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1973 PROGRESS REPORT

PLANT PRODUCTIVITY AND NUTRIENT INTERRELATIONSHIPS
OF PERENNIALS IN THE MOHAVE DESERT

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ABSTRACT

Studies for the past three years on plant productivity of five desert plant species have been conducted in an experimental garden at Mercury at the Nevada Test Site in the northern Mohave Desert. The plant species are *Ambrosia dumosa*, *Krameria parvifolia*, *Larrea divaricata*, *Lycium andersonii*, and *Lycium pallidum*. Photosynthesis, respiration and transpiration are being studied in relation to seasonal temperature, humidity and soil moisture conditions. Translocation, utilization and storage of assimilates have been studied for periods of two weeks to a year on naturally-growing shrubs. Root growth, biomass and associated ATP activity have been studied as a means of estimating below-ground activity and its relationship to below-ground productivity and biomass.

There has been a large difference in the response of these desert shrubs in rates and duration of photosynthesis and total carbon uptake over the last two years. Total carbon uptake for the five shrubs increased from 142 kg/ha in 1972 to 508 kg/ha in 1973, a 257% increase in gross productivity. This increase is the result of a more favorable moisture regime in which effective seasonal moisture was 90.6 mm in 1972 compared to 246.7 mm for 1973, an increase of 172%.

Translocation of assimilates in 1972 showed only a small, but variable, proportion stored in roots. Small stems seem to be the major storage site for most assimilated carbon. This is the site where the greatest use of assimilate for new leaf and stem production occurs.

Root biomass increased approximately three-fold in 1973 in response to a tremendous growing season. Preliminary results of ATP concentrations did not show a corresponding increase in biological activity, but this may have been due to a seasonality effect of increasing stress in the period of March to August, 1973, and activity may peak at different seasons.

Preliminary estimates are given for total carbon input in the desert ecosystem at Rock Valley, but a total carbon budget must await the derivation of better estimates of losses to respiration, herbivory and amount of below-ground activity.

INTRODUCTION

Perennial plants are a component of the desert ecosystem which not only forms the structure and physiognomy, but also produces the primary biological inputs of carbon and energy into the system. As the primary producers, plant processes are of importance in themselves and for their effects on the consumer and soil components. In the northern Mohave Desert, perennial shrubs are the most stable, obvious plant species. Trees are few, succulents and grasses comprise less than 1% of biomass on open slopes and bajadas, and annuals are important only in a few "good" years.

The present study, started in 1971, concerns primary productivity in the principal perennial shrubs and the transfer, storage and use of assimilates both above- and below-ground in a *Larrea-Ambrosia* community in the Rock Valley area of the Nevada Test Site. In 1973, gas exchange measurements, particularly the effects of temperature, humidity and water stress on photosynthesis and night respiration were continued. The translocation of labeled $^{14}\text{CO}_2$ was continued with tagged plants sampled periodically to determine the use of stored materials. We initiated studies on below-ground biological activity to determine the root biomass of major shrubs on a seasonal and spatial basis. ATP concentrations were determined from whole soil samples.

A comparison of photosynthetic productivity and biomass produced for a dry year, 1972, and a wet year, 1973, is attempted using curves derived from gas exchange measurements (DSCODES A3UBD01, BD02 and BD07) and indirect harvest data (A3UTJ25). This comparison is presented using CO_2 input converted to C and biomass, and

biomass converted to C and CO_2 . Other estimates of carbon flow for a carbon budget in the autotrophic component will be given for the major portions (including roots) of important shrubs. These figures are expected to provide an independent check for the plant productivity submodel of the Desert Biome. The below-ground portion of our study uses the same sample sites and procedures as those of Edney and McBrayer for invertebrates, and Mankau and Freckman for nematodes. Dr. B. S. Ausmus of the Deciduous Forest Biome at ORNL is assaying the ATP concentration in soils and coordinating that part of the investigation. These field studies will give information for predicting decomposition processes in desert shrub communities.

OBJECTIVES

The objectives during 1973 were to determine rates of photosynthesis, transpiration, respiration, and translocation; and to measure root activity as affected by environmental factors; and to relate these processes to plant productivity and to carbon and nutrient balance in the Mohave Desert plant ecosystem.

During 1973 we determined:

1. CO_2 uptake, transpiration and dark respiration as a function of temperature, moisture status and humidity for five species of desert shrubs growing under natural field conditions.
2. Gas exchange in two species of shrubs under manipulated conditions of soil moisture and their response and acclimation to temperature and moisture stress.
3. Translocation of ^{14}C assimilated and its partitioning

and re-distribution in naturally growing shrubs for periods up to one year. This phase will be complete in April, 1974.

4. Standing crop of roots, in two size classes, and their change throughout the growing season of March through August in relation to shrub dispersion.
5. Amounts of total ATP extracted from soils and the change in relation to season and species of shrub.
6. Estimates of carbon flux and amount in a part of the plant component versus environmental conditions during two contrasting years.

METHODS

These studies were carried out at two locations on the Nevada Test Site in the northern Mohave Desert 100 km NW of Las Vegas, Nevada. The Rock Valley area of NTS, 24 km west of Mercury, Nevada, is a US/IBP Desert Biome validation site and its characteristics are given in Turner et al. (1973). This area was used, as in previous years, for the field portions of the study for gas exchange and translocation studies on five species of desert shrubs. Species studied, which comprise 74.2% (A3UTJ25) of the standing live biomass and in 1973 contributed 76.1% (A3UTJ25) of the above-ground biomass increment, were *Ambrosia dumosa*, *Krameria parvifolia*, *Larrea divaricata*, *Lycium andersonii* and *Lycium pallidum*. The below-ground activity study area is located just off the east and south edges of the validation site. At Mercury, plants were tested in an experimental garden located west of the CETO Laboratory building.

The gas exchange measurements on shrubs were made both at Rock Valley and Mercury using a modified Siemens chamber (Koller, 1970). This system measures CO₂ exchange and transpiration of plants enclosed in an assimilation chamber in which temperature, relative humidity and CO₂ concentration are controlled and recorded. The chamber can be set to follow and approximate ambient conditions of temperature and CO₂. Carbon dioxide is monitored with a Beckman Model 315A infrared gas analyzer and relative humidity by Hygrodynamics narrow range sensors.

Other measurements and determinations include radiation in the 400 to 700 nm range inside the chamber using a filtered and calibrated photocell (A3UBD01 and BD07), soil temperature and moisture tensions, plant-tissue water potentials of the test plant (A3UBD01 and BD07) and phenology (A3UTJ22 and TJ23). Plant water stress was measured using a Scholander pressure bomb, and soil temperatures and moisture tension using Wescor thermocouple psychrometers. Leaf area measurements were attempted using a photoelectric planimeter, designed after a system described by Caldwell and Moore (1971). However fluctuating voltages plus the small area of the stage utilized and a large variability in samples due to leaf size and age, introduced too much error to calculations of leaf dry weight:leaf area ratios. We are presently using a planimeter compensated for voltage and amount of stage area used (modified after Gist and Swank, 1974). In most tests

involving temperature or humidity manipulations, plants are allowed to equilibrate to new conditions, and then measurements made for 20 min. This allows a series of tests during a short period in which light and other conditions are not radically different.

For translocation, photosynthate was labeled with ¹⁴C by enclosing entire plants in airtight plastic bags and releasing ¹⁴C₂ inside the plastic bag via the evolution of ¹⁴CO₂ from labeled NaHCO₃ treated with HCl. Plants were bagged between 8 and 9 a.m. and left to absorb the labeled CO₂ until 11 a.m. About 45 plants were labeled in March, 1973. Sampling is being done at three intervals; the last harvest will be during the peak of spring flush in 1974 to determine use of stored material. Aerial portions of sampled plants are collected in 10 cm horizontal increments, and are then separated into plant parts. The root system is mapped and individual roots separated into 10 cm lengths, resulting in about 100 samples per plant. These samples were still being separated and counted at the time of writing and the last set of samples in spring, 1974, had not been taken; consequently the results of the translocation studies will not be reported at this time, except for a general discussion. Portions of this translocation work were reported in Wallace et al. (1973).

Root biomass and ATP concentrations were determined from samples taken in a spatial relationship to four shrubs: *Ambrosia dumosa*, *Krameria parvifolia*, *Larrea divaricata*, and *Lycium andersonii*. The sample area is 100 x 400 m with sites chosen by a random loci selection program (Kaaz, 1972). A single shrub of each species was sampled each week at each locus so that three radii of the shrub did not infringe on a neighboring shrub. Nine soil samples were collected: one set each at the base (numbers 1, 2, 3), one radius (numbers 4, 5, 6) and three radii (numbers 7, 8, 9) out from the base; and each set having three depths at 0-10, 10-20 and 20-30 cm (Figure 1). There is a considerable bias in the sampling procedure due to the association of 65% of the shrubs in clumps of from two to 12 individuals which were excluded from sampling. Dispersion of shrubs is uneven, so that considerable overlap exists within the three radii of shrubs or shrub clumps and complicates the conversion of biomass numbers to an area basis. These problems will be

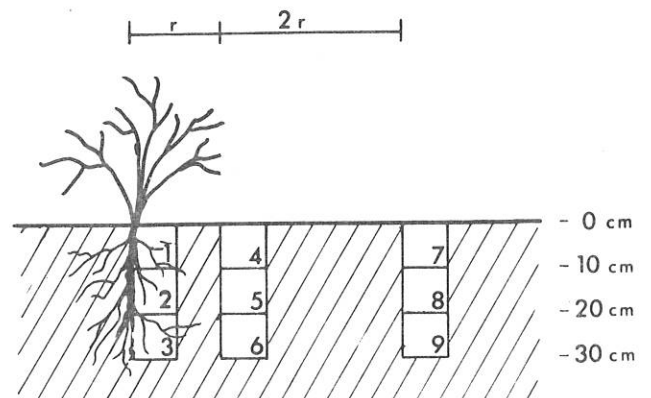


Figure 1. Graphic representation of root and ATP sample locations.

resolved in the coming season. There is also the near impossibility of assigning values of root biomass or ATP concentration to a specific shrub beyond the edge of the shrub canopy, since mingling of roots in the interspace is known.

We separated small (0.5-2 mm) roots by screening and then flotation in $MgSO_4$ solution from 0.3 l of soil, and larger roots 2 mm diameter by hand-picking from 1.5 l of soil. Roots were oven-dried and weighed. These root biomass data represent all roots exclusive of the shrub base-root crown portion. The fraction of material 0.5-2 mm is all of the fine organic material and not just fine roots; its composition will be discussed later.

ATP was extracted from 40 g of each soil sample by a TRIS buffer technique. Hot TRIS buffer (90-95 C) was mixed with an equal volume of soil and allowed to set for 5 minutes. Liquid was decanted and centrifuged at 1000 G for 10 min to remove particulates, and then the pH of the extract was measured. ATP sample extracts were frozen, stored on dry ice and shipped frozen to Oak Ridge National Laboratory for analysis on a GeMSAEC photometric

analyzer using a luciferin-luciferase enzyme system (Ausmus, 1973). Before analyzing for ATP, the extracts were run through an ion exchange column at ORNL.

Estimates of net primary productivity and carbon input and distribution were obtained by plotting CO_2 uptake versus season for each major plant species. Net photosynthetic productivity curves are derived from CO_2 uptake measurements taken seasonally with the Siemens chamber and a net value derived from the photosynthesis value minus dark respiration. Mean diurnal temperatures were used to adjust photosynthetic rates and nocturnal temperatures for night respiration. Natural photoperiods provided day length values and end points were determined by phenology. The areas extrapolated under each curve for the total seasonal uptake on a dry weight basis were multiplied by the mean dry weight of leaves on an area basis determined on the validation site at Rock Valley for carbon input for 1972 and 1973. Values derived from ^{14}C tagging were used for translocation of carbon. Conversion of carbon to biomass permits a comparison with biomass estimates obtained by harvest technique on the Rock Valley Validation site. A biomass/carbon ration of 2.5 was used in the conversion.

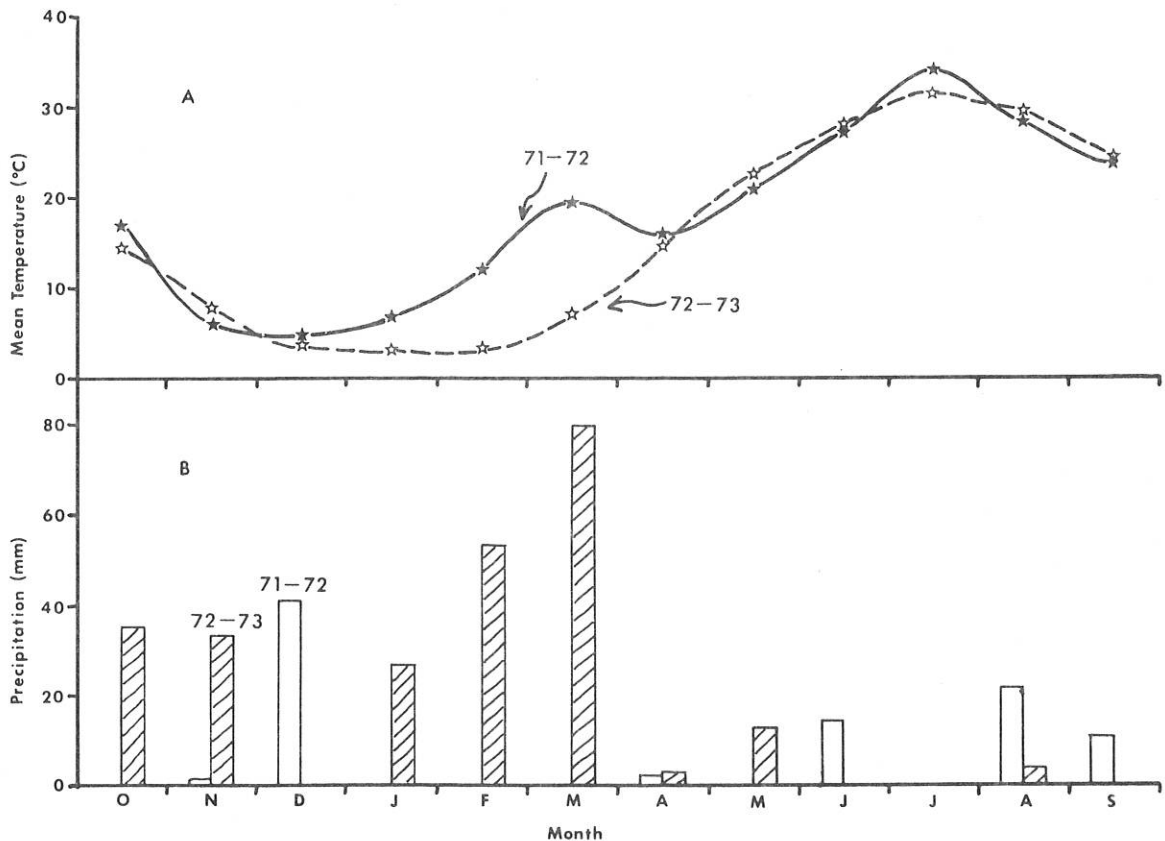


Figure 2. Monthly rainfall and mean temperature in Rock Valley (Station V) during the 1972 and 1973 season.

RESULTS

ABIOTIC

Data of abiotic variables are stored under DSCODES A3UTJ02, TJ08, TJ09, TJ12, and A3UBD01, BD02, BD03.

Since plant responses are being compared and contrasted for conditions during a dry vs. wet year, rainfall patterns and temperatures for the last two seasons, 1972 and 1973, are presented in Figure 2. The most significant aspect of 1973 is the timing and evenness of the rainfall regime. In October and November of 1972, rains totaling 67.6 mm in Rock Valley provided sufficient moisture for some species to resume photosynthesis, others put out new leaves. Soil moisture remained near field capacity (< -5 bars) throughout the winter until mid-April, 1973. Temperatures exhibited a difference in that the 1973 season was cooler throughout the early spring period at the time of increased precipitation. After April the temperature regimes for the two seasons are fairly similar.

Precipitation totaled 246.7 mm for the growing season (Oct.-May) in 1973 compared to 58.1 mm for the same period in 1972. Our method of measuring soil moisture tension with thermocouple psychrometers in 1973 was accurate only to about -50 bars. Recently, soil psychrometers capable of measuring to -90 bars have been acquired.

Soil temperatures and moistures taken (at nine locations) under the four shrubs in the below-ground study indicate

seasonal trends in a wet year (Figures 3 and 4). Both temperature and moisture were more variable at the surface and base of the shrub and were more even with depth and distance from the shrub. No differences were detected between shrub species in either soil moisture or temperature at any location. For the purposes of this study, a general trend of soil moisture and temperature will be used to relate these variables to biological activity.

GAS EXCHANGE

CO₂ Assimilation

As in 1972 (Bamberg et al., 1973), the seasonal uptake of CO₂ for each species (A3UBD02, BD07) was related to the soil moisture and air temperature patterns (Figures 5, 6 and 7). However, in 1973, CO₂ assimilation started later for all species, reached higher peak values and continued later in the summer than in 1972. These gas exchange differences are the result of the cooler and wetter season described in the abiotic section above. More results on seasonal trends will be given in the section on carbon inputs.

The effects of temperature and relative humidity on CO₂ assimilation, night respiration and transpiration were investigated on plants in the field at Rock Valley throughout the spring and early summer and on watered and unwatered plants in a garden at Mercury. Results of the temperature effects are given in Tables 1 to 4 and humidity effects in Tables 5 and 6. Temperature optima and upper compensation points for the 1973 season are more difficult

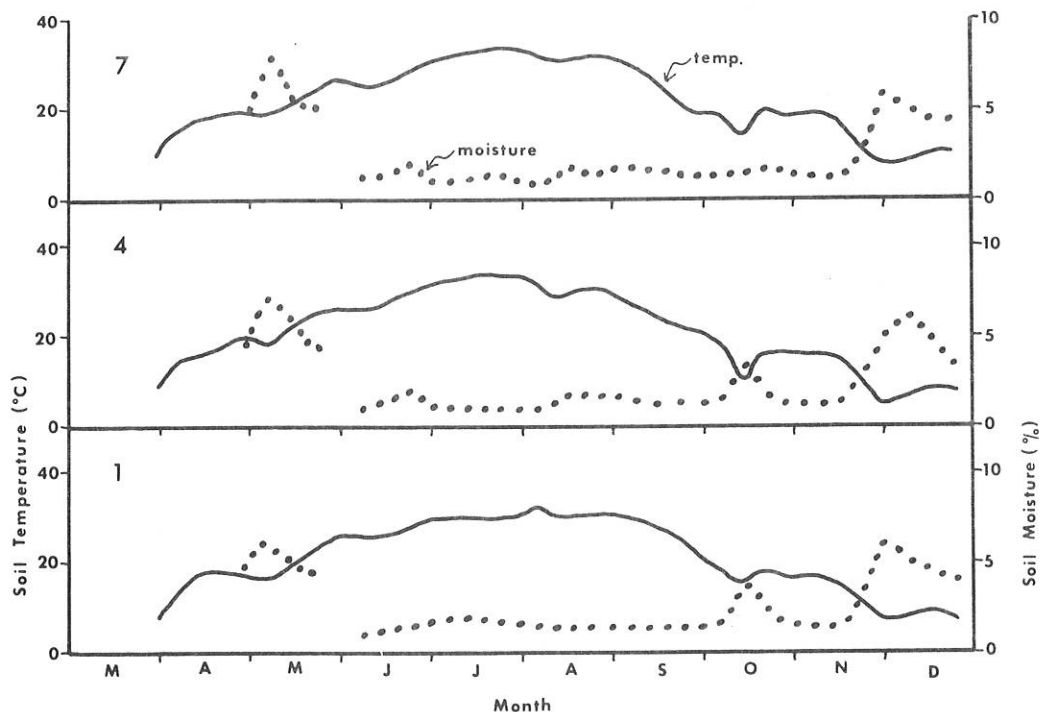


Figure 3. Soil temperature and moisture for root and ATP sample locations within 0-10 cm from the surface.

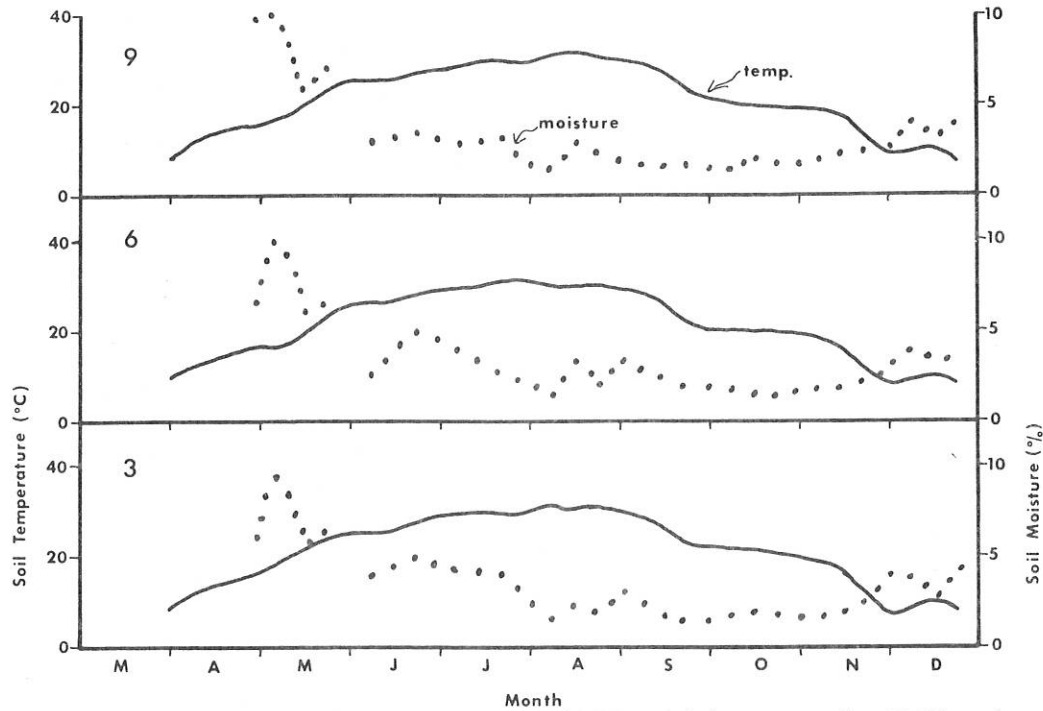


Figure 4. Soil temperature and moisture for root and ATP sample locations within 20-30 cm from the surface.

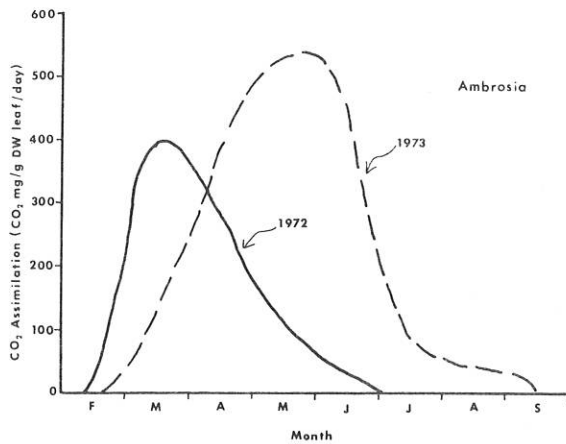


Figure 5. Net CO₂ uptake for *Ambrosia dumosa* during the 1972 and 1973 seasons.

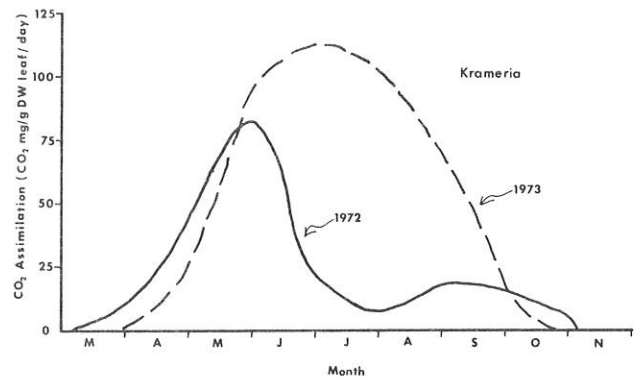


Figure 6. Net CO₂ uptake for *Krameria parvifolia* during the 1972 and 1973 seasons.

to determine than in 1972, since soil moisture is higher and temperatures lower throughout much of the 1973 spring than in 1972. The adequate moisture plus lower temperature delayed acclimation and hardening, resulting, as stated earlier, in higher gas exchange rates and prolonged CO₂ assimilation. A temperature control failure for the assimilation chamber delayed complete temperature runs from April until late in June, again making interpretation in 1973 difficult for the field data.

At Mercury, there was a consistent decrease in CO₂ assimilation rates and upper thermal compensation points related to water status in the irrigated and non-irrigated plots (Tables 3 and 4). These differences are distinct in *Ambrosia*. In *Larrea*, however, individual variation of shrubs caused an overlap in rates; one irrigated *Larrea* had lower rates and no differences in the upper thermal compensation points between treatments could be determined.

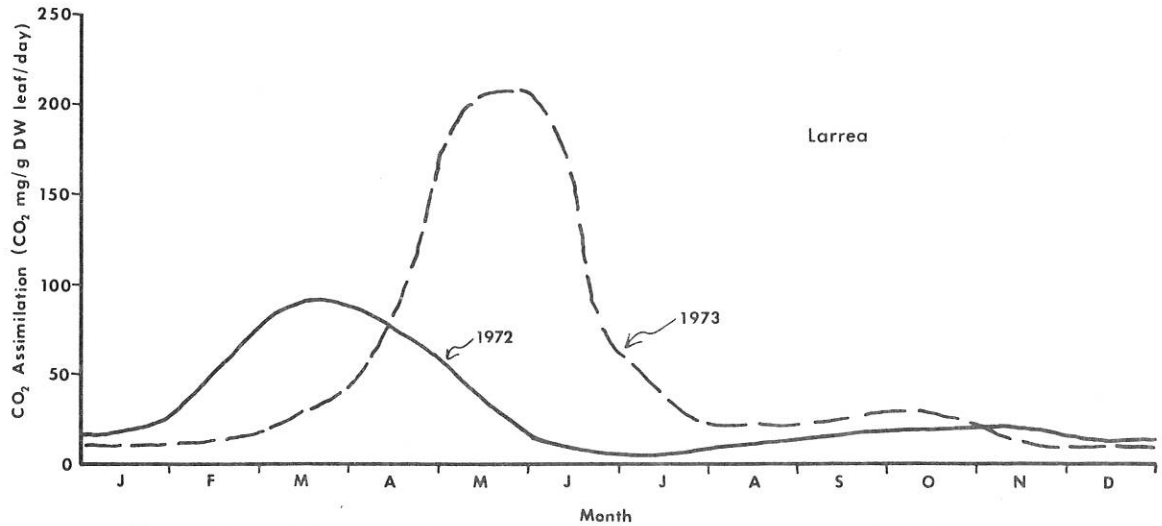


Figure 7. Net CO₂ uptake for *Larrea divaricata* during the 1972 and 1973 seasons.

Table 1. Effects of temperature on photosynthesis and transpiration of shrubs in Rock Valley, 1973

Species/Year-Day	Chamber Temperature (°C)								
	10	15	20	25	30	35	40	45	50
<i>Lycium p.</i>									
080	Ps 10.1	24.3	36.4						
	Tr 0.0	0.1	0.1						
093	21.9	25.9	22.8	25.5	17.1	17.3	7.7	1.1	
	0.1	0.1		0.1	0.1	0.1	0.0	0.0	
<i>Lycium a.</i>									
123			30.9	32.9	31.9				
			1.3	3.1	3.8				
148						37.1	27.2		
						10.1	9.1		
177					6.3	7.6	6.3	3.8	
					0.0	2.7	4.9	7.0	
<i>Ambrosia</i>									
096			26.6	31.4					
			1.8	3.1					
106					31.4				
					3.9				
151					50.2	37.8	36.6		
					7.7	12.7	9.8		
185			3.5	3.2	4.1	3.2	1.4	2.5	
			0.9	2.4	1.8	2.1	2.5	2.7	
<i>Larrea</i>									
095			6.7	4.4	4.2	1.6	-4.5		
			0.2	0.6	0.7	0.9	0.7		
131					12.4	14.0	9.0		
					1.8	2.9	2.8		
149					17.3		7.8		
					2.7		3.0		
176					10.4	8.6	8.5	3.0	
					1.3	2.0	2.6	2.8	
192				0.3	0.3	0.2	0.1	0.1	
				0.0	0.1	0.1	0.1	0.1	
198			3.1	1.0	1.6	2.1	1.8	0.0	-1.5
			0.1	0.4	0.7	0.8	1.0	1.1	1.1
<i>Krameria</i>									
145		9.3	10.4	10.9	12.1	2.2	0.4		
		0.0	1.9	3.6	2.9	5.2	5.0		
155					6.3	2.5			
					1.1	0.8			
186				4.7	7.1	6.8	4.2	2.3	
				1.0	1.6	2.2	2.7	3.0	
200				8.3	10.3	11.8	4.9	2.1	-1.2
				1.1	2.0	2.7	2.9	2.4	2.1

Ps photosynthesis (mg CO₂/g DW leaf/hr)
Tr transpiration (g H₂O/g DW leaf/hr)

The effects of relative humidity on CO₂ assimilation both in the field and at the Mercury garden are shown in Tables 5 and 6. For maximum CO₂ assimilation the optimum humidity for all species lies between 20 and 40% for the temperature of 35 C which was used as a standard for all tests. Below 20% RH there is a slight depression or neutral effect on *Larrea*, *Krameria* and *Ambrosia*. Above 40%, RH effects can either be neutral (*Ambrosia* and *Atriplex confertifolia*), or for the species of *Larrea* and *Krameria* there is a consistent decrease from 30% RH to very low rates, < 1 mg CO₂/g D.W./hr, at 70% RH. Irrigated plants of *Larrea* and *Ambrosia* show higher CO₂ uptakes at all humidities. When *Ambrosia* was irrigated in the summer, or early in the spring when moisture was plentiful, it did not have a decreased CO₂ uptake at high humidities. There is evidently a control on stomatal openings by the species studied which is influenced by water status and responds to the moisture present in the air. However, the result that there is an optimum at 20-30% RH and that gas exchange decreases at both higher and lower humidities was not expected. The most obvious control is a change in diffusive resistance by the stomatal openings. This response of net photosynthetic CO₂ fixation to varying conditions of RH may reflect an adaptive mechanism by which desert plants limit water loss during adverse conditions.

Respiration

Dark respiration rates (A3UBD02, BD07) as affected by nocturnal temperatures throughout the season are given in Tables 2 and 4. The

effects of irrigation at Mercury on dark respiration rates are given in Table 4. Respiration rates in all species generally decreased throughout one season, and the rate of increase at higher temperatures in late summer of 1973 was reduced. This was most evident for *Krameria*, which had extremely high rates of respiratory CO₂ loss in May (8 mg CO₂/g D.W./hr at less than 30 C) but had lower rates by mid-July (2 mg CO₂/g D.W./hr at 40 C), while photosynthetic CO₂ uptake rates were comparable for both periods. This reduction would indicate some acclimation or response to increased plant tissue water potential.

Water Use and Efficiency

Transpiration rates (A3UBD02, BD07) were measured in relation to temperature and humidity both at Rock Valley under field conditions and at Mercury for irrigated and non-irrigated plants. The effects of temperature on seasonal water loss in Rock Valley are given in Tables 1 and 2. Water loss in the field in 1973 was highly variable for individual plants within a species and between species. The deciduous species again, as in 1972, had higher transpiration rates than the species retaining functional leaves throughout the entire season.

In the plots at Mercury, the differences in water loss between irrigated and non-irrigated plants in relation to temperature are shown in Tables 3 and 4. The irrigated plants of both *Ambrosia* and *Larrea* had higher rates of water loss than both the non-irrigated plants at Mercury and the field plants in Rock Valley.

The effects of humidity on water loss for plants in Rock Valley and at Mercury are given in Tables 5 and 6. These results are in striking agreement with the CO₂ uptake measurements in that the greatest water loss occurs at 25-30% relative humidity and that loss decreases at lower humidities and at higher humidities. Water loss is again higher for the irrigated plants; however, water use efficiency was greater at the lower and higher humidities since the decrease in CO₂ uptake was less than that of water loss.

Water use efficiency also varied between species. A comparison of water use efficiencies for 1972 and 1973 is given in Table 7. In the dry 1972 season, water use efficiency steadily decreased in all species as the season progressed, reaching low values by June or early July in the evergreen or summer-green species. Early in the 1973 season with abundant moisture and low temperatures, the two *Lycium* species had a high water use efficiency* of over 200

Table 2. Effect of temperature on respiration and transpiration on shrubs in Rock Valley, 1973

Species/Year-Day	Chamber Temperature (°C)						
	15	20	25	30	35	40	45
<i>Larrea</i>							
131	R		-1.7	-3.8			
	Tr		0.5	1.1			
149		-2.0	-2.9	-5.3	-7.6		
		0.03	0.5	1.0	1.9		
176			-2.1	-2.7	-1.2	-4.0	-5.8
			0.04	0.6	1.2	1.9	2.7
192				0.0	-0.3	-0.3	-0.3
				0.01	0.01	0.04	0.1
197			-0.1	-2.2	-2.3	-2.1	-2.6
			0.1	0.1	0.1	0.1	0.2
<i>Krameria</i>							
144		-2.8	-6.8				
		0.2	0.3				
155			0.0	-0.5	-1.0	-2.4	
			0.0	0.1	0.2	0.5	
198		0.0	0.0		-1.0	-2.8	-6.3
		0.0	0.0		0.02	0.1	0.4
<i>Lycium a.</i>							
123			-9.2				
			0.8				
148		-0.3	-5.4	-17.9	-12.0		
		0.01	0.7	2.9	3.6		
<i>Ambrosia</i>							
106		-0.9	-3.9				
		0.01	0.6				
151			-0.6	-3.5	-4.0	-7.0	-9.1
			0.01	0.1	0.1	0.1	1.3
185				0.0	-2.2	-2.1	-5.3
				0.0	0.05	0.05	0.1

R respiration (mg CO₂/g DW leaf/hr)
Tr transpiration (g H₂O/g DW leaf/hr)

with a large plant-to-plant variation. *Larrea* and *Krameria*, which do not become active photosynthetically until later in the season, had peak water use efficiency of only 5 for *Larrea* and 4 for *Krameria*. *Ambrosia* had intermediate values of 7.5. Later in the season all species decreased in their water efficiency and by mid-July most species had Ps/Tr values of from 1.3 to 3.9 (see Table 7). Presumably at higher temperatures (>35 C) transpiration is increased with CO₂ uptake decreasing. *Ambrosia*, *Larrea* and *Krameria* had low mid-summer water use efficiencies with ratios increasing through late summer and early fall. Late in the summer at more favorable temperatures, *Larrea* had a change in leaf color from olive to green, indicating a change in leaf water status.

PLANT WATER STATUS

Plant water status of the species tested in 1973 (A3UBD02, BD07) were again comparable to the trends established in 1972 (Table 8) except that by mid-July water potentials were about the same as in mid-May, showing an extended active season which will later be related to total seasonal CO₂ uptake. *Krameria* early in the season in March, while still dormant, had greater water potential than from April through June. *Larrea* and *Krameria* had tissue water potentials of from -10 to -15 bars more than the three deciduous species and *Ephedra* throughout the season.

* $Ps/Tr = \frac{\text{mg CO}_2/\text{g D.W.}/\text{hr}}{\text{g H}_2\text{O}/\text{g D.W.}/\text{hr}}$

Table 3. Effect of temperature on photosynthesis and transpiration on irrigated and non-irrigated plants in Mercury Valley, 1973.

Species/Year-Day	Chamber Temperature (°C)								
	15	20	25	30	35	40	45	50	
<i>Ambrosia</i>									
unw 215	Ps Tr	10.0 0.5	11.3 1.5	13.3 2.3	11.7 2.7	4.6 2.7	1.7 3.4	0.0 9.1	
w 233		23.2 0.1	32.4 5.3	37.1 4.3	26.5 5.2	26.5 7.3	16.7 6.9	6.7 9.1	
w 236			28.6 1.5	28.6 2.5	16.6 3.4	13.0 4.0	8.9 4.0	4.8 5.7	
unw 248		0.0 0.0	6.9 0.0	5.7 1.1	6.6 1.7	2.0 2.4	0.0 1.6		
w 264			30.3 1.0	25.8 2.5	25.2 3.8	18.4 4.3	13.9 5.2	8.2 8.2	6.7 13.3
<i>Atriplex</i>									
unw 222			2.7 0.1	3.2 0.2	4.6 0.3	4.2 0.4	1.6 0.4	0.5 0.6	
w 257			1.1 0.0	4.3 0.3	4.0 0.4	3.7 0.5	0.7 0.4		
<i>Krameria</i>									
unw 227			3.8 0.1	6.8 1.7	5.3 2.1	8.3 2.2	1.9 1.7	-3.4 1.2	
unw 228			5.3 2.3	7.4 2.5	6.3 3.3	5.2 2.9	1.0 2.3		
unw 250			1.8 0.4	5.8 1.1	6.6 1.3	4.7 1.5	1.5 0.9	0.7 0.8	
<i>Larrea</i>									
unw 220			5.8 0.4	4.0 0.6	5.7 0.7	3.2 0.8	2.2 0.9	0.4 0.9	0.0 2.2
unw 221				5.8 0.5	6.1 0.8	3.6 0.7	2.2 1.1	0.1 1.2	
w 234		2.8 0.0	6.6 0.5	4.2 0.8	5.0 0.7	2.8 1.4	2.0 1.2	0.4 1.4	
w 240		6.2 0.0	7.2 0.3	6.9 0.7	5.5 0.9	5.7 1.2	1.9 1.3	1.3 1.5	
unw 242		2.7 0.0	2.5 0.4	2.8 0.4	2.6 0.7	2.3 1.0	1.9 1.1	0.0 1.4	
unw 254			4.1 0.0	5.2 0.2	4.4 0.3	4.6 0.2	2.7 0.2	2.8 0.5	2.6 1.1
unw 256			0.0 0.0	0.0 0.3	0.0 0.5	-1.3 0.5	-0.9 0.8		
w 262			8.4 0.0	8.3 0.7	6.6 1.1	7.8 1.5	2.6 1.3		

Ps photosynthesis (mg CO₂/g DW leaf/hr)
Tr transpiration (g H₂O/g DW leaf/hr)
w watered
unw unwatered

Differences in the plant water potentials between the irrigated and non-irrigated plants of *Larrea* were more than 25 bars and showed a diurnal change of 10 bars. *Ambrosia* had differences of around 10 bars, -32 irrigated compared to -42 bars for non-irrigated; however, diurnal shifts were around 10 bars (-22 to -32) in the irrigated and over 20 bars in the non-irrigated plants (-25 to -45 bars). During the summer, plants exhibit a large variability in plant tissue water potential for individual shrubs depending on microsite and plant response.

LEAF TEMPERATURE

Leaf temperatures in comparison to chamber and ambient air temperatures showed several definite relationships depending on insolation and temperature differentials (A3UBD02, BD07). At low ambient temperature (< 30 C), or when air temperatures were the same as chamber temperatures, leaf temperatures varied from approximately the same to about 2 C above chamber temperatures. When

chamber temperatures were kept more than 20 C below ambient and when insolation was greatest (between 1000 and 1500 hr), leaf temperatures were between 2 and 6 C above chamber values. This was the same relationship whether transpiration was nil or up to 12 g H₂O/g transpiration, indicating a good heat exchange in these microphyllous species with the surrounding air. Most studies of leaf temperatures of microphyllous shrubs at ambient conditions indicate a 2 to 3 C differential with leaf temperatures, tending to be somewhat lower than ambient.

At higher temperatures (> 30 C), or when chamber temperatures were above ambient temperatures, leaf temperatures would approximate chamber temperatures. At temperatures approaching 50 C the chamber and leaf temperature were approximately the same. High transpiration rates of over four times that at 40 C contribute to the cooling of the leaves.

We presume from our measurements that in small-leaved active desert species the leaf temperatures during the day would vary from air temperatures by only 1-2 C, being generally higher in a closed chamber, and that this difference would only be greater under intense heat loads at high temperatures and/or when transpiration is low.

TRANSLOCATION

Since the last sample of this year's (1973-74 season) treatment (A3UBD03) has not been taken, we can at this time give only brief results. A summary of previous work is given in Wallace et al. (1973).

Earlier results indicate that 90% of ¹⁴C fixed in one labeling period is still present after two weeks, 50% after five months, and 25-30% after seven to eight months. Our samples in the 1974 season which were labeled in spring, 1973, should provide us with the amount left after one year and the redistribution of this ¹⁴C stored during the winter. In the field studies, only 10 to 20% of the photosynthate labeled was recoverable in the roots. Several reasons were given for this fact: (1) greater above-ground losses due to leaf abscission, fruit fall, herbivory, wind trim, etc., (2) the mixing of ¹⁴C in a carbohydrate pool before translocation, (3) translocation to roots may occur later, i.e., the following spring, and (4) greater relative loss by roots through respiration, sloughing of fine unrecoverable roots (estimated at 15%) and exudates.

Small roots range in amounts of labeled ¹⁴C from undetectable to quite hot. This labeling would depend on whether roots were actively growing at the time of tagging. In some cases, all roots on one plant will be labeled and none on another contain labeled assimilate, indicating a

Table 4. Effect of temperature on night respiration and transpiration of irrigated and non-irrigated plants in Mercury Valley, 1973

Species/Year-Day	Chamber Temperature (°C)							
	15	20	25	30	35	40	45	50
<i>Ambrosia</i>								
unw 219	R		0.0	-4.3	-5.9	-5.6	-4.3	-8.2
	Tr		0.0	0.1	0.1	0.5	2.0	4.5
w 232			-2.5	-4.2	-2.5	-7.3	-6.9	
			0.1	0.9	0.1	0.3	1.8	
w 235	0.0	-2.5	-3.0	-1.9	-9.6	-5.4	-9.7	
	0.0	0.04	0.04	0.04	0.2	0.6	2.7	
unw 247			-1.4	-4.7	-0.9	-6.8	-12.0	
			0.02	0.1	0.01	0.1	0.5	
w 263		-3.6	-5.7	-5.4	-3.8	-8.9		
		0.1	0.1	0.5	0.8	0.8		
<i>Krameria</i>								
unw 226				0.0	0.0	-8.7	-11.7	
				0.0	0.0	0.3	2.0	
unw 249		-1.3	-1.7	-0.4	-1.7	-2.2	-2.2	
		0.02	0.03	0.01	0.03	0.1	0.02	
<i>Larrea</i>								
unw 221				-1.8	-1.2	-2.2	-3.1	-4.0
				0.1	0.2	0.4	1.0	1.9
w 234			-0.9	-1.5	-3.9	-4.4	-8.8	
			0.02	0.03	0.1	0.2	0.4	
w 239			-0.5	-2.0	-2.6	-5.3		
			0.01	0.1	0.2	0.5		
unw 241			-0.7	-2.6	-3.1	-6.0	-7.5	
			0.01	0.2	0.7	1.3	2.1	
unw 256			-0.1	-0.6	-1.4	-2.6	-2.6	
			0.00	0.1	0.2	0.3	0.6	
w 262			-1.6	-1.5	-3.5	-4.4	-8.0	
			0.03	0.2	0.7	1.0	1.7	

R respiration (mg CO₂/g DW leaf/hr)
 Tr transpiration (g H₂O/g DW leaf/hr)
 w watered
 unw unwatered

Table 5. Effect of relative humidity on photosynthesis and transpiration in Rock Valley, 1973

Species	Relative Humidity (%)					
	9%	20%	28%	44%	56%	68%
<i>Lycium a.</i>						
177	Ps 4.4	3.8	0.6	0.0		
	Tr 2.6	4.8	4.5	0.0		
<i>Ambrosia</i>						
150	49.2	42.2	58.9	21.5	18.6	
	4.7	13.8	16.2	10.2	4.6	
184	1.4	1.8	2.1	2.1		
	1.5	2.7	2.6	1.1		
<i>Larrea</i>						
149	14.6	15.3	17.3			
	1.7	2.8	2.7			
176		9.1	7.6	6.1	6.1	
		2.6	2.6	2.0	0.8	
193	0.0	0.0	0.1	0.1	0.2	0.0
	0.0	0.1	0.1	0.1	0.0	0.0
198	2.3	2.0	2.3	1.9	0.0	1.6
	0.5	1.0	1.2	0.7	0.7	0.0
<i>Krameria</i>						
186	1.5	4.0	2.5	1.9	1.9	
	1.0	2.1	2.2	1.9	1.0	
200	3.9	4.6	3.1	3.0	3.1	-1.1
	0.9	2.0	2.1	1.3	0.2	0.0

Ps photosynthesis (mg CO₂/gEW leaf/hr)

Tr transpiration (gH₂O/gDW leaf/hr)

periodicity of transport to roots within a species. Data from 1973 will provide a good comparison of assimilate transport in a year of high productivity (compare with C input discussed later and with plant production data in the Rock Valley Validation Site report for 1973).

Use of a ¹⁴C-pulse technique for measuring root growth has not been successful for our species. The new growth is obscured by labeled photosynthate continuing to move into the roots for as long as three weeks after a pulse, so that there is no sharp decline to lodging of ¹⁴C in roots after the main response to the pulse.

There was a discrepancy between the actual weight of new growth of roots in plants grown in the glass house, 26.4% of total biomass, and the fraction of labeled photosynthate transported to roots, 10%. In another glasshouse study, the above-ground to below-ground phytomass was about equal. Growth in roots evidently occurs either at seasons other than maximum above-ground growth or in years of good productivity as in 1973 (see section on root biomass).

SEASONAL PHOTOSYNTHETIC PRODUCTIVITY AND PRIMARY PRODUCTIVITY

A preliminary estimate of the seasonal course of net photosynthetic productivity expressed as carbon uptake on a leaf dry weight basis was calculated for five of the major plant species in Rock Valley.

Figures 5, 6 and 7 are examples of CO₂ uptake curves for *Krameria*, *Larrea* and *Ambrosia* for 1972 and 1973. Carbon inputs for all five species are given in Table 9. For a comparison of the two contrasting seasons of a "dry" 1972 and a "wet" 1973, refer to the abiotic section. *Larrea* showed the least difference in the two years in total carbon uptake although both *Larrea* and *Krameria* had a shift in peak production of two months later in 1973 with its cool, wet spring. The smallest shift in time of production occurred in the two *Lycium* species, although the change in their total production was the greatest. Differences in species response are related to the adaptive strategies of these species in the timing and utilization of the moisture available during these two seasons (Bamberg et al., 1973).

Biomass production by the five species is compared for the two seasons on the basis of photosynthetic productivity and production estimates using a harvest method. Differences

in these estimates range from 16% in *Krameria* in 1972 to 320% in *Ambrosia*, also in 1972 (Table 10).

The discrepancy in these two methods of estimating productivity can be accounted for in several ways. Below-ground activity and loss are not reflected in the harvest method, but since below-ground biomass may approximately equal that above-ground, then presumably carbon utilization is also equal, although ^{14}C fixed in the photosynthesis does not remain in roots in equal amounts. The figure for *Krameria* then is too low to account for both above- and below-ground utilization. However, in all the other species an additional loss of carbon must be accounted for in other ways. Additional losses between the time when carbon is fixed and when it can be harvested can occur through grazing by mammals and invertebrates, additional respiratory losses of flowers and fruit, wind pruning and damage, and sloughing or high turnover rates of plant parts, particularly roots. Since the photosynthetic productivity estimates are on a complete seasonal basis and the harvesting was done only during the peak vegetative and reproductive phases, additional growth or maintenance loss may have occurred after harvest sampling. One component of growth not measured was base and radial stem growth of plants. We presently have no reliable figures on root vs. stem respiration during seasonal plant activity.

BELOW-GROUND BIOLOGICAL ACTIVITY

Root Biomass

The biomass of roots plus fine organic matter in relation to shrub spacing is given in Table 11, and to sample location in Table 12 (refer to Methods for sample location). All roots decrease both with depth and distance from a shrub base. The least amount of roots was at the surface 5-10 cm in the interspaces, and the 10-20 cm depth at the shrub canopy edge had a slightly higher biomass of roots than the 20-30 cm depth.

The change in total root weight during the 1973 growing season is given in Table 13. During the 1973 growing season there was a large increase in biomass both above- and below-ground. Root biomass was increased by root growth approximately three-fold, and reached a peak the end of June and first of July and then leveled off during August. Sampling variability was large and our data show no smooth trend of root biomass increase, but a general increase throughout the season until the end of June. Since these are total roots, the root biomass includes the increase of roots of both annual plants and perennial shrubs through the season. The increase in root biomass was mainly in the medium-sized roots. The fine root fraction was fairly constant throughout the season.

Table 6. Effect of relative humidity on photosynthesis and transpiration in irrigated and non-irrigated plants in Mercury Valley, 1973

Species/Year-Day	Relative Humidity (%)						
	9	20	28	44	56	68	
<i>Ambrosia</i>							
unw 219	Ps	8.3	10.7	10.3	7.3	5.8	6.5
	Tr	1.6	3.6	4.5	3.7	1.6	0.1
w 232		18.5	22.1	23.2	15.8	30.9	16.9
		2.7	4.8	6.3	4.7	4.7	1.4
w 236		11.3	12.4	13.0	19.1		11.5
		1.7	3.8	4.0	3.6		0.1
unw 247		9.8	1.0	4.9	4.6	0.9	1.2
		0.8	1.5	2.6	1.4	0.1	0.0
w 263		19.7	27.1	24.0	28.7	30.1	22.5
		2.4	4.9	8.1	6.9	5.0	6.2
<i>Krameria</i>							
unw 227		2.6	2.1	0.0	1.7	0.5	0.0
		0.7	1.3	1.9	0.8	0.1	0.0
unw 228		0.0	3.6	1.9	2.9	1.6	1.2
		0.5	1.8	2.7	1.7	0.6	0.0
unw 249		1.0	1.6	2.6	0.7	1.7	0.0
		0.3	0.9	1.3	0.9	0.3	0.0
<i>Atriplex</i>							
unw 222		3.5	3.4	4.2	3.2	4.2	3.0
		0.2	0.4	0.4	0.6	0.5	0.0
w 257		1.6	2.1	2.0	2.9	1.7	
		0.2	0.3	0.4	0.3	0.0	
<i>Larrea</i>							
unw 220		2.1	2.8	3.1	1.7	0.6	
		0.2	0.7	0.4	0.3	0.0	
unw 221		2.8	2.7	2.1	2.1	1.4	1.8
		0.3	0.7	1.0	0.7	0.4	0.0
w 234		1.9	1.4	1.4	1.0	0.8	0.9
		0.4	0.8	1.1	0.7	0.3	0.0
w 240		3.1	3.1	5.1	2.6	2.1	1.9
		0.4	0.8	1.0	0.6	0.4	0.0
unw 242		2.1	3.1	1.7	0.6	0.2	0.0
		0.3	0.5	0.5	0.3	0.0	0.0
unw 256		-1.1	-1.1	-0.6	-1.0	-0.9	-1.1
		0.1	0.2	0.4	0.2	0.0	0.0
w 260		5.1	6.2	3.3	7.7	3.6	3.2
		0.5	1.1	1.6	1.6	0.9	0.0

Ps net photosynthesis (mg $\text{CO}_2/\text{g DW leaf/hr}$)
 Tr transpiration (g $\text{H}_2\text{O}/\text{g DW leaf/hr}$)
 w watered
 unw unwatered

These root biomass figures include both living and dead roots, although obviously dead or decaying roots were discarded. Table 14 gives a breakdown of the below-ground biomass as a seasonal average. The total average root biomass in 1973 of 4540 kg/ha is considerably higher than previously determined and makes the root/shoot ratio about 2:1 for the Rock Valley site.

The fine organic matter which floated out of the soil in the MgSO_4 solution along with the fine roots was composed of a heterogeneous mixture of: (1) above- and below-ground plant parts, (2) fungal and algal spores, hyphae, and fruiting bodies, and (3) insect parts and frass. A surprising amount of leaves, twigs and fruit were found in the soil even at the 30 cm level, indicating active transport of surface materials by insects or other animals.

ATP Concentration

There were too few samples of ATP concentrations to give

Table 7. Seasonal changes in water use efficiency expresses as Ps/Tr ratios for shrubs in Rock Valley for 1972 and 1973

Month/Week	Larrea		Ambrosia		Krameria	
	'72	'73	'72	'73	'72	'73
Mar. 12	7.0					
13	7.5		11.8			
Apr. 14	5.9		10.0		55.8	
15			8.1		26.2	
16			11.6			
17						
May 18					6.6	
19	12.5	5.6				
20	8.3					
21						3.1
Jun. 22	10.2			7.8	7.9	4.2
23					7.1	5.6
24	2.8					
25	1.3	6.5	2.3		2.4	
26		8.2	1.9			
Jul. 27					1.8	4.3
28	1.3	3.6			2.5	
29	2.1	2.3				5.2
30	2.6					
Aug 31	2.1		2.8*		3.1	
32	2.5		1.6*		2.6	
33	1.8		1.2*			2.5
34	2.3		2.8*			1.9
35	3.0	3.8	1.6*			
Sep. 36					2.6	5.0
37					3.9	
38	5.6*				2.3	

*Irrigated

Table 8. Plant tissue water potentials for desert shrubs in Rock Valley and Mercury Valley, 1972 and 1973

Site/Week	Negative Bars									
	Krameria		Ambrosia		Larrea		Lycium a. Lycium P.		Ephedra	
	'72	'73	'72	'73	'72	'73	'72	'73	'72	'73
Rock Valley										
Mar. 12	45	15	15	26	14	14	14	14	21	21
Apr. 14	31	15	15	28	17	17	18	18	13	13
17	25	19	19	33	21	21	17	17	18	18
May 18	48	39	39	51	41	41	44	44	39	39
19	51	32	40	21	54	32	47	25	44	23
21	36	25	25	41	30	30	28	28	27	27
22	63	47	47	63	52	52	51	51	42	42
Jun. 23	65	44	33	42	D	44	D	30	43	43
24	66	D	D	63	D	D	D	D		
25	72	54	D	39	65	49	D	40	D	38
Jul. 28	59	D	50	57	D	44	D	47	46	46
Mercury Valley										
	Larrea		Ambrosia		Krameria					
	'72	'73	'72	'73	'72	'73	'72	'73	'72	'73
	w	unw	w	unw	w	unw	w	unw	w	unw
Jul. 28										
29	48	42	43	35						
30				35	43					
Aug. 31	57	57	43	43						
34	35	46	67	34	42					
Spt. 37				54	62	33	43			51

*D = dormant

Table 9. Carbon input by dominant shrubs based on net CO₂ exchange as a function of leaf dry weight (kg/ha), Rock Valley

Species	Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total	% Change of 73 Over 72
<i>Ambrosia</i>	72		2.69	20.06	17.07	6.51	1.14							47.47	
	73		0.28	8.83	33.53	45.09	32.52	6.80	4.29	1.01				132.35	179
<i>Krameria</i>	72			0.43	3.04	8.00	6.12	1.63	1.45	2.14	1.24			24.05	
	73				1.54	8.89	16.52	17.04	13.85	6.21	0.74			64.79	169
<i>Larrea</i>	72	1.49	3.34	10.25	9.24	4.12	1.36	0.67	0.97	1.44	1.84	1.71	1.17	37.60	
	73	1.11	1.24	2.55	10.08	22.06	17.47	4.47	1.68	2.52	2.36	1.37	1.18	68.09	81
<i>Lycium a.</i>	72		3.25	14.53	5.58	0.78								24.41	
	73		4.42	58.72	68.60	37.03	8.64	1.10						178.51	631
<i>Lycium p.</i>	72		1.21	4.23	2.81	0.50	0.02							8.77	
	73		2.42	24.52	25.05	9.35	1.83	0.77						63.94	629
Totals	72													142.30	
	73													507.68	257

much information on seasonal or spatial changes. Table 15 gives ATP concentrations for whole soil samples at the nine locations in relation to shrubs. These concentrations show the same pattern of decrease with depth and distance from the shrub base as the root biomass. Again the sample location #5 at 10-20 cm at the canopy edge had a slightly higher ATP concentration, as did the root biomass. However, the surface sample (#7) in the interspaces had a higher ATP concentration than the two sampled below (#8 and 9) although the root biomass was the reverse. This increased surface concentration is probably due to more microfloral activity, principally algae and lichens in the upper portions of the soil crust.

The ATP concentrations do not decrease at the same rate from the base of the shrub to the interspaces as the total root biomass, but they do approximate the same spatial pattern as the biomass of fine roots and organic debris. There is a much higher ATP activity associated with the fine roots and microfloral activity. During 1973 no attempt was made to separate ATP activity associated with roots from various microfloral components (Ausmus, 1972). Conversion of ATP concentration to carbon or live biomass of roots and microflora will be attempted at the end of the 1974 season.

DISCUSSION

The results in 1973 confirm the general pattern of CO₂ uptake, water use and productivity exhibited by the five species of perennial shrubs in Rock Valley. In contrast to 1972, a dry year, CO₂ uptake during 1973, which had four times more effective moisture, was greater in all species measured, but there was some species variation in response to increased precipitation and cooler temperatures. Not only were the rates of carbon fixation higher, but total C fixed

Table 10. Comparison of biomass input estimates for Rock Valley based on net CO₂ exchange and harvest sampling (kg/ha).

Species	Year	New Biomass (CO ₂) ¹	New Biomass harvest ²	% difference
<i>Ambrosia</i>	72	118.68	27.62	320
	73	330.88	101.48	226
<i>Krameria</i>	72	60.13	52.02	16
	73	161.98	105.56	53
<i>Larrea</i>	72	94.00	20.58	357
	73	170.23	53.98	215
<i>Lycium a.</i>	72	61.03	26.71	128
	73	446.28	120.18	271
<i>Lycium p.</i>	72	21.93	7.81	181
	73	159.85	55.00	191
TOTAL	72	355.75	134.74	164
	73	1269.20	436.20	191
% increase over 72	73	356	223	

¹biomass = 2.5 x net carbon uptake

²includes above-ground only - data from validation site report

was increased by a much greater leaf biomass which was incremented throughout the season.

Even in a year of favorable growing conditions, considerable variation is evident in the gas exchange in desert plants of the same species growing close together. This variability is demonstrable in CO₂ uptake, water use, growth, fruit production, and the associated phenological events of bud burst, leafing out, flowering, leaf fall, and dormancy. On an ecosystem basis, this individual variability plus the different strategies employed by plant species could explain the general lack of species dominance in the Mohave Desert and the spatial and changing patterns of species associations. Only in situations of high stress such as high salt concentrations do monotypic communities occur. Although productivity was high in all species during 1973, in previous years one or two species exhibited good growth

or reproduction depending on certain temperature or moisture conditions. *Lycium andersonii* and *Ephedra nevadensis* in 1972 had proportionally a higher fruit production than in 1973 (Turner, 1973) while other species produced little fruit in 1972.

Total productivity increased by an estimated 257% from 1972 to 1973, calculated on a CO₂ uptake basis. The greatest increase was in species growing in the cool, moist conditions of early spring (both *Lycium* species which had over a 600% increase in carbon fixation). The least increase of 81% was in *Krameria*, a plant adapted to grow in hotter, drier conditions of summer and therefore not particularly favored by a cool, moist spring.

Table 11. Root biomass in relation to shrub spacing (kg/ha) for upper 30 cm, Rock Valley, 1973

Species (n)	Shrub base	Canopy edge	Interspaces	Total
<i>Ambrosia</i> (13)	372 ^a 40 ^b	70 40	240 250	682 330
<i>Larrea</i> (13)	621 68	90 94	435 339	1146 501
<i>Lycium a.</i> (14)	459 72	105 86	330 332	894 490
<i>Krameria</i> (11)	362 52	90 62	231 252	683 366
Totals	1814 232 2046 ^c	355 282 637	1237 1173 2409	3405 1687 5092

^alarge and medium roots
^bfine roots
^call roots

Table 12. Root biomass in relation to sample location (g/300 cm³ soil), Rock Valley, 1973

Species (n)	Sample Location								
	1	2	3	4	5	6	7	8	9
<i>Ambrosia</i> (13)	a 4.98 b 0.38	2.96 0.37	2.48 0.36	0.02 0.13	0.49 0.22	0.47 0.22	0.06 0.13	0.22 0.16	0.14 0.15
<i>Larrea</i> (13)	8.16 0.63	3.39 0.48	2.25 0.39	0.12 0.34	0.48 0.37	0.40 0.33	0.02 0.10	0.22 0.16	0.36 0.21
<i>Lycium a.</i> (14)	5.60 0.71	3.12 0.56	2.04 0.42	0.18 0.31	0.50 0.32	0.55 0.37	0.08 0.11	0.19 0.17	0.21 0.20
<i>Krameria</i> (11)	5.10 0.69	2.10 0.31	1.36 0.23	0.14 0.25	0.50 0.23	0.42 0.25	0.05 0.12	0.16 0.12	0.13 0.13
Mean	5.96 0.60	2.89 0.43	2.03 0.35	0.12 0.26	0.49 0.29	0.46 0.27	0.05 0.12	0.20 0.15	0.21 0.17

^alarge and medium roots
^bfine roots

Translocation, utilization and storage of assimilates will be clarified when the results of the full year of sampling ¹⁴C fixed in whole plants are analyzed. Based on estimates of percentage of ¹⁴C in plant parts produced by the various species, greater proportional amounts of assimilates were used in root growth (which more than doubled during the 1973 season) followed by fruit production (40% increase in 1973), flower, stem, and leaf production. Leaf biomass was only 44% of productivity in 1973 compared to 59% in 1972.

Root biomass and turnover rates investigated in 1973 gave preliminary weights of roots much higher than previously estimated by whole shrub harvesting. The total average weight of roots in 1973 in Rock Valley estimated by volumetric extraction of the roots was 4205 kg/ha in the top 30 cm of soil and 4540 kg/ha in the total soil profile. If this is compared to the standing above-ground biomass (living and dead; of 2300 kg/ha in Rock Valley, then the above-ground to below-ground biomass ratio is 1:2, which is considerably different from our previous estimates. The ratio of above- to below-ground may be lower than 1:2 since there was such a tremendous increase in root biomass during the 1973 season. We are uncertain what the effect of an atypically moist year had on these ratios and should average the weights for several years for a better estimate.

The greatest increase of roots measured throughout the season was in the medium size range, 1 to 3 mm, and increased in response to a favorable season for growth and productivity.

The amount of fine roots extracted from a volume of soil was fairly constant throughout the season. This indicated either a fairly constant production of fine roots in a volume of soil which were periodically replaced, or a maximum biomass of roots which can penetrate a soil. We were not able to determine living from dead roots, making determination of root turnover rates difficult. Based on

observations of root samples, we postulate a rapid turnover rate of a few weeks on fine roots and increasing times on medium and larger roots to a full season or a few years. There is some evidence that whole sections of roots may die in a process analogous to stem pruning of above-ground parts during periods of stress. Almost all soil in the interspaces had a low and variable amount of roots present. A surprising result was the presence of medium and fine roots in gravel pavement areas some distance from the nearest shrub.

ATP concentrations give a good index of biological activity in the soil profile. In contrast to results reported in the Great Basin (Skujins and West, 1973), total biological activity does not decrease as rapidly with depth in the Mohave Desert soils. There were too few samples throughout the season to determine a peak activity period.

Table 13. Seasonal changes in total root weights for shrub species in Rock Valley (g/l soil) 1973

Month	Week #	<i>Ambrosia</i>	<i>Larrea</i>	<i>Lyctium</i>	<i>Krameria</i>	Mean
March	13			2.37		
	14	1.27	3.40	2.53	2.50	2.43
April	15	1.17	1.73	1.73		
	16			4.93	2.17	2.33
	17	2.80	4.00	3.03	5.30	3.80
	18	4.87	4.50		3.30	4.23
	19		3.57	5.77		4.67
May	20		3.63	3.67	6.43	4.57
	21	5.23	7.37	5.03		5.87
	22		8.37		10.10	
	23	3.60		4.23	5.93	6.43
June	24	3.50	8.23	6.30	4.17	5.56
	25	4.47	8.33	7.90	2.33	5.77
	26	8.90	11.00			9.33
	27			9.90		
	28	7.47	12.30		6.60	8.80
July	29		5.40	7.63	5.57	6.20
	30	5.87		5.97	3.57	5.13
	31	6.10	7.33	7.07	4.03	6.13
	32	6.13	4.83	10.03	5.93	6.73
	33	6.43	8.40	6.03	6.50	6.83
	Aug.	34	7.53		6.13	5.87

Table 14. Components of below-ground biomass for upper 30 cm on Rock Valley Validation Site (kg/ha), 1973

Large and medium roots	3519
Fine roots	666
Organic debris	1028
Total organic	5233

*Visual estimates of organic debris components at 20-30 cm level.

leaves	20%
stems	15%
fruits and seeds	20%
fungi and algae	10%
insect parts	5%
insect frass	20%
unidentified	10%

Table 15. ATP concentration in upper 30 cm of Rock Valley soil ($\mu\text{g/g}$ dry wt. soil), 1973

Species (n)	Sample Locations								
	Shrub base			Canopy edge			Interspace		
	1	2	3	4	5	6	7	8	9
<i>Ambrosia</i> (6)	1.93	1.75	1.49	0.68	0.76	0.76	0.39	0.33	0.28
<i>Larrea</i> (5)	2.81	1.96	1.51	0.87	0.95	0.78	0.56	0.56	0.62
<i>Lyctium a.</i> (5)	2.08	2.05	1.44	1.03	1.10	1.12	0.84	0.74	0.57
<i>Krameria</i> (2)	2.45	1.86	1.26	0.74	1.04	0.67	0.55	0.45	0.46
Mean	2.32	1.91	1.43	0.83	0.96	0.83	0.59	0.52	0.48

Carbon balance and flux values for the Rock Valley site on an ecosystem basis as derived from individual plant measurements were attempted for 1972 and 1973. The five species of plants measured gave an average value of 142 kg/ha of carbon taken up in 1972 and 1973. Since these five plants contributed 69.3% of the biomass, a total of 205 kg/ha carbon uptake is postulated for 1972 and 733 kg/ha for 1973 for the whole Rock Valley Validation Site.

It is beyond the scope of this report to give a total carbon budget for the site. Several values are missing, such as carbon fixed in root biomass, root respiration, stem and fruit respiration, and losses due to herbivory. This makes a total carbon budget difficult although some values can be derived from productivity figures. Turnover rates and amounts of plant material lost into the decomposer cycle are not known at this time. Estimates of these carbon budget values will be attempted at a later date.

EXPECTATIONS

This project is continuing in 1974 with emphasis on the following types of study for plant productivity.

1. CO₂ exchange will be continued with emphasis on stem vs. leaf CO₂ exchange rates in relation to temperature and season.
2. Plants established in 20 gallon enclosed containers will be tested for growth, response to nitrogen and water, and root growth and respiration.
3. Translocation studies using ¹⁴CO₂ for estimating assimilate distribution (with watered and non-watered treatments) to roots, stems and leaves.
4. A major emphasis is being given to root growth, biomass, turnover rates, and respiration. Root respiration of whole soil samples and individual roots will be studied as a function of season, location with reference to shrubs, and depth. A series of tests will be conducted on the effect of various temperatures on respiration of roots throughout the season for different shrubs. ATP concentrations will be assessed for whole-soil sample extracts throughout the season, and related to root and microfloral biomass. Total carbon efflux from the soil will be measured throughout the season.
5. Attempts will be made to derive a first approximation of a carbon budget for the Rock Valley site.

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