OBSERVATIONS ON THE DISTRIBUTION OF MICROORGANISMS IN DESERT SOIL

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ABSTRACT.— Population estimates of fungi, bacteria, and actinomycetes in desert soil were determined with respect to soil depth and distance from shrubs. In general the highest numbers of microbes were found at the shrub base; the lowest numbers were found in the interspaces. While the total number of organisms usually declined in deeper soil, the relative importance of the actinomycetes increased. These population trends are attributed to substrate availability and utilization and interspecific interactions.

As the soils became drier and warmer the total number of microorganisms decreased. Mold populations remained at about the same level during the study. While the numbers of both bacteria and actinomycetes declined, the relative importance of the actinomycetes increased.

The numbers and activities of soil microflora are important in desert soils in the processes of root and litter decomposition, for the timing and release of nutrients tied up in dead organic matter, and also for the physical binding of soil particles (Went and Stark 1968, Khudairi 1969, Fuller 1974). For this report we determined spatial and temporal differences in the populations of fungi, bacteria, and actinomycetes in Mojave Desert soils.

This work was conducted as part of a large study of primary productivity and nutrient interrelationships sponsored by the U.S. International Biological Program (IBP). Soils were gathered from the IBP Desert Biome's Rock Valley validation site, Nye County, Nevada. This area is in the northern Mojave Desert about 100 km northwest of Las Vegas, and is part of the U.S. Energy Research and Development Administration's Nevada Test Site. In Rock Valley soils are well-drained and have moderate permeability. Soil beneath shrubs is fine sand to depths of around 15 cm, gravelly loamy sand to 33 cm, and cemented gravel between 33 and 57 cm. Soils in bare areas are gravelly sandy loam to around 43 cm, and cemented gravel below that (Romney et al. 1973). The vegetation is composed primarily of perennial shrubs, which cover about 20 percent of the surface. More detailed descriptions of edaphic and biotic features may be found in Turner (1974).

METHODS

Soil was sampled from nine locations during the middle of the plant growing season, March-April 1973, around the shrub species, *Lycium andersonii* Gray. Samples were collected from three depths (0–10 cm, 10–20 cm, and 20–30 cm) at each of three distances from the shrub: the shrub base (samples 1, 2, and 3, starting at the surface), at the canopy edge or one shrub radius (samples 4, 5, and 6), and in the shrub interspace or three-canopy radii from the plant base (samples 7, 8, and 9). These soil samples were aliquots of those used in other below-ground studies of root biomass and soil ATP activity (Bamberg et al. 1974).

Dilution plate counts were made to quantify and differentiate the fungal and bacterial populations of the soil samples collected during the 12th, 13th, 15th, and 16th weeks of 1973. Twenty grams of oven-dried soil (ODS) from each soil sample were added to

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100 ml of sterile, distilled water and were shaken for 10 minutes. Coarser particles were allowed to settle, and one-ml samples of the soil suspension were used to prepare dilutions for plate counts according to standard procedures (Clark 1965). The dilutions used were $5X10^{-2}$ and $5X10^{-3}$ for fungi and $5X10^{-4}$ and $5X10^{-5}$ for bacteria-actinomycete counts. Five plates of each dilution were poured. Cooke's Rose Bengal agar with 35 μg Aureomycin/ml added was used for fungal determinations, and sodium albuminate agar was used for bacteria and actinomycetes. The plates were incubated at room temperatures. Mold counts were made after two days, and bacteria and actinomycetes were counted after 14 days.

Penicillium, *Aspergillus*, and *Streptomyces* were differentiated and their percents of occurrence were reported.

Soil pH was measured using a 1:5 soil solution. Determinations of soil moisture were made after the soil was oven-dried at 105–110 C for 24 hours. Total numbers of organisms per gram of oven-dried soil were calculated according to the method of Clark (1965).

Root biomass was determined by a combination of sieving and flotation in saturated $MgSO_4$ solution (see Bamberg et al. 1974).

RESULTS

Soil pH averaged about 9.0 and did not vary significantly with either location or time. Soil temperature and moisture are presented in Table 1.

Temperatures, which were taken in the morning, showed little variation within a sampling period with the exception of Location 7. As one might expect, this surface sample in the interspace was slightly warmer than soil from the other locations. Soil temperatures for April during the 15th and 16th weeks averaged 5-10 C higher than those from March.

At the shrub base and the canopy edge the soil moisture decreased from about 15 percent during weeks 12 and 13 to about 5 percent during weeks 15 and 16. With the exception of week 13, little change in soil moisture was noticed over this period of time at the interspace locations. The high moisture levels for week 13 were the result of 25 mm of rain that fell during the period between the first and second sampling dates. Moisture content in the interspace was slightly lower at week 12 and higher at week 16 than in the other locations.

There was considerable variation in root biomass under *Lycium andersonii* during the study (Table 2). Most of the roots (64 percent) were found under the shrub and the least (less than 7 percent) were present in the interspaces. Root biomass at the shrub base usually decreased with depth, while vertical distribution was fairly uniform at the canopy edge and in the interspaces. Flowering and continued growth occurred during the sampling period; fruit formation had started by the end of this period.

Estimates of the population sizes of fungi, bacteria, and actinomycetes are given in Table 3 for soil samples collected between the 12th and 16th weeks of 1973 from Rock Valley. Table 4 and Figure 1 show the percentage of the total mold population made up of organisms of the genera *Penicillium* and *Aspergillus*. Over 95 percent of the actinomycetes isolated belonged to the genus *Streptomyces*.

Results are summarized according to location:

1. Shrub Base: At the plant base the mold numbers in the surface soil increased during the course of the study. As the spring progressed the number of fungi decreased by about half at the 20–30 cm level. *Penicillium* was the dominant fungal genus underneath the shrub throughout the five-week period. The relative importance of *Aspergillus* dropped off during weeks 15 and 16.

Populations of bacteria and actinomycetes were much higher than those of the fungi. In April the numbers of bacteria decreased by 55–85 percent. During the study *Streptomyces* increased its dominance under the shrub from 50 percent to 80 percent, even though actual numbers declined. Bacterial population size estimates did not appear to be related to sample depth.

2. Canopy Edge: Soil from the canopy edge taken at locations 4, 5, and 6 yielded mold population estimates that did not

change radically during the experiment. Soil from Location 6 usually yielded a lower number of fungi than did soil from shallower depths. *Penicillium* dominance over *Aspergillus* increased sharply during weeks 15 and 16.

Bacteria and actinomycete numbers were lower at the canopy edge than they were underneath the shrub. Population size and dominance trends of these two groups followed those found at the plant base.

3. Interspaces: The lowest total numbers of fungi were found in the shrub interspace. Mold counts in April were highest at the 0–10 cm level. In the shrub interspaces, *Aspergillus* replaced *Penicillium* as the dominant genus.

The populations of bacteria and actinomycetes at three canopy radii from the shrub base were slightly lower than those at the canopy edge. With the exception of week 13, there was little difference in population size estimates with time or depth. *Streptomyces* continued its strong dominant role.

DISCUSSION

Generally both root biomass and total number of microbes were highest at the shrub base. This relationship indicates that the soil microflora utilize the roots or root exudates as a substrate (Starkey 1958, Friedman and Galun 1974). It must be pointed out, however, that other types of organic matter, such as litter, had a distribution pat-

TABLE 1. Soil temperature and moisture at nine sample locations during March and April 1973.

	Sample Location								
Week	Shrub Base			Canopy Edge			Interspace		
	1	2	3	4	5	6	7	8	9
	Temperature (C)								
12	8.5	9.0	9.5	9.0	9.0	9.5	10.0	9.0	8.5
13	8.5	9.0	10.0	9.0	9.0	10.0	10.9	9.0	9.0
15	18.0	16.5	16.0	17.0	15.0	15.0	24.0	18.0	16.0
16	14.5	12.5	13.0	13.0	12.0	13.0	16.0	15.0	13.0
	Moisture (%)								
12	15	15	16	14	15	15	9	10	13
13	14	16	17	16	19	17	17	19	17
15	5	6	6	5	6	6	7	7	7
16	5		6	3	5	7	7	10	13

TABLE 2. Root biomass (gODW/l soil) in relation to sample location under *Lycium andersonii* in Rock Valley, 1973.

	Sample Location								
Week	Shrub Base			Canopy Edge			Interspace		
	1	2	3	4	5	6	7	8	9
12	5.5	2.9	2.8	1.1	6.3	1.7	<0.4	<0.6	<0.4
13	1.4	8.9	1.5	6.0	1.6	2.6	<0.3	<0.2	<0.3
15	3.9	2.1	2.9	1.5	1.6	0.4	1.4	0.5	0.3
16	14.9	8.8	10.3	1.7	1.1	5.2	<0.3	0.3	1.9

tern similar to that of roots (Bamberg et al. 1974).

Fungal populations remained relatively stable as the season progressed. Bacteria and actinomycetes, however, decreased with time. These changes in the microbial community are probably related to soil moisture. Soil water potentials reached about -25 bars in April in Rock Valley. Bacterial activity is known to decline rapidly when the soil water potential drops below -5 bars, while many fungi and actinomycetes can tolerate much lower water potentials (Griffin 1972). Increases in the relative importance of streptomycetes and fungi may be partially attributable to reduced competition by bacteria. The percent of *Streptomyces* increased in April, which may indicate the beginning of a more active decomposition role assumed by this group. This increase is particularly evident at the shrub base and canopy edge.

Penicillium was the dominant mold genus close to the plant, but *Aspergillus* was also common in the surface soils and was dominant in the interspace zone. Since these two genera are spore-formers, plate counts may only indicate the potential rather than the actual activity during the sampling period. The sample locations at which *Aspergillus* numbers were highest are also those that usually become the warmest and driest during the year. These results agree with reports that have found *Aspergillus* to be a more xerothermic genus than *Penicillium* (Griffin 1972).

As mentioned previously, roots, root exudates, and other substrate matter influence the soil microflora. Mold populations were found to decline in deeper soil, while *Streptomyces* dominance increased with soil depth. These differences may have resulted because the availability of preferred nutrient sources varied with soil depth. Most of the roots were located in the upper 20 cm of the soil. Siu (1951) reported that actinomycetes were generally poor cellulose utilizers, while fungi were highly cellulolytic. Went and Stark (1968) postulated that fungi may play an important role in deserts not only in decomposition of soil organic matter but also in the direct cycling of nutrients to living roots from dead organic material.

TABLE 3. Plate counts from soil gathered at nine locations during March and April 1973 (Organisms /gODS).

Week	Sample Location								
	Shrub Base			Canopy Edge			Interspace		
	1	2	3	4	5	6	7	8	9
	Fungi X10^3								
12	25.5	24.9	30.8	23.0	24.5	8.5	9.9	13.1	3.9
13	41.4	22.4	26.1	9.3	23.0	9.8	3.8	3.4	9.2
15	44.7	50.3	16.3	20.1	23.5	12.7	13.2	9.0	5.2
16	47.8	27.8	16.8	18.3	15.1	10.3	7.3	3.6	4.7
	Bacteria X10^5								
12	34.4	93.0	78.8	26.6	63.7	13.6	9.6	13.8	3.3
13	82.2	54.4	20.8	34.3	22.3	22.3	23.1	38.0	16.6
15	5.8	16.9	4.6	11.8	9.4	11.5	18.4	10.7	13.3
16	15.6	19.9	10.4	7.0	9.9	6.8	17.3	4.8	5.9
	Actinomycetes X10^5								
12	51.6	73.0	67.2	45.4	66.3	54.4	19.4	29.2	33.7
13	72.9	92.6	78.2	53.7	70.7	74.7	53.9	72.0	66.4
15	39.2	48.1	18.4	35.3	29.6	25.5	35.6	26.3	24.7
16	36.4	63.1	58.7	30.0	33.1	38.3	16.7	25.2	21.1

TABLE 4. Percentage of total mold colonies composed of the genera *Penicillium* and *Aspergillus*.

Week	Sample Location: Shrub Base 1	Shrub Base 2	Shrub Base 3	Canopy Edge 4	Canopy Edge 5	Canopy Edge 6	Interspace 7	Interspace 8	Interspace 9
				Penicillium					
12	17	54	93	23	48	40	6	21	13
13	35	50	32	21	60	16	0	15	7
15	71	72	58	50	50	29	14	19	29
16	73	25	36	44	75	56	3	6	4
				Aspergillus					
12	13	15	4	10	42	12	62	61	10
13	27	13	8	27	17	16	47	71	1
15	2	3	3	4	4	2	78	57	64
16	1	6	21	8	9	22	71	39	19

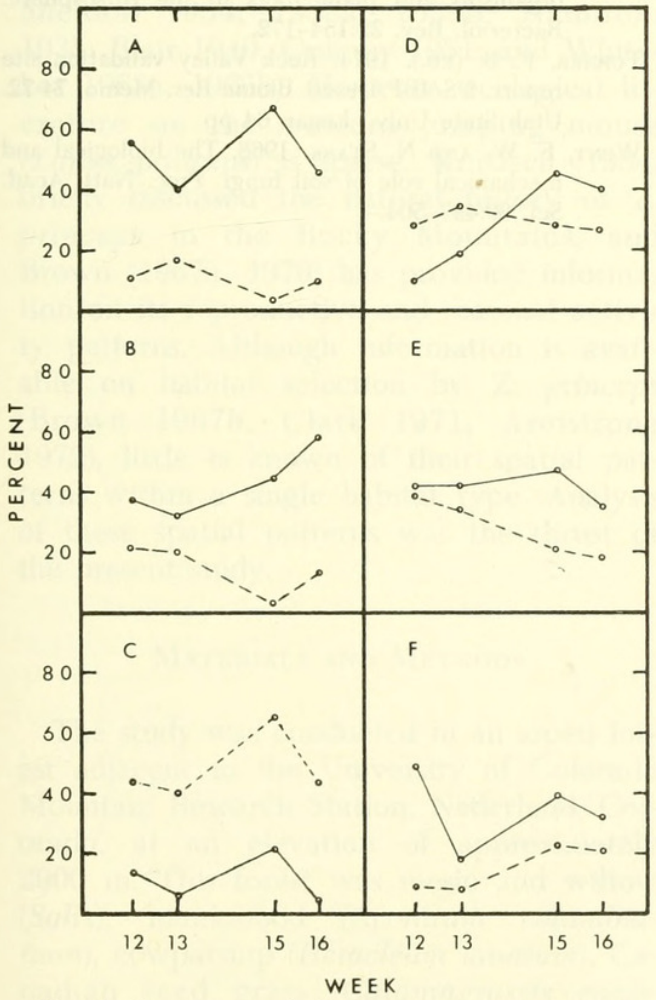

Fig. 1. Percentage of all fungi represented by the genera *Penicillium* (solid line) and *Aspergillus* (dashed line) at: A. Shrub Base (locations 1, 2, and 3); B. Canopy Edge (4, 5, 6); C. Interspace (7, 8, 9); D. 0-10 cm (1, 4, 7); E. 10-20 cm (2, 5, 8); F. 20-30 cm (3, 6, 9).

Alexander (1971) stated that the extant conditions in a habitat will dictate that only one, or a few, of the indigenous species will actually exploit an energy source. The fact that seasonal variation in the soil environment will cause a shift in the relative numbers of various microbial populations is seen by the higher percentage of *Streptomyces* in week 16 over week 12 at the shrub base location. This response corresponds with a decrease in moisture and an increase in temperature during that time interval. The numerical dominance of *Streptomyces* in this study may be attributable to the warm, dry nature of our desert soils.

Throughout the sampling period actinomycetes outnumbered bacteria; fungi represented only a small portion of the total number of microorganisms. These results agree with those reported for other desert soils (Fuller 1974). It has been pointed out, however, that enumeration techniques alone do not necessarily give an accurate indication of the importance of the various microbial groups. For example, while these methods usually give low population estimates for molds, fungal biomass often exceeds that of other microorganisms (Went and Stark 1968, Fuller 1974).

We feel, however, that differences in the number of observed colonies within the var-

ious groups of microorganisms are good indicators of spatial and temporal fluctuations in population size. These population trends in turn give an indication of changes in the relative importance of the different microbial groups.

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