	2.6 ± .3	2.0 ± .2	.41 ±.02	.12 ±.02	69 ± 20	33.3 ±10.5	54 ± 5	66 ±20	363 ±21	60 ±30	3.8 ±1.8	2.9 ± .6
Control	stem	.90 ±.12	.18 ±.02	2.3[a] ± .1	.63[a] ±.01	.25[a] ±.05	.05[a] ±.04	39[a] ± 1	8.0[a] ± 3.7	27[a] ± 3	67[a] ±38	48[a] ± 9	49[a] ±32	4.7[a] ±1.8	2.6[a] ± .7
100 N	stem	1.49 ±.30	.19 ±.03	2.4 ± .2	.62 ±.01	.22 ±.02	.09 ±.06	68 ± 17	7.4[a] ± 0.6	26 ± 6	106 ±75	44 ±21	103 ±73	5.3 ±2.2	2.6 ± .4
300 N	stem	2.23 ±.12	.21 ±.04	1.8 ± .3	.62 ±.12	.24 ±.02	.16 ±.08	100 ± 42	16.1 ± 7.9	39 ±11	235 ±44	87 ±17	151 ±34	7.2 ±3.9	2.8 ± .8
100 P	stem	.76 ±.06	.19 ±.03	2.4 ± .3	.64 ±.12	.23 ±.02	.05 ±.03	51 ± 7	13.2 ± 3.4	34 ±14	77 ±34	55 ± 8	54 ±38	5.6 ±3.5	1.1 ± .7
300 P	stem	.87 ±.04	.19 ±.02	2.5 ± .2	.60 ±.03	.23 ±.02	.04 ±.03	38 ± 14	11.2[a] ± 7.0	27 ± 4	47 ±17	57 ± 4	28 ±22	3.3 ±1.3	1.5 ± .5

c. *Ceratoides lanata*

Treatment	Part	N %	P %	K %	Ca %	Mg %	Si %	Na ppm	Zn ppm	Cu ppm	Fe ppm	Mn ppm	Al ppm	Ti ppm	Mo ppm
Control	leaf	.52 ±.13	.17 ±.04	1.8 ± .5	2.2 ± .3	.72 ±.06	.12 ±.03	422 ± 85	12[b]	15 ± 5	68 ±17	63 ±27	69 ±13	7.3 ±2.5	3.9 ±1.8
100 N	leaf	.70 ±.11	.10 ±.01	1.9 + .1	2.8 ± .3	.80 ±.08	.17 ±.11	577 ±105	12 ± 3	14 ± 4	146 ±153	83 ±18	193 ±201	9.8 ±7.8	6.0 ±0.9
300 N	leaf	1.84 ±.21	.07 ±.01	2.4 ± .3	3.4 ± .6	.88 ±.14	.14 ±.03	491 ± 82	22 ±15	19 ±10	127 ± 44	128 ±71	209 ±92	12.3 ±7.8	7.8 ±1.7
100 P	leaf	.69 ±.06	.46 ±.07	2.0 ± .4	2.5 ± .2	.65 ±.14	.10 ±.02	462 ± 19	< 5[c]	20 ±12	64 ±15	65 ±34	76 ±35	6.6 ±3.5	1.2 ± .6
300 P	leaf	.60 ±.17	..69 ±.24	2.3 ± .5	2.5 ± .4	.67 ±.10	.12 ±.01	765 ±478	13 ± 7	18 ± 7	95 ±16	82 ±41	123 ±21	12.7 ±4.2	1.3 ± .4
Control	stem	.80 ±.32	.12 ±.03	1.7 ± .1	.7 ± .3	.31 ±.05	.02 ±.02	132 ± 44	9[a] ± 5	12 ± 8	24 ±16	52 ±10	30 ±28	2.8[a] ±3.9	2.4 ± .6
100 N	stem	1.03 ±.30	.11 ±.00	2.1 ± .4	.5 ± .1	.25 ±.05	.02 ±.01	128 ± 51	7[a] ± 1	13 ± 1	33 ±11	40.3 ± 1	27 ±19	4.2 ±2.8	3.9 ± .9
300 N	stem	1.66 ±.20	.10 ±.02	2.0 ± .4	.7 ± .3	.32 ±.07	.03 ±.02	106 ± 38	13[a] ± 2	16 ±17	55 ±44	84 ±28	32 ±24	2.5 ± .6	4.9 ± .7
100 P	stem	.98 ±.15	.12 ±.05	1.7 ± .2	.5 ± .1	.30 ±.10	.01 ±.01	89 ± 29	7[a] ± 2	8 ± 1	24 ±12	60 ±26	12 ± 6	1.1 ± .3	.2[b]
300 P	stem	.90 ±.23	.10 ±.02	2.1 ± .4	.6 ± .1	.31 ±.12	.03 ±.02	168 ± 82	7[a] ± 3	16 ± 4	71 ±32	65 ±33	56 ±50	3.9 ±1.9	.6[b]

[a] Two replicates instead of three. Values too low to measure or more than 10X higher than the next largest measurement.

[b] One measurement.

[c] Below the detection limit.

The significance of these and other changes in the elemental composition of plant tissues is difficult to assess at this early stage of project development for several reasons. First, there was an induced carbohydrate dilution effect on the nitrogen and mineral element composition of some desert plant tissues which is not yet fully understood. Second, there were differences in the physiological condition of plants growing on the dry and watered plots upon which the nitrogen treatments were superimposed. Finally, the question arises as to whether or not the surface-applied nitrogen fertilizer had moved down into the dry soil sufficiently to influence plant growth. We shall continue to periodically monitor the elemental composition of certain plant tissues in order to gain a better understanding of shrub response to supplemental moisture and nitrogen fertilization.

Glasshouse Pot Experiments

Effects of fertilizer on yield and nitrogen content of potted *Ceratoides lanata*, *Atriplex canescens* and *Artemisia tridentata* were included in our 1973 progress report (Romney et al. 1974). In Table 13 we report the effects on mineral composition of these plants (A3URM06). It will be seen that concentrations of many more elements are significantly affected when compared to effects of fertilizer applied in the field. This is, perhaps, due to increased fertilizer levels as well as the necessarily unusual conditions involved in growth of plants in a glasshouse. The induced carbohydrate dilution effects on nitrogen and mineral element composition were more prevalent under glasshouse than under field conditions.

DISCUSSION

Short-term effects of irrigation and fertilization on the plant communities of the northern Mohave Desert are reasonably predictable. Most of the increased productivity seen was due to growth of well-established, large shrubs and summer annuals. One year of summer irrigation resulted in new productivity of from 1700 to 2100 kg/ha, a large increase over the -50 to +150 kg/ha on control plots. From 50 to 100 kg/ha of this increase were due to growth of new seedlings.

A fairly large proportion of the increased productivity was due to growth of summer annuals, 250 to 450 kg/ha. This portion might be fairly strongly affected by timing of irrigation. We would expect irrigation during fall and winter to affect, primarily, growth of shrubs and winter annuals, while late spring and midsummer irrigation should dramatically increase yield of summer annuals, herbs and grasses.

Long-term effects are much less predictable as we expect a fairly large change in species distribution. Many of the long-lived and drought-hardy species do not increase rapidly in population, whereas the short-lived perennials and summer annuals respond dramatically to added moisture. Some species, notably *Lycium andersonii* and the *Ephedra* species, appear to be temperature-dependent and respond to added moisture only during cooler spring and fall months.

We anticipate an increase in grass population on the trickle-irrigated plots like that which occurred earlier on the sprinkle-irrigated plots. However, there is such a small reservoir of perennial grass seed naturally available in the trickle-irrigation area that such a population change might take several years. The introduced annual grass, *Bromus rubens*, is widespread in the area and was prevalent in the study plots during the wet spring of 1975.

One method of predicting population changes over a longer time span might be to study the vegetation along roadsides. These populations are obviously different from the adjacent desert areas and seem to have a significantly wetter environment, probably due to moisture runoff from the roadbed.

Trickle irrigation has proved surprising in two ways. First, it leads to a greater rate of seedling survival over a short term, as is evident from comparisons of Table 1 and Table 5. We tentatively attribute this effect to salt-burning or sunscald of leaves associated with prolonged sprinkling treatments. Second, the radius to which trickle irrigation was effective was much greater than expected from visible appearance of the adjacent plants. Summer annuals, particularly *Eriogonum brachypodum*, grew well as much as 2 m from the nearest outlet valve. Perennial shrubs showed marked effects as much as 4 m from the nearest valve, no doubt due to root distribution as much as to capillary flow of moisture. A related observation of interest is that we recently have found living roots of *Yucca schidigera* 20 m from the nearest representative of that species.

There remain some unanswered questions related to irrigation. The nature of caliche is one. If a caliche layer is thick and unbroken, it can be thought of as a lower limit to the soil and root zones. This, of course, limits the amount of water that can be applied and stored. Romney et al. (1973) found that such layers can significantly affect vegetation. However, the layer's variable depth, the possibility of breaks allowing passage of roots and moisture, and the possibility that it may partially dissolve under shrub clumps or under the wetter areas in washes or depressions must all be considered. Projecting and evaluating the long-term effectiveness of adding supplemental moisture to Mohave Desert areas by irrigation are difficult without increased knowledge of the caliche layer.

In our study area we have placed soil psychrometers at depths to 60 cm and have not reached a restrictive caliche layer. The man-made wash bisecting the area shows no signs of well-developed hardpan in its 1- to 2-m depth.

The nature of movement of water through soil may be changed by irrigation. This is suggested by the appearance, in October 1974, of a salt deposit on the surfaces of watered plots which did not occur on dry plots. We feel this indicates capillary flow to the surface of wet plots, while on control plots the presence of two drying fronts caused capillary flow to be primarily downward.

Nitrogen fertilization had little effect during the first year's treatment. There is some indication it affected production of flowers and fruit in *Ambrosia dumosa* and production of new leaves in *Larrea tridentata* (the latter inference is drawn from the mineral analysis in Table 12). Soil nitrate levels probably are sufficient to last for one to two years even considering productivity increases caused by irrigation.

EXPECTATIONS

We expect few changes in procedure next year. More extensive soil sampling will be done in addition to a more sophisticated statistical analysis of acquired data. The watered plots will be split into two groups, one watered in winter and spring, and the other during summer. We shall continue to sample leaf and stem tissues periodically for nitrogen and mineral element analyses. Population and productivity changes will be followed as in 1974. Seed production will be more adequately estimated next year. In addition, some gas exchange measurements will be made on the shrubs in wet and dry plots.

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