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# Comparison of Biological Processes in Western Deserts

J. Skujins

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# COMPARISON OF BIOLOGICAL PROCESSES IN WESTERN DESERTS

J. Skujins
Utah State University

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Ecology Center, Utah State University, Logan, Utah 84322

## ABSTRACT

Soils from the Great Basin, Sonoran, Chihuahuan and Mohave deserts were collected at certain periods throughout several seasons which would best exhibit microbial response (or lack of it) to moisture or vegetation. The soils were analyzed for several chemical and physical properties. Biological and biochemical characteristics, such as respiration, dehydrogenase activity, ATP concentration, proteolytic activity, autotrophic and heterotrophic nitrogen fixation, nitrification potential, denitrification and microbial numbers, were measured.

The soils exhibited fluctuations in microbial and biochemical activities as measured by respiration, dehydrogenase activity, ATP concentration, proteolytic activity, nitrification potential and other parameters during different moisture seasons. Increase in soil moisture as modified by precipitation did not cause a significant difference in respiration or proteolysis between desert soils; however, an increase in moisture did cause a significant difference in nitrification potential of desert soils. Proteolytic activity was highest in soils collected when above-ground portions of desert plants were dormant.

Low nitrification potential of desert soils was found. Nitrite accumulation was observed in perfusion experiments but not in the field. Respiration, dehydrogenase activity and ATP concentration did not respond proportionally in desert soils adjusted to different moisture levels. These results suggest that respiration, dehydrogenase activity and ATP concentration each appear to represent a different phase of microbial metabolism in desert soils.

Cluster analysis was used to compare the measured soil microbiological and biochemical parameters of the four western deserts.

Nitrogen fixation and ammonification explained 79.2% of the variability between sampling stations. It was found that moistening soil to —3 bars did not significantly stimulate microbial activity in these desert soils.

Wetting dry soils, allowing them to dry and rewetting them stimulated parameter activities an average of 73.5% from the wetted state. Dehydrogenase activity was enhanced an average of 178% compared to the wetted state. Rewetting a soil after initial wetting and then drying apparently released organic matter and stimulated ammonification.


## INTRODUCTION

A comparative study of biological and biochemical properties of western desert soils was initiated in 1975. Microbiological and chemical properties of the soils have been reported (Skujins 1976). This report concludes the analysis of soils for biological and biochemical characterization and includes statistical analysis of data comparing the Great Basin, Sonoran, Mohave and Chihuahuan deserts.

## MATERIALS AND METHODS

All of the soil samples were retrieved from the primary Desert Biome sites as previously reported (Skujins 1976). The following are sample designations:

| | |
|---|---|
| P | Jornada, playa (New Mexico, Chihuahuan Desert) |
| B-1 | Jornada, bajada 1 |
| B-2 | Jornada, bajada 2 |
| B-3 | Jornada, bajada 3 |
| S | Silverbell (Arizona, Sonoran Desert) |
| RV | Rock Valley (Nevada, Mohave Desert) |
| PV | Pine Valley (Utah, Great Basin Desert) |
| C5 | Curlew Valley 5, *Artemisia tridentata*-dominated (Utah, Great Basin Desert) |
| C6 | Curlew Valley 6, *Ceratoides lanata*-dominated |
| C7 | Curlew Valley 7, *Atriplex confertifolia*-dominated |

### Precipitation Patterns and Sampling Dates

Precipitation data were obtained from weather stations at, or near, the sampling sites to determine if collection periods fell within wet or dry seasons.

Figure 1 shows precipitation patterns at the five desert sites for 1975 and 1976. Samples were collected at the Curlew stations June 1975 (dry vegetative), March 1976 (dry nonvegetative) and April 1976 (wet vegetative). January 1973 (wet nonvegetative) data were used in the analysis of variance. Jornada samples were collected March 1975 (wet vegetative) and December 1975 (dry nonvegetative). Silverbell samples were collected March 1975 (wet nonvegetative), June 1975 (dry vegetative), August 1975 (wet vegetative) and December 1975 (dry nonvegetative). Rock Valley samples were collected March 1975 (wet nonvegetative), July 1975 (dry nonvegetative) and December 1975 (dry nonvegetative). April 1973 data (wet vegetative) were used in the analysis of variance. Pine Valley samples were collected March 1975 (wet nonvegetative), July 1975 (wet vegetative), December 1975 (dry nonvegetative) and May 1975 (dry vegetative).

### Chemical Analyses

Nitrogen fixation potentials were measured using the acetylene reduction technique. For photoautotrophic

fixation measurements, 2 g of soil were placed into a 13 x 60 mm glass tube, moistened and sealed with an injectable system; 0.6 ml of $C_2H_2$ were injected into each tube and all the tubes were illuminated at 10,000 lux for 48 hr at 22 C. The surface area of the soil in each tube was 1.69 $cm^2$.

Heterotrophic fixation was measured by adding a 2% glucose solution to each 2-g soil sample prior to the injection of acetylene. All tubes were incubated in the dark for 24 hr at 30 C. The analysis for ethylene has been described elsewhere (Rychert and Skujins 1974).

Ammonification potentials were measured by the procedure outlined by Patel (1972).

Nitrate reduction (denitrification) potentials were determined by adding 5.6 mg of $^{15}N$-labeled $KNO_3$ (Prochem, 96.8 atom % excess) to 10 g of soil (surface 0-3 cm) in a 125-ml flask and moistened to 25% (vol/wt), approximately —0.3 bar. Flasks were covered with cotton plugs and incubated in the dark for seven days at 22 ± 2 C. Following incubation, soils were immersed in a dry ice-acetone bath and lyophilized.

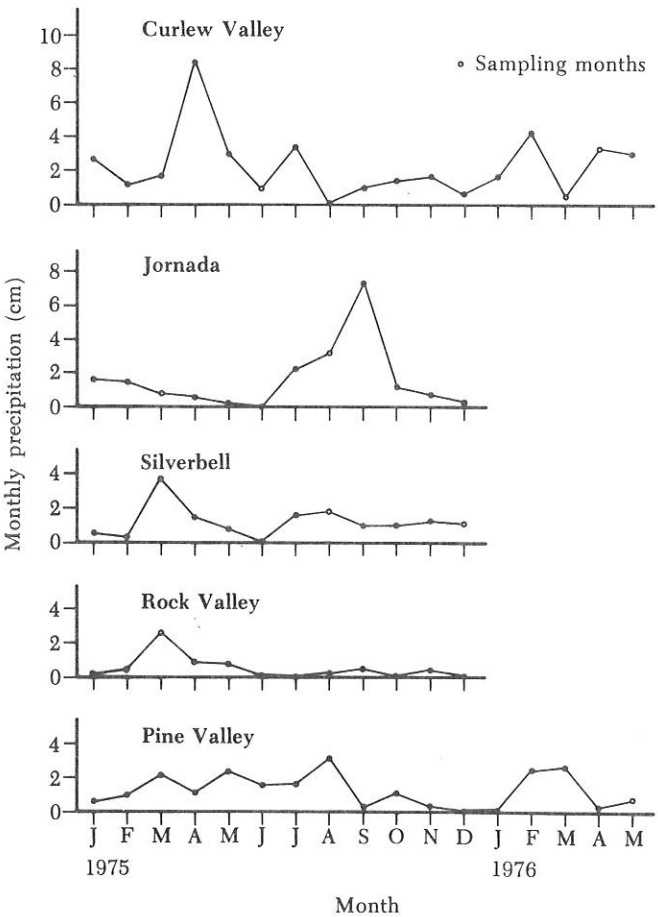



**Figure 1.** Precipitation at study sites during the sampling period.

Soils were analyzed for total N, and nitrite and nitrate N ($NO_2^-$- and $NO_3^-$-N). Analysis of $^{15}N$ was performed by Dr. T. C. Tucker, University of Arizona, Tucson.

Procedures for measuring dehydrogenase activity, ATP concentration and respiration have been described previously (Skujins 1972).

### Adjusted Moisture Levels

Soils collected from Jornada, Silverbell, Rock Valley and Pine Valley sites, and Curlew Valley 5, 6 and 7 soils collected in June and July 1975 were used in this experiment. The amount of added water necessary to adjust soil moisture to field capacity (—0.3 bar) was determined. Respiration, dehydrogenase activity and ATP concentration were measured at original field moisture. The soils were weighed into flasks or tubes in which the experiment was run and the soil moisture was adjusted to full field capacity, 2/3, 1/2 and 1/6 field capacity, and air dried. After adjusting the soils to each moisture level, they were allowed to incubate for 24 hr in the dark with the containers loosely capped. After the 24-hr incubation, the soils were analyzed for dehydrogenase activity, respiration and ATP concentration. Respiration was run in triplicate, and dehydrogenase and ATP concentration were run in duplicate. Water potential was measured 1 hr after respiration experiments to allow the soil temperature to equilibrate with room temperatures.

### Adjusted Moisture Level Plus Organic Matter

Soils collected from playa and bajada 1 (Jornada), Rock Valley and Curlew 7 in June and July 1975 were used in this experiment. These four stations were selected because of their organic carbon content. Playa and Curlew 7 were the highest and bajada 1 (Jornada) and Rock Valley were the lowest in organic carbon content. The intention for selecting the soils with these criteria was to compare the response between soils high and low in organic carbon.

A sufficient amount of soil to measure respiration and dehydrogenase at five moisture levels was weighed into 400-ml beakers and a 1% (wt/wt) amount of glucose was added. The soil and the glucose were mixed well and then enough water was added to completely moisten the soil. The wet soils were quick frozen and lyophilized for 24 hr. The lyophilized soils were removed from the beakers and mixed in a mortar with pestle. Respiration and dehydrogenase were measured in the lyophilized soils and the amount of added water necessary to bring the soil moisture level to field capacity was determined. The soils were then moistened to 1/2, 1/4, 1/6 and 1/12 field capacity. Respiration and dehydrogenase were run in triplicate, and dehydrogenase was measured in duplicate. At higher moisture levels (1/2 and 1/4 field capacity) only half the amount of soil designated in the procedure was taken. Water potential measurements were taken 1 hr after the respiration measurements.

### Drying Experiment #1

Soils collected March 1975 or March 1976 from all 10 sampling stations within the five desert sites were used in

this experiment. Enough soil to measure respiration, dehydrogenase activity and ATP concentration at six drying intervals was weighed out, and each soil was spread to a depth of 1-2 cm in a 9-inch aluminum cake pan. The amount of added water necessary to bring the soils to field capacity was determined. Respiration, dehydrogenase activity and ATP concentration were measured in the soils at original moisture. The soils in the aluminum pans were moistened to field capacity and then allowed to air dry. Respiration, dehydrogenase and ATP concentration were measured at field capacity, 24 hr after drying, 96 hr after drying and 192 hr after drying. After the 192-hr drying period, the soils were placed in a 30 C incubator for 24 hr, and respiration, dehydrogenase activity and ATP concentration were then measured. The remaining soils were then placed in a 37 C incubator for 24 hr, and respiration, dehydrogenase activity and ATP concentration were measured. Water potential was measured before and 1 hr after respiration measurements at each interval. At each drying interval one flask of soil was treated with propylene oxide for 22 hr, and $CO_2$ evolution was measured. This value was subtracted from the untreated samples. This control was used for all drying experiments.

### Drying Experiment #2

Soils collected June or July 1, 1975, from playa, bajada 1, 2 and 3 (Jornada), Silverbell, Rock Valley and Pine Valley were used in this experiment. Respiration and dehydrogenase activity were measured at original soil moisture. The amount of added water necessary to bring the soils to field capacity was determined. Enough soil to measure respiration and dehydrogenase at four drying intervals was weighed into a beaker. The soil was moistened to field capacity and then spread out to a depth of 1-2 cm on double-thickness paper towels and allowed to air dry. Respiration and dehydrogenase were measured at 24-, 48-, 96- and 192-hr drying intervals. Water potential was measured 1 hr after the respiration experiments concluded.

### Wetting-Drying Experiment

Soils collected June or July 1975 from all 10 stations at the five desert sites were used in this experiment. Enough soil to measure respiration, dehydrogenase activity, ATP concentration and nitrogen fractions including total nitrogen, total ammonium, exchangeable ammonium and nitrate plus nitrite, at four intervals, was weighed into a 400-ml beaker. Casein (1% wt/wt) was added and mixed into the soil. Enough water to thoroughly wet the soils was then added. The soils were quick frozen in dry ice and acetone and then lyophilized for 24 hr. The lyophilized soil was analyzed for respiration, dehydrogenase, ATP concentration and nitrogen fractions. The amount of added water necessary to bring the soil moisture to field capacity was determined. The soils were moistened to field capacity and spread out to a depth of 1-2 cm on a double-thickness paper towel and allowed to air dry for 8 days. The soils were analyzed for the aforementioned variables at field capacity, and 8 days after air drying the 8-day air dry soil was rewetted and analyzed for respiration, dehydrogenase activity, ATP concentration and nitrogen fractions.

### Statistical Analysis

The field data collected in 1975 were analyzed statistically using analysis of variance, cluster analysis and principal components analysis techniques (Sneath and Sokal 1973). A correlation analysis between the variables was also run. The analysis of variance was run using factorial analysis of variance (FCTCVR) program (STATPAC Library, prepared by Dr. Rex Hurst, Department of Applied Statistics and Computer Science, Utah State University, Logan), three-way factorial with a single replication to find significant differences between stations, and significant differences between stations at different moisture and vegetative seasons. The variables used to characterize the stations were respiration, dehydrogenase activity, ATP concentration, proteolytic activity, moisture content, nitrification potential, exchangeable ammonium and nitrate content.

The cluster analysis was run using the MINT numerical taxonomy computer program written F. James Rohlf (Department of Ecology and Evolution, SUNY, Stonybrook, New York). The options used in the cluster analysis were: 1) similarity index, average Euclidean distance, and 2) clustering method, unweighted pair-group arithmetic average clustering (UPGMA). The attributes of the 10 sampling stations being clustered included respiration, dehydrogenase activity, proteolytic activity, ATP concention, moisture content, water potential, salinity, pH, total ammonium, exchangeable ammonium, nitrate, nitrification potential, number of aerobic bacteria, number of fungi, total nitrogen and organic carbon. The cluster where all attributes were used is referred to as the All Attributes Cluster. These attributes were also used in one principal components analysis. The purpose of running these analyses was to determine similarities and dissimilarities between sampling stations based on these attributes, and to determine which attributes explained the greatest amount of variability between sampling stations.

Several cluster analyses were run with different combinations of the aforementioned attributes. One combination included activities such as respiration, dehydrogenase, proteolytic activity, ATP concentration, water potential and nitrification potential. This is referred to as the Potential Activities Cluster. Another included such attributes as soil status measurements which included organic carbon, total nitrogen, nitrate, total ammonium, salinity and pH. This is referred to as the Soil Status Cluster.

Finally, a cluster analysis was run with the attributes being nitrogen potential activities such as nitrogen fixation potential, ammonification potential, denitrification potential, potential proteolytic activity and nitrification potential. This is referred to as the Nitrogen Attributes Cluster. For these cluster analyses, values for all dates were averaged for each site.

## RESULTS AND DISCUSSION

### Nitrogen Fixation

The data for photoautotrophic and heterotrophic nitrogen fixation are given in Tables 1 and 2. It is observed that the Pine Valley transect samples have the greatest average activity at 22 C (3.35 g $N_2$ fixed·$ha^{-1}$·$hr^{-1}$), followed by Rock Valley (1.70), Silverbell (0.74) and Jornada sites -- playa (0.63), bajada 1 (0.23), bajada 2 (0.24) and bajada 3 (0.05).

Heterotrophic fixation potentials show a different set of results, with playa having the greatest activity (4.1 g $N_2$ fixed/ha) and Pine Valley the lowest (0.28).

### Ammonification Potential

Table 3 gives the ammonification potential data. The Jornada sites (playa and bajada 1, 2 and 3) have the greatest activities with 98 to 100% ammonification. This was followed by Silverbell (81%), Pine Valley (72%) and Rock Valley (67%).

### Denitrification

The results on reduction of $^{15}NO_3^-$ are given in Table 4. More than 73% of the applied $^{15}NO_3^-$ is assimilated, immobilized and/or denitrified. Pine Valley had the highest potential (89.7%), while the Jornada bajada 1 site had the lowest (73.75%).

$^{15}N$ data on the reduction of nitrate N (Tables 5 and 6) suggest a high potential for the utilization of inorganic nitrogen in the form of nitrate exists in all soils studied.

Further, it appears that the overwhelming majority of reduced nitrate is denitrified with, depending on site, an average of only 4.7-18.5% of the added $^{15}NO_3^-$-N being assimilated in the organic fraction or existing as fixed or exchangeable ammonium.

The Pine Valley and Rock Valley soils had the greatest potential for denitrification of added nitrate overall, with 84.98 and 82.34%, respectively, of the added $^{15}NO_3^-$ lost via denitrification.

The lowest denitrification potentials observed were in the Jornada bajada soils with an overall loss of 63.2% of the added $^{15}NO_3^-$ attributed to denitrification. Conversely, the bajada (Jornada) soils exhibited the greatest potentials for assimilation of reduced nitrate N into organic or ammonium nitrogen forms with between 8.26 and 18.49% of the added nitrogen existing in the soil in reduced forms.

The data reported suggest several possibilities. In nitrogen fixation potentials, the Pine Valley and Rock Valley samples had lower values when potentiated in the dark than in the light. This would first suggest that there are fewer heterotrophic N-fixing bacteria in these soils than in other sites. Second, since greater values were obtained under illuminated conditions, it further suggests that the algae are the main nitrogen fixers in these soils compared to the other soils. However, caution must be used as the activities may vary under different incubation temperatures. Thus, the Silverbell and Jornada sites may have greater photoautotrophic fixation potentials at 30 or 37 C, while the Rock Valley and Pine Valley sites may have greater heterotrophic activities at 22 C. Rychert and Skujins (1974) have shown that for Curlew Valley soils, greater photoautotrophic and heterotrophic activities occur at 22 C but little to none at 37 C.

The ammonification and nitrate reduction activities of these soils indicate the high potential which exists for the mineralization of ammonium and the assimilation and/or dissimilation of nitrate N.

**Table 1.** Photoautotrophic nitrogen fixation potential at 22 C for transect samples as measured by acetylene reduction technique

| Pine Valley | nm $C_2H_4$ | g $N_2$ fixed·$ha^{-1}$·$hr^{-1}$ |
|---|---|---|
| 1 | 15.95 | 7.02 |
| 2 | 9.71 | 4.28 |
| 3 | 4.45 | 1.96 |
| 4 | 10.45 | 4.60 |
| 5 | 5.22 | 2.30 |
| 6 | 3.82 | 1.68 |
| 7 | 1.01 | 0.45 |
| 8 | 14.39 | 6.34 |
| 9 | 3.51 | 1.55 |
| Ave. | 7.61 | 3.35 |
| Rock Valley | | |
| 1 | 1.125 | 0.50 |
| 2 | 2.325 | 1.02 |
| 3 | 0.015 | 0.01 |
| 4 | 14.898 | 6.56 |
| 5 | 0.023 | 0.01 |
| 6 | 0.03 | 0.013 |
| 7 | 3.2175 | 1.42 |
| 8 | 0.0345 | 0.02 |
| 9 | 2.025 | 0.89 |
| 10 | 14.892 | 6.56 |
| Ave. | 3.8585 | 1.70 |
| Silverbell | | |
| 1 | 0.1155 | 0.05 |
| 2 | 0.0525 | 0.02 |
| 3 | 10.92 | 4.81 |
| 4 | 1.48 | 0.65 |
| 5 | 0.555 | 0.24 |
| 6 | 0.4425 | 0.20 |
| 7 | 0.015 | 0.01 |
| 8 | 2.505 | 1.10 |
| 9 | 0.1875 | 0.08 |
| 10 | 0.615 | 0.27 |
| Ave. | 1.6888 | 0.74 |

Table 1, continued

| Playa (Jornada) | nm $C_2H_4$ | g $N_2$ fixed·$ha^{-1}$·$hr^{-1}$ |
|---|---|---|
| 1 | 0.1935 | 0.09 |
| 2 | 0.615 | 0.27 |
| 3 | 0.1425 | 0.06 |
| 4 | 6.72 | 2.96 |
| 5 | 0.6945 | 0.31 |
| 6 | 2.295 | 1.01 |
| 7 | 0.075 | 0.03 |
| 8 | 0.795 | 0.35 |
| 9 | 0.09 | 0.04 |
| 10 | 2.64 | 1.16 |
| Ave. | 14.2605 | 0.63 |
| Bajada-1(Jornada) | | |
| 1 | 1.05 | 0.46 |
| 2 | 0.6 | 0.26 |
| 3 | 0.5625 | 0.25 |
| 4 | 0.3225 | 0.14 |
| 5 | 0.045 | 0.02 |
| 6 | 0.585 | 0.26 |
| 7 | 0.8325 | 0.37 |
| 8 | 0.8205 | 0.36 |
| 9 | 0.0675 | 0.03 |
| 10 | 0.405 | 0.18 |
| Ave. | 0.529 | 0.23 |
| Bajada-2 (Jornada) | | |
| 1 | 0.1275 | 0.06 |
| 2 | 0.1725 | 0.08 |
| 3 | 0.585 | 0.26 |
| 4 | 0.135 | 0.06 |
| 5 | 0.0975 | 0.04 |
| 6 | 3.405 | 1.50 |
| 7 | 0.15 | 0.07 |
| 8 | 0.0375 | 0.02 |
| 9 | 0.465 | 0.21 |
| 10 | 0.255 | 0.11 |
| Ave. | 0.543 | 0.24 |
| Bajada-3 (Jornada) | | |
| 1 | 0.015 | 0.01 |
| 2 | 0.09 | 0.04 |
| 3 | 0.3075 | 0.14 |
| 4 | 0.03 | 0.01 |
| 5 | 0.142 | 0.06 |
| 6 | 0.075 | 0.03 |
| 7 | 0.09 | 0.04 |
| 8 | 0.015 | 0.01 |
| 9 | 0.09 | 0.04 |
| 10 | 0.2075 | 0.09 |
| Ave. | 0.1062 | 0.05 |

**Table 2.** Heterotrophic nitrogen fixation potential at 30 C for transect samples as measured by acetylene reduction technique

| Sample | nm $C_2H_4$ | g $N_2$ fixed·$ha^{-1}$·$hr^{-1}$ |
|---|---|---|
| PV-1 | 0.21 | 0.19 |
| PV-2 | 0.405 | 0.36 |
| PV-3 | 0.36 | 0.32 |
| Ave. | 0.3217 | 0.28 |
| RV-1 | 1.4595 | 1.29 |
| RV-2 | 0.855 | 0.75 |
| RV-3 | 0.2745 | 0.24 |
| Ave. | 0.863 | 0.76 |
| S -1 | 2.316 | 2.04 |
| S -2 | 9.6 | 8.46 |
| S -3 | 1.2 | 1.06 |
| S -4 | 1.02 | 0.90 |
| Ave. | 3.534 | 3.11 |
| P-1 | 1.4325 | 1.26 |
| P-2 | 14.52 | 12.79 |
| P-3 | 1.89 | 1.67 |
| P-4 | 0.78 | 0.69 |
| Ave. | 4.656 | 4.10 |
| B-1-1 | 0.8625 | 0.76 |
| B-1-2 | 0.27 | 0.24 |
| B-1-3 | 0.2175 | 0.19 |
| B-1-4 | 0.105 | 0.09 |
| Ave. | 0.3638 | 0.32 |
| B-2-1 | 1.5705 | 1.40 |
| B-2-2 | 1.5825 | 1.39 |
| B-2-3 | 0.0225 | 0.02 |
| B-2-4 | 0.06 | 0.05 |
| Ave. | 0.8089 | 0.71 |
| B-3-1 | 0.1275 | 0.11 |
| B-3-2 | 1.9725 | 1.74 |
| B-3-3 | 0.5175 | 0.46 |
| B-3-4 | 0.045 | 0.04 |
| Ave. | 0.6656 | 0.59 |

Note: 1 = Soils collected March 1975.

2 = Soils collected June for the Silverbell and Jornada sites; July for Rock Valley and Pine Valley.

3 = Soils collected in August for Silverbell and Jornada; December for Rock Valley and Pine Valley.

4 = Soils collected in December for Silverbell and Jornada.

**Table 3.** Ammonification potential (all values expressed as mg N/g soil)

| Site | Initial Total $NH_4^+$-N | Final Total $NH_4^+$-N | % Ammonification |
|---|---|---|---|
| Pine Valley | 0.023 | .763 | 72% |
| Rock Valley | 0.019 | .71 | 67% |
| Silverbell | 0.051 | .885 | 81% |
| Playa (Jornada) | 0.091 | 3.26 | 100% |
| Bajada 1 (Jornada) | 0.014 | 1.14 | 98% |
| Bajada 2 | 0.02 | 0.95 | 90% |
| Bajada 3 | 0.016 | 1.18 | 99% |

Calculations: Final total $NH_4^+$-N − Initial total $NH_4^+$-N

= Total $NH_4^+$-N mineralized.

$$\therefore \frac{\text{Total } NH_4^+\text{-N mineralized} \times 100}{\text{mg } NH_4^+\text{-N (in casein)}} = \% \text{ Ammonification.}$$

**Table 4.** Nitrate reduction potential

| Site | Average % of reduced $^{15}NO_3^-$ Incorporated in soil | Average % $^{15}NO_3^-$ Denitrified | Total % Nitrate Reduced |
|---|---|---|---|
| PV | 4.71 | 84.98 | 89.7 |
| RV | 5.28 | 82.34 | 87.6 |
| S | 8.40 | 76.42 | 84.8 |
| P | 11.88 | 70.46 | 82.3 |
| B-1 | 18.49 | 55.26 | 73.8 |
| B-2 | 8.26 | 68.63 | 76.9 |
| B-3 | 11.77 | 65.81 | 77.6 |

**Table 5.** Denitrification of $^{15}NO_3^-$ (all values in $\mu$g/g soil)

| Sample and month | Reduced $^{15}N$ in soil | $NO_2^- + NO_3^-$ $^{15}N$ | Total $^{15}N$ | Initial $NO_3^-$ $^{15}N$ | Denitrified $^{15}N$ | % Denitrified |
|---|---|---|---|---|---|---|
| PV III | 24.81 | 66.30 | 91.11 | 552.16 | 461.05 | 83.49 |
| PV VII | 25.51 | 70.25 | 95.76 | 552.16 | 456.40 | 82.66 |
| PV XII | 27.66 | 34.26 | 61.92 | 552.16 | 490.24 | 88.79 |
| RV III | 35.38 | 71.38 | 106.76 | 552.16 | 445.40 | 80.67 |
| RV VII | 28.43 | 77.72 | 106.15 | 552.16 | 446.01 | 80.78 |
| RV XII | 23.64 | 56.04 | 79.68 | 552.16 | 472.48 | 85.57 |
| S III | 86.65 | 111.82 | 198.47 | 552.16 | 353.69 | 64.06 |
| S VI | 17.29 | No data | — | 552.16 | -- | -- |
| S VIII | 40.70 | 47.21 | 87.91 | 552.16 | 464.25 | 84.08 |
| S XII | 40.93 | 63.39 | 104.32 | 552.16 | 447.84 | 81.11 |
| P III | 111.70 | 203.05 | 314.75 | 552.16 | 237.41 | 43.00 |
| P VI | 50.44 | 57.37 | 107.81 | 552.16 | 444.35 | 80.47 |
| P VIII | 47.74 | 64.07 | 111.81 | 552.16 | 440.35 | 79.75 |
| P XII | 52.53 | 65.47 | 118.00 | 552.16 | 434.16 | 78.63 |
| B-1 III | 84.76 | 330.69 | 415.45 | 552.16 | 136.71 | 24.16 |
| B-1 VI | 23.74 | 79.92 | 103.66 | 552.16 | 448.50 | 81.23 |
| B-1 VIII | 26.01 | 88.61 | 114.62 | 552.16 | 437.54 | 79.24 |
| B-1 XII | 273.81 | 80.54 | 354.35 | 552.16 | 197.81 | 35.88 |
| B-2 III | 57.24 | 219.67 | 162.43 | 552.16 | 389.73 | 70.58 |
| B-2 VI | 75.70 | 226.59 | 302.29 | 552.16 | 249.87 | 45.25 |
| B-2 VIII | 24.04 | 87.10 | 111.14 | 552.16 | 441.02 | 79.87 |
| B-2 XII | 25.48 | 91.41 | 116.89 | 552.16 | 435.27 | 78.83 |
| B-3 III | 106.11 | 170.82 | 276.93 | 552.16 | 275.23 | 49.85 |
| B-3 VI | 105.99 | 80.60 | 186.59 | 552.16 | 365.57 | 66.21 |
| B-3 VII | 25.29 | No data | — | 552.16 | -- | — |
| B-3 XII | 22.55 | 80.34 | 102.89 | 552.16 | 449.27 | 81.37 |

**Table 6.** Percentage of reduced $^{15}NO_3^-$ incorporated in soil as organic $^{15}N$ and $^{15}NH_4^+$

| | | | | | |
|---|---|---|---|---|---|
| PV III | 4.49 | RV III | 6.41 | S III | 15.69 |
| VII | 4.62 | VII | 4.28 | VI | 3.13 |
| XII | 5.01 | XII | 5.15 | XIII | 7.37 |
| | | | | XII | 7.41 |
| Ave. = | 4.71 | Ave. = | 5.28 | Ave. = | 8.40 |
| P III | 20.23 | B-1 III | 15.35 | B-2 III | 10.37 |
| VI | 9.14 | VI | 4.30 | VI | 13.71 |
| VII | 8.65 | VIII | 4.71 | VIII | 4.35 |
| XII | 9.51 | XII | 49.59 | XII | 4.61 |
| Ave. = | 11.88 | Ave.= | 18.49 | Ave. = | 8.26 |
| B-3 III | 19.22 | | | | |
| VI | 19.20 | | | | |
| VIII | 4.58 | | | | |
| XII | 4.08 | | | | |
| Ave. = | 11.77 | | | | |

### Microbial Activities Response to Moisture Availability

Several experiments measuring microbial response to moisture under laboratory conditions were performed on the soils collected in 1975 and 1976. Table 7 shows respiration, dehydrogenase and ATP values at six adjusted moisture levels. Table 8 shows the water potentials at each moisture level. The analysis of variance for this experiment is shown in Table 9. There was no significant difference in respiration between moisture levels nor sampling stations at different moisture levels. There is a difference in dehydrogenase values and ATP values obtained at different moisture levels. Tables 10 and 11 show the means for moisture level comparison of dehydrogenase and ATP, respectively. According to this experiment, moistening these soils to —3.1 bars will not significantly increase dehydrogenase activity, although ATP is stimulated significantly at —23 bars. Table 11 shows that Curlew 6 is significantly different in ATP concentration at all moisture levels from all other stations except Curlew 5. Curlew 6 is also significantly different from all other stations in dehydrogenase activity, except Curlew 7.

The adjusted moisture plus glucose (organic matter) experiment results are shown in Tables 12 to 16. Tables 12 and 13 show respiration, dehydrogenase and water potential values for playa and bajada 1 (Jornada), Rock Valley and Curlew 7 samples at five moisture levels. Glucose was added to potentiate the heterotrophic organisms. Table 14 shows the analysis of variance for this experiment. Again as with the nonpotentiated soils at adjusted moisture levels, respiration was not significantly different due either to varying moisture levels or to sampling stations. Dehydrogenase was significantly different between moisture levels and sampling stations. Table 15 shows the dehydrogenase means for a moisture level comparison. The LSD (least significant difference) value is 0.0126, and it is noted that microbial activity is stimulated significantly in a soil in a dry state when the soil is moistened to —7 bars. This result in the analysis of variance could be weighted by Curlew 7 soil, playa (Jornada) soil and Rock Valley soil in which the water potential was —4, —3 and —4 bars, respectively. Bajada 1 (Jornada) soil water potential was —16 bars and may not have contributed to the results. Table 16 shows that all sites were different from each other even though two were high in organic carbon and two were low.

Tables 17 through 22 show the results of drying experiment #1. Tables 17 to 20 show results of respiration, dehydrogenase, ATP and water potential at five drying intervals compared to original moisture and wetted soils. All soils approached or had water potentials less than —275 bars after 24 hr drying (Table 20). Table 21 shows the analysis of variance for drying experiment #1. Respiration and ATP were significantly different at different moisture levels (drying intervals). Respiration, dehydrogenase and ATP all were significantly different between sampling stations. Table 22 shows means for the moisture level comparison. Only after 192 hr of drying was there a significant decrease in respiration. Even though soils became dryer, respiration was increased when incubated at both 30 and 37 C. On the other hand, soil after 192 hr of drying plus 24 hr at 30 C plus 24 hr at 37 C showed the highest ATP level. This increase may be due to either ATP storage in the cell for extremely desiccated conditions or higher recovery from the soil.

Water potentials for drying experiment #2 are given in Table 23. Table 24 shows a partial analysis of variance for this experiment. The soils in this experiment were wetted and mixed in a beaker and then spread out on a paper towel so there was breaking up of aggregates and uneven drying, which probably affected the results obtained.

Tables 25 and 26 show results of the wetting-drying experiment. In this experiment, the dry soils were wetted, allowed to air dry for 8 days and then rewetted. This was to observe the response by microorganisms to wetting, drying and rewetting. The soils were also amended with casein, an organic matter source with nitrogen. Table 25 shows results of measures of respiration, dehydrogenase and ATP concentration. Respiration was stimulated an average of 73.5% upon rewetting. ATP concentration was generally the same at all intervals. Dehydrogenase was stimulated an average of 178% upon rewetting. Table 26 shows nitrogen fraction measurement. Generally, there was very little nitrification taking place. Fixed ammonium also increased upon rewetting, which was probably a function of release of organic matter and subsequent ammonification.

Table 27 shows Pearson correlation coefficients between activities. The only significant correlation was between dehydrogenase and respiration in the adjusted moisture level plus organic matter experiment at 1/2 field capacity where $r = 0.91$.

### Biological Activities: Statistical Comparison of Western Deserts

Averages for all activities and soil attributes measured for all stations sampled in 1975 (Skujins 1976) and 1976 are shown in Table 28. These data were used in the cluster analyses. Table 29 shows the analysis of variance for field data. There is a significant difference between sites for respiration, dehydrogenase, proteolysis, nitrate content and nitrification potential. There is no significant difference between sites at the 90% level for ATP concentration. This reaffirms the verity that ATP may be a better indicator of microbial biomass than microbial numbers. In previous reports where microbial numbers were given it could be noted that numbers were generally similar between stations. Table 30 shows the means for station comparison. Playa (Jornada), Curlew 5, Curlew 6 and Curlew 7 are significantly different from all other stations, although Silverbell and Rock Valley are not significantly different from Curlew 7 in respiration activity. Playa (Jornada), Curlew 5 and Curlew 6 are not significantly different from each other. Curlew stations and Silverbell are all significantly different from the others in dehydrogenase activity but are not different from each other. Similar groups as reflected by proetolytic activity are the Curlew stations; Silverbell, Rock Valley and Pine Valley; and all Jornada stations. The only station that stands out from all the rest with respect to nitrate content and nitrification potential is playa (Jornada).

**Table 7.** Adjusted moisture level experiment showing average values of respiration, dehydrogenase and ATP at six adjusted moisture levels

| Sample | Original Moisture | | | Field Capacity | | | 2/3 Field Capacity | | |
|---|---|---|---|---|---|---|---|---|---|
| | Respiration ($\mu$moles $CO_2$ $\cdot g^{-1} \cdot min^{-1}$) | Dehydrogenase (mg formazan/g) | ATP ($\mu$g/g) | Respiration ($\mu$moles $CO_2$ $\cdot g^{-1} \cdot min^{-1}$) | Dehydrogenase (mg formazan/g) | ATP ($\mu$g/g) | Respiration ($\mu$moles $CO_2$ $\cdot g^{-1} \cdot min^{-1}$) | Dehyrogenase (mg formazan/g) | ATP ($\mu$g/g) |
| P | 22.3 | .182 | .0096 | 31.0 | .508 | .0319 | 36.7 | .362 | .0303 |
| B-1 | 4.1 | .054 | .0091 | 3.8 | .125 | .0260 | 8.7 | .155 | .0212 |
| B-2 | 4.3 | .038 | .0077 | 2.5 | .150 | .0248 | 21.0 | .246 | .0169 |
| B-3 | 2.4 | .044 | .0095 | 3.6 | .226 | .0371 | 19.6 | .277 | .0188 |
| S | 2.9 | .077 | .0084 | 8.5 | .458 | .0639 | 15.3 | .403 | .0194 |
| RV | 8.8 | .049 | .0077 | 6.0 | .353 | .0198 | 9.6 | .438 | .0271 |
| PV | 9.8 | .586 | .0069 | 4.4 | .473 | .0344 | 13.0 | .464 | |
| C5 | 14.4 | .523 | .0090 | 9.3 | .446 | .1049 | 14.2 | .518 | .0695 |
| C6 | 17.3 | .892 | .0064 | 19.1 | 1.116 | .0875 | 30.6 | .621 | .0938 |
| C7 | 19.9 | .716 | .0134 | 15.2 | 1.135 | .0752 | 17.2 | .883 | .0684 |

| Sample | 1/2 Field Capacity | | | Air Dried | | | 1/6 Field Capacity | | |
|---|---|---|---|---|---|---|---|---|---|
| | Respiration ($\mu$moles $CO_2$ $\cdot g^{-1} \cdot min^{-1}$) | Dehydrogenase (mg formazan/g) | ATP ($\mu$g/g) | Respiration ($\mu$moles $CO_2$ $\cdot g^{-1} \cdot min^{-1}$) | Dehydrogenase (mg formazan/g) | ATP ($\mu$g/g) | Respiration ($\mu$moles $CO_2$ $\cdot g^{-1} \cdot min^{-1}$) | Dehydrogenase (mg formazan/g) | ATP ($\mu$g/g) |
| P | 26.6 | .498 | .0429 | 22.6 | .667 | .1301 | 19.0 | .551 | .0548 |
| B-1 | 2.4 | .084 | .0578 | 3.8 | .089 | .1656 | 10.7 | .130 | .1058 |
| B-2 | 5.4 | .099 | .0332 | 7.0 | .114 | .0483 | 8.2 | .129 | .0668 |
| B-3 | 7.6 | .135 | .1324 | 8.6 | .104 | .1566 | 8.9 | .130 | .0923 |
| S | 6.2 | .272 | .1972 | 8.7 | .231 | .0971 | 6.1 | .206 | .0237 |
| RV | 8.5 | .185 | .1039 | 6.7 | .140 | .0826 | 5.1 | .191 | .1113 |
| PV | 10.2 | .269 | .0777 | 8.4 | .232 | .1224 | 8.8 | .228 | .0941 |
| C5 | 14.2 | .354 | .1779 | 9.0 | .564 | .1454 | 12.0 | .620 | .1550 |
| C6 | 19.9 | .944 | .2423 | 15.3 | 1.044 | .2124 | 15.3 | 1.004 | .2697 |
| C7 | 25.6 | .548 | .0334 | 21.2 | .748 | .1912 | 14.9 | .506 | .0341 |

**Table 8.** Adjusted moisture level experiment showing water potential (negative bars) at each moisture level

| Sample | Original Moisture | Field Capacity | 2/3 Field Capacity | 1/2 Field Capacity | Air Dried | 1/6 Field Capacity |
|---|---|---|---|---|---|---|
| P | <275 | 0.3 | 5.0 | 4.3 | 11.1 | 36.8 |
| B-1 | 263 | 0.3 | 2.0 | 4.3 | 24.3 | 23.0 |
| B-2 | 256 | 0.3 | 1.8 | 4.0 | 28.2 | 8.7 |
| B-3 | <275 | 0.3 | 1.0 | 3.8 | 21.0 | 7.3 |
| S | <275 | 0.3 | 2.0 | 3.5 | 21.9 | 9.8 |
| RV | 247 | 0.3 | 2.0 | 2.3 | 24.1 | 6.1 |
| PV | 141 | 0.3 | 1.0 | 1.5 | 30.0 | 9.3 |
| C5 | <275 | 0.3 | 1.0 | 2.1 | 25.6 | 14.1 |
| C6 | <275 | 0.3 | 1.0 | 2.1 | 23.1 | 20.8 |
| C7 | 230 | 0.3 | 0.8 | 3.0 | 20.2 | 5.3 |
| $\bar{X}$ | <227 | 0.3 | 1.8 | 3.1 | 23.0 | 14.1 |

**Table 9.** Analysis of variance for adjusted moisture level experiment

| Source of Variation | d.f. | Expected Mean Square and Significance: Respiration | Dehydrogenase | ATP |
|---|---|---|---|---|
| Sites | 9 | 4890.927 | .931* | .014* |
| Moisture Level | 5 | 5988.908 | .090* | .048* |
| SM | 45 | 5437.863 | .033 | .003 |
| Sampling | 120 | 5518.827 | .007 | .001 |
| Total | 179 | 5480.034 | .090 | .005 |

* significant at $\alpha$ = .10 (SM = error).

**Table 10.** Comparison of mean values for dehydrogenase and ATP at different soil moisture levels

| Moisture Level | Dehydrogenase | ATP |
|---|---|---|
| Original Moisture | .3162 | .0085 |
| Field Capacity | .4988 | .0499 |
| 2/3 Field Capacity | .4365 | .0391 |
| 1/2 Field Capacity | .3386 | .1126 |
| Air Dried | .3932 | .1347 |
| 1/6 Field Capacity | .3708 | .1023 |
| LSD ($\alpha$ = .10) | .1158 | .0349 |

**Table 11.** Comparison of mean values for dehydrogenase and ATP at different sites

| Site | Dehydrogenase | ATP |
|---|---|---|
| P | .461 | .0499 |
| B-1 | .106 | .0647 |
| B-2 | .129 | .0319 |
| B-3 | .152 | .0739 |
| S | .275 | .0682 |
| RV | .226 | .0616 |
| PV | .375 | .0624 |
| C5 | .504 | .1115 |
| C6 | .937 | .1524 |
| C7 | .758 | .0687 |
| LSD ($\alpha$ = .10) = | .224 | .0529 |

**Table 12.** Respiration and dehydrogenase values resulting from adjusted moisture plus glucose (organic matter) experiment

| Site | Original Moisture | | 1/2 Field Capacity | | 1/4 Field Capacity | | 1/6 Field Capacity | | 1/12 Field Capacity | |
|---|---|---|---|---|---|---|---|---|---|---|
| | *Resp. | *Dehydro. | Resp. | Dehydro. | Resp. | Dehydro. | Resp. | Dehydro. | Resp. | Dehydro. |
| Playa | 11.2 | .111 | 81.5 | .136 | 141.4 | .099 | 83.4 | .102 | 31.4 | .108 |
| Bajada 1 | 4.4 | .017 | 21.1 | .028 | 22.9 | .027 | 0.5 | .014 | 3.7 | .034 |
| Rock Valley | 3.9 | .032 | 27.4 | .071 | 21.5 | .048 | 17.5 | .032 | 5.8 | .040 |
| Curlew 7 | 0.4 | .098 | 67.1 | .121 | 53.4 | .112 | 48.7 | .092 | 10.4 | .096 |

*Respiration units = $\mu$moles $CO_2 \cdot g^{-1} \cdot min^{-1}$.

Dehydrogenase units = mg formazan/g.

**Table 13.** Water potential values (negative bars) resulting from adjusted moisture plus glucose (organic matter) experiment

| Samples | Lyophilized Soil | 1/2 Field Capacity | 1/4 Field Capacity | 1/6 Field Capacity | 1/12 Field Capacity |
|---|---|---|---|---|---|
| Playa | <275 | 3 | 14 | 67 | 75 |
| Bajada 1 | 241 | 16 | 58 | 98 | 175 |
| Rock Valley | 252 | 4 | 59 | 65 | 95 |
| Curlew 7 | <275 | 4 | 16 | 42 | 71 |
| $\bar{X}$ | <261 | 7 | 37 | 68 | 104 |

**Table 14.** Analysis of variance for adjusted moisture plus glucose (organic matter) experiment

| Source of Variation | d.f. | Expected Mean Square and Significance | |
|---|---|---|---|
| | | Respiration | Dehydrogenase |
| Site | 3 | 2956.416 | .0187* |
| Moisture Level | 4 | 47690.10 | .0010* |
| SM | 12 | 45018.05 | .00014 |
| Sampling | 40 | 49797.21 | .0008 |
| Total | 59 | 46300.59 | .0016 |

*significant at $\alpha$ = .10 (SM = error).

**Table 15.** Comparison of mean values for dehydrogenase at different soil moisture levels from adjusted moisture plus glucose (organic matter) experiment

| Moisture Level | Dehydrogenase |
|---|---|
| 1/2 Field Capacity | .0894 |
| 1/4 Field Capacity | .0714 |
| 1/6 Field Capacity | .0603 |
| 1/12 Field Capacity | .0693 |
| Lyophilized-Original Moisture | .0644 |
| LSD ($\alpha$ = .10) = | .0126 |

**Table 16.** Comparison of mean values for dehydrogenase at different sites from adjusted moisture plus glucose (organic matter) experiment

| Site | Dehydrogenase |
|---|---|
| Playa | .1112 |
| Bajada 1 | .0238 |
| Rock Valley | .0448 |
| Curlew 7 | .1039 |
| LSD ($\alpha$ = .10) = | .0125 |

**Table 17.** Respiration values ($\mu$moles$\cdot g^{-1} \cdot min^{-1}$) from drying experiment #1

| | P | B-1 | B-2 | B-3 | S | RV | PV | C5 | C6 | C7 |
|---|---|---|---|---|---|---|---|---|---|---|
| Original Moisture | 37.6 | 9.2 | 9.5 | 7.5 | 7.6 | 11.0 | 20.6 | 31.9 | 28.5 | 24.9 |
| Wetted to -7 bars | 29.7 | 6.5 | 11.0 | 5.4 | 11.7 | 8.9 | 9.2 | 17.7 | 17.5 | 22.0 |
| Air Dried 24 hours | 18.8 | 3.6 | 6.5 | 7.2 | 5.6 | 9.0 | 11.2 | 15.5 | 15.1 | 13.3 |
| Air Dried 96 hours | 16.0 | 8.1 | 9.1 | 7.2 | 7.9 | 11.9 | 10.8 | 11.1 | 17.1 | 9.4 |
| Air Dried 192 hours | 10.0 | 6.1 | 6.5 | 6.5 | 11.7 | 6.6 | 11.0 | 9.8 | 5.9 | 5.5 |
| Air Dried 192 hours + 24 hours at 30 C | 19.8 | 7.4 | 10.1 | 8.7 | 10.3 | 13.5 | 11.2 | 12.7 | 11.7 | 10.3 |
| Air Dried 192 hours + 24 hours at 30 C + 24 hours at 37 C | 11.0 | 8.8 | 11.0 | 9.2 | 14.6 | 13.2 | 12.5 | 15.5 | 16.1 | 14.8 |

**Table 18.** Dehydrogenase values (mg formazan/g soil) from drying experiment #1

| | P | B-1 | B-2 | B-3 | S | RV | PV | C5 | C6 | C7 |
|---|---|---|---|---|---|---|---|---|---|---|
| Original Moisture | .110 | .017 | .027 | .073 | .054 | .029 | .016 | .079 | .048 | .106 |
| Wetted | .113 | .021 | .029 | .012 | .059 | .028 | .018 | .047 | .040 | .172 |
| Air Dried 24 hours | .118 | .019 | .022 | .008 | .051 | .027 | .016 | .057 | .031 | .158 |
| Air Dried 96 hours | .081 | .014 | .022 | .009 | .042 | .014 | .012 | .053 | .068 | .134 |
| Air Dried 192 hours | .105 | .024 | .036 | .011 | .066 | .022 | .014 | .042 | .023 | .118 |
| Air Dried 192 hours + 24 hours at 30 C | .110 | .017 | .020 | .009 | .058 | .023 | .011 | .079 | .094 | .161 |
| Air Dried 192 hours + 24 hours at 30 C + 24 hours at 37 C | .095 | .027 | .028 | .016 | .074 | .022 | .043 | .062 | .088 | .140 |

**Table 19.** ATP concentration results (μg/g soil) from drying experiment #1

| | P | B-1 | B-2 | B-3 | S | RV | PV | C5 | C6 | C7 |
|---|---|---|---|---|---|---|---|---|---|---|
| Original Moisture | .0114 | .0287 | .0160 | .0188 | .0196 | .0186 | .0340 | .0639 | .1054 | .0690 |
| Wetted | .0739 | .0694 | .0842 | .1136 | .2180 | .0731 | .0549 | .1398 | .1874 | .2141 |
| Air Dried 24 hours at 22 C | .0162 | .0368 | .0184 | .0130 | .0267 | .0192 | .0048 | .0336 | .0372 | .0317 |
| Air Dried 96 hours at 22 C | .0159 | .0283 | .0187 | .0182 | .0385 | .0147 | .0069 | .0177 | .0217 | .0214 |
| Air Dried 192 hours at 22 C | .0275 | .0410 | .0226 | .0332 | .0308 | .0218 | .0101 | .0266 | .0251 | .0237 |
| Air Dried 192 hours + 24 hours at 30 C | .0250 | .0478 | .0280 | .0383 | .0680 | .0286 | .0355 | .0512 | .0295 | .0298 |
| Air Dried 192 hours at 22 C + 24 hours at 30 C + 24 hours at 37 C | .0263 | .0415 | .0190 | .0343 | .0479 | .0231 | .0188 | .0442 | .0290 | .0535 |

**Table 20.** Water potential values (negative bars) from drying experiment #1

| Sample | Original Moisture | Wetted | After 24 hours Drying | After 96 hours Drying | After 192 hours Drying | 192 hours Drying + 24 hr at 30 C | 24 hours at 30 C + 24 hr at 37 C |
|---|---|---|---|---|---|---|---|
| P | 119 | 10 | 247 | <275 | <275 | <275 | <275 |
| B-1 | 196 | 6 | <275 | <275 | <275 | <275 | <275 |
| B-2 | 193 | 5 | 272 | <275 | <275 | <275 | <275 |
| B-3 | 219 | 4 | 272 | <275 | <275 | <275 | <275 |
| S | 114 | 4 | <275 | <275 | <275 | <275 | <275 |
| RV | 96 | 4 | <275 | <275 | <275 | <275 | <275 |
| PV | 5 | 6 | <275 | <275 | <275 | <275 | <275 |
| C5 | 17 | 6 | <275 | <275 | <275 | <275 | <275 |
| C6 | 19 | 4 | <275 | <275 | <275 | <275 | <275 |
| C7 | 48 | 5 | <275 | <275 | <275 | <275 | <275 |

**Table 21.** Analysis of variance for drying experiment #1

| | | Expected Mean Square and Significance* | | |
|---|---|---|---|---|
| Source of Variation | d.f. | Respiration | Dehydrogenase | ATP |
| Site | 9 | 263.877* | .02047* | .00371* |
| Moisture Level | 6 | 232.3998* | .00161 | .02636* |
| SM | 54 | 38.44629 | .00075 | .00129 |
| Sampling | 70 | 5.61643 | .000561 | .000238 |
| Total | 139 | 44.88145 | .00197 | |

*significant at α = .10 (SM = error).

**Table 22.** Comparison of mean values for ATP and respiration at different soil moisture levels (drying experiment #1)

| | Respiration | ATP |
|---|---|---|
| Original Moisture | 18.80 | .0385 |
| Wetted Soil | 13.94 | .1228 |
| After 24 hours drying | 10.56 | .0226 |
| After 96 hours drying | 10.88 | .0173 |
| After 192 hours drying | 7.93 | .2623 |
| 192 hours drying + 24 hours at 30 C | 11.565 | .0354 |
| 192 hours + 24 hours at 30 C + 24 hours at 37 C | 12.65 | .3281 |
| LSD (α = .10) = | 3.810 | .0221 |

**Table 23.** Water potential values (negative bars) from drying experiment #2

| Sample | Original Moisture | After 24 hours Drying | After 48 hours Drying | After 94 hours Drying | After 192 hours Drying |
|---|---|---|---|---|---|
| P | <275 | 1 | 71 | <275 | <275 |
| B-1 | 263 | 146 | 247 | 270 | 234 |
| B-2 | 256 | 134 | 223 | 127 | 193 |
| B-3 | <275 | 72 | 250 | 233 | 251 |
| S | <275 | 31 | 223 | 239 | 208 |
| RV | 247 | 63 | <275 | <275 | 197 |
| PV | 141 | 109 | 254 | <275 | 255 |

**Table 24.** Analysis of variance for drying experiment #2

| Source of Variation | Expected Mean Square and Significance d.f. | Dehydrogenase |
|---|---|---|
| Sites | 6 | .231* |
| Moisture Level | 4 | .013 |
| SM | 24 | .025 |
| Sampling | 35 | .005 |
| Total | 69 | .033 |

*significant at $\alpha = .10$ (SM = error).

**Table 25.** Results showing respiration, dehydrogenase and ATP values from wetting-drying experiment

| STATIONS | Lyophilized Soil Resp. ($\mu$moles $\cdot g^{-1} \cdot min^{-1}$) | Dehydro. (mg formazan/g) | ATP ($\mu$g/g) | Moistened to Field Capacity Resp. ($\mu$moles $\cdot g^{-1} \cdot min^{-1}$) | Dehydro. (mg formazan/g) | ATP ($\mu$g/g) | Air Dry Soil Resp. ($\mu$moles $\cdot g^{-1} \cdot min^{-1}$) | Dehydro. (mg formazan/g) | ATP ($\mu$g/g) | Rewetted Soil Resp. ($\mu$moles $\cdot g^{-1} \cdot min^{-1}$) | Dehydro. (mg formazan/g) | ATP ($\mu$g/g) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| P | 13.4 | .063 | .0195 | 143.8 | .382 | .0359 | 15.7 | .049 | .0213 | 185.2 | .685 | .0241 |
| B-1 | 3.4 | .015 | .0145 | 82.8 | .052 | .0299 | 5.6 | .012 | .0231 | 140.3 | .196 | .0337 |
| B-2 | 3.6 | .015 | .0122 | 72.2 | .043 | .0118 | 6.4 | .025 | .0130 | 135.9 | .196 | .0119 |
| B-3 | 6.0 | .025 | .0187 | 72.0 | .057 | .0165 | 5.7 | .029 | .0193 | 146.6 | .070 | .0092 |
| S | 4.3 | .029 | .0151 | 121.9 | .070 | .0101 | 3.8 | .034 | .0268 | 169.9 | .233 | .0065 |
| RV | 5.0 | .040 | .0082 | 136.1 | .091 | .0053 | 5.3 | .090 | .0104 | 226.6 | .247 | .0029 |
| PV | 4.2 | .085 | .0156 | 106.2 | .132 | .0090 | 8.1 | .092 | .0073 | 192.4 | .321 | |
| C5 | 3.7 | .067 | .0211 | 100.2 | .230 | .0278 | 8.9 | .121 | .0147 | 248.6 | .431 | .0037 |
| C6 | 5.2 | .113 | .0210 | 132.5 | .181 | .0293 | 8.9 | .196 | .0356 | 229.9 | 1.058 | .0034 |
| C7 | 4.5 | .148 | .0155 | 117.7 | .401 | .0104 | 16.5 | .225 | .0118 | 207.3 | 1.117 | .0049 |

**Table 26.** Nitrogen fraction measurement (ave. mg N/g soil) from wetting-drying experiment

| Without Organic Matter | P | B-1 | B-2 | B-3 | S | RV | PV | C5 | C6 | C7 |
|---|---|---|---|---|---|---|---|---|---|---|
| Organic $N_+$ | 3.047 | 0.813 | 0.462 | 0.410 | 0.742 | 1.222 | 0.970 | 2.466 | 2.195 | 3.834 |
| Fixed $NH_4^+$ | 0.151 | 0.013 | 0.021 | 0.037 | 0.222 | 0.042 | 0.047 | 0.101 | 0.100 | 0.127 |
| Exchangeable $NH_4^+$ | 0.008 | 0.002 | 0.006 | 0.003 | 0.003 | 0.001 | 0.005 | 0.003 | 0.003 | 0.003 |
| $NO_2^- + NO_3^-$ | 0.018 | 0.005 | 0.003 | 0.005 | 0.003 | 0.003 | 0.007 | 0.012 | 0.014 | 0.022 |
| Lyophilized Soil + O.M.* | | | | | | | | | | |
| Organic $N_+$ | 6.326 | 3.452 | 3.611 | 3.473 | 4.779 | 4.396 | 5.595 | 4.609 | 4.521 | 5.978 |
| Fixed $NH_4^+$ | 0.476 | 0.296 | 0.287 | 0.336 | 0.332 | 0.184 | 0.188 | 0.302 | 0.302 | 0.213 |
| Exchangeable $NH_4^+$ | 0.039 | 0.015 | 0.008 | 0.012 | 0.013 | 0.008 | 0.005 | 0.011 | 0.008 | 0.038 |
| $NO_2^- + NO_3^-$ | 0.039 | 0.001 | 0.008 | 0.008 | 0.012 | 0.010 | 0.005 | 0.026 | 0.016 | 0.026 |
| Lyophilized Soil + O.M. Moistened | | | | | | | | | | |
| Organic $N_+$ | 7.411 | 3.620 | 3.226 | 3.915 | 4.300 | 4.244 | 5.143 | 5.187 | 4.154 | 4.099 |
| Fixed $NH_4^+$ | 0.469 | 0.174 | 0.084 | 0.176 | 0.092 | 0.114 | 0.120 | 0.103 | 0.136 | 0.161 |
| Exchangeable $NH_4^+$ | 0.042 | 0.020 | 0.017 | 0.028 | 0.033 | 0.030 | 0.017 | 0.061 | 0.070 | 0.280 |
| $NO_2^- + NO_3^-$ | 0.007 | 0.005 | 0.004 | 0.006 | 0.004 | 0.007 | 0.005 | 0.021 | 0.014 | 0.010 |
| Air-Dry Lyophilized Soil | | | | | | | | | | |
| Organic $N_+$ | 6.227 | 3.051 | 2.943 | 2.924 | 2.424 | 2.433 | 3.322 | 2.773 | 5.461 | 6.174 |
| Fixed $NH_4^+$ | 0.475 | 0.243 | 0.288 | 0.377 | 0.257 | 0.267 | 0.202 | 0.412 | 0.297 | 0.196 |
| Exchangeable $NH_4^+$ | 0.020 | 0.004 | 0.011 | 0.014 | 0.014 | 0.043 | 0.036 | 0.054 | 0.079 | 0.156 |
| $NO_2^- + NO_3^-$ | 0.000 | 0.000 | 0.002 | 0.004 | 0.002 | 0.002 | 0.005 | 0.001 | 0.014 | 0.024 |
| Rewetted Air-Dry Soil | | | | | | | | | | |
| Organic $N_+$ | 6.181 | 3.884 | 4.067 | 4.485 | 4.702 | 3.312 | 5.149 | 5.391 | 5.108 | 5.153 |
| Fixed $NH_4^+$ | 0.694 | 0.383 | 0.406 | 0.324 | 0.320 | 0.284 | 0.192 | 0.244 | 0.272 | 0.143 |
| Exchangeable $NH_4^+$ | 0.053 | 0.067 | 0.073 | 0.060 | 0.104 | 0.183 | 0.134 | 0.269 | 0.298 | 0.547 |
| $NO_2^- + NO_3^-$ | 0.000 | 0.006 | 0.003 | 0.007 | 0.008 | 0.003 | 0.005 | 0.009 | 0.008 | 0.014 |

*2.759 mg N/g added.

**Table 27.** Pearson correlation coefficients between activities

| Field Data | $r = \frac{\Sigma(X-\bar{X})(Y-\bar{Y})}{\sqrt{\Sigma(X-\bar{X})^2 \Sigma(Y-\bar{Y})^2}}$ |
|---|---|
| Respiration - Proteolysis | .50 |
| Respiration - ATP | .38 |
| Respiration - Moisture Content | .54 |
| Dehydrogenase - Protelysis | .69 |
| Dehydrogenase - Moisture Content | .61 |
| Proteolysis - ATP | .39 |
| ATP - Nitrate | .45 |
| Proteolysis - Moisture Content | .45 |
| Nitrate - Nitrification Potential | .79 |
| **Adjusted Moisture Level Experiment** | |
| Original Moisture | r |
| Dehydro.-Resp. | .65 |
| Resp. - ATP | .19 |
| Dehydro. - ATP | -.37 |
| Field Capacity | |
| Dehydro.-Resp. | .58 |
| Resp. - ATP | .24 |
| Dehydro. - ATP | .63 |
| 2/3 Field Capacity | |
| Dehydro.-Resp. | .11 |
| Resp. - ATP | .33 |
| Dehydro.-ATP | .63 |
| 1/2 Field Capacity | |
| Dehydro.-Resp. | -.20 |
| Resp. - ATP | -.62 |
| Dehydro.-ATP | .37 |
| Air Dried | |
| Dehydro.-Resp. | .73 |
| Resp. - ATP | .33 |
| Dehydro.-ATP | .59 |
| 1/6 Field Capacity | r |
| Dehydro.-Resp. | .59 |
| Resp. - ATP | .17 |
| Dehydro. - ATP | .63 |
| **Adjusted Moisture Level and O. M. Expt.** | |
| 1/2 Field Capacity | r |
| Dehydro.-Resp. | .91 |
| 1/4 Field Capacity | |
| Dehydro.-Resp. | .61 |
| 1/6 Field Capacity | |
| Dehydro.-Resp. | -.39 |
| 1/12 Field Capacity | |
| Dehydro.-Resp. | .79 |
| Lyophilized Soil | |
| Dehydro.-Resp. | -.32 |

**Table 28.** Averages for all activities and soil attributes measured for all stations sampled in 1975 and 1976

| | Playa | Bajada 1 | Bajada 2 | Bajada 3 | Curlew 5 | Curlew 6 | Curlew 7 | Silverbell | Rock Valley | Pine Valley |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 19.900 | 8.100 | 8.000 | 6.800 | 19.700 | 21.200 | 17.700 | 12.700 | 9.600 | 11.400 |
| 2 | 0.056 | 0.030 | 0.028 | 0.024 | 0.097 | 0.150 | 0.269 | 0.198 | 0.073 | 0.062 |
| 3 | 5.400 | 4.600 | 4.400 | 7.500 | 27.300 | 23.400 | 31.500 | 16.300 | 12.900 | 17.700 |
| 4 | 0.017 | 0.057 | 0.035 | 0.030 | 0.271 | 0.167 | 0.172 | 0.447 | 0.037 | 0.102 |
| 5 | 8.100 | 1.400 | 1.600 | 1.400 | 4.700 | 4.600 | 5.900 | 4.400 | 2.600 | 4.600 |
| 6 | 208.000 | 266.000 | 261.000 | 279.00 | 77.000 | 120.000 | 91.000 | 152.000 | 188.000 | 167.000 |
| 7 | 0.700 | 0.400 | 0.400 | 0.400 | 0.500 | 0.600 | 1.900 | 0.600 | 0.300 | 0.400 |
| 8 | 2.470 | 0.310 | 0.360 | 0.350 | 1.120 | 0.960 | 1.280 | 0.800 | 0.300 | 0.490 |
| 9 | 0.140 | 0.040 | 0.040 | 0.050 | 0.120 | 0.120 | 0.130 | 0.090 | 0.040 | 0.050 |
| 10 | 1.310 | 0.090 | 0.100 | 0.090 | 0.060 | 0.040 | 0.050 | 0.680 | 0.090 | 0.140 |
| 11 | 3.300 | 1.000 | 1.800 | 1.600 | 4.500 | 1.800 | 1.700 | 2.500 | 1.600 | 1.200 |
| 12 | 7.700 | 7.500 | 7.800 | 7.900 | 8.200 | 8.300 | 8.500 | 7.400 | 8.200 | 8.300 |
| 13 | 17.300 | 0.980 | 0.560 | 1.490 | | | | 1.650 | 0.830 | 0.930 |
| 14 | 81000.000 | 17000.000 | 7300.000 | 12300.000 | | | | 15500.000 | 6500.000 | 5700.000 |
| 15 | 512.380 | 5.310 | 4.090 | 16.390 | 48.690 | 31.190 | 52.020 | 190.020 | 9.520 | 7.020 |
| 16 | 91.200 | 14.900 | 22.100 | 15.200 | 47.100 | 26.100 | 59.800 | 58.100 | 26.500 | 25.000 |

1 Respiration, $\mu m\ CO_2 \cdot g^{-1} \cdot min^{-1}$.
2 Dehydrogenase, mg formazan/g.
3 Proteolysis, % hydrolysis.
4 ATP concentration, µg/g.
5 water content, %.
6 water potential, - bars.
7 Salinity, $EC_e$, mmhos/cm.
8 Organic Carbon, %.
9 Nitrogen, %.
10 Nitrate, µg/g.
11 exchangeable $NH_4^+$, µg/g.
12 pH.
13 aerobic bacteria, number x $10^{-6}$.
14 fungi, number.
15 nitrification potential (integral below $NO_3^-$ curve).
16 Total $NH_4^+$, µg/g.

**Table 29.** Analysis of variance for field data

| | | Expected Mean Square and Significance* | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Source of Variation | df | Resp. | Dehydro. | Proteo. | ATP | % Moist. | $NO_3^-$ | Ex. $NH_4^+$ | Nitrif. |
| Site | 9 | *179.73 | .039 | 424.12 | .070 | 94.54 | .430 | 5.013 | 97269.7 |
| Moisture | 1 | .06 | .055 | *116.62 | .0007 | 248.00 | .006 | 5.929 | *10800.8 |
| G. Season | 1 | 726.76 | .002 | *122.85 | .077 | 204.30 | .007 | 9.604 | 202.6 |
| SM | 9 | 31.99 | .014 | 29.97 | .099 | 51.96 | .147 | 4.576 | 40743.8 |
| SG | 9 | 200.71 | .008 | 20.65 | .020 | 77.30 | .056 | 5.985 | 681.1 |
| MG | 1 | 86.73 | .0003 | 61.26 | .016 | 290.52 | .00006 | .025 | 7.0 |
| SMG | 9 | 73.50 | .009 | 25.50 | .037 | 39.83 | .079 | 3.419 | 2563.2 |
| Total | 39 | | | | | | | | |

* alpha = .10.

**Table 30.** Comparison by station of mean values for soil activities and attributes measured in four sampling periods

| Station | Resp. | Dehydro. | Proteo. | ATP | Moisture | $NO_3^-$ | Exch. $NH_4^+$ | Nitrif. |
|---|---|---|---|---|---|---|---|---|
| P | 19.85 | .056 | 5.40 | .017 | 8.1 | .98* | 3.3 | 512.4* |
| B-1 | 8.10* | .030 | 4.55 | .038 | 1.4 | .09 | 1.0 | 5.3 |
| B-2 | 7.95* | .028 | 4.35 | .035 | 1.6 | .10 | 1.8 | 4.1 |
| B-3 | 6.80* | .024 | 7.53 | .030 | 1.4 | .09 | 1.6 | 16.4 |
| S | 10.80 | .198 | 16.25 | .447 | 4.4 | .68 | 2.5 | 142.5 |
| RV | 10.80 | .080 | 12.68 | .028 | 3.8 | .07 | 1.2 | 9.5 |
| PV | 8.58* | .062 | 13.25 | .077 | 4.6 | .14 | 1.2 | 7.0 |
| C5 | 22.23 | .200 | 28.20 | .203 | 12.7 | .05 | 4.5 | 79.1 |
| C6 | 22.38 | .188 | 22.58 | .125 | 12.4 | .03 | 1.3 | 36.6 |
| C7 | 21.70 | .308 | 33.50 | .129 | 13.2 | .04 | 1.6 | 51.1 |
| LSD ($\alpha$ = .10) | (Least Significant Difference) | | | | | | | |
| | 11.11 | .123 | 6.55 | | | .36 | | 65.6 |

*variable significant between stations (those with asterisk different from those without asterisk).

**Table 31.** Mean respiration values from vegetative season-station interaction

| | Vegetative | Nonvegetative |
|---|---|---|
| P | 18.20 | 21.50 |
| B-1 | 7.25 | 8.95 |
| B-2 | 9.40 | 6.50 |
| B-3 | 7.10 | 6.50 |
| S | 8.10 | 13.50 |
| RV | 11.65 | 9.95 |
| PV | 11.20 | 5.95 |
| C5 | 9.20 | 35.25* |
| C6 | 6.10 | 38.65** |
| C7 | 8.35 | 35.05* |
| | LSD = 15.715 ($\alpha$ = .10) | LSD = 15.715 ($\alpha$ = .10) |

*Significantly different from all others except playa.

**Significantly different from all except C5 and C7.

Tables 31 and 32 show vegetative season-station interaction and moisture season-station interaction means, respectively. Respiration was the only variable showing significant difference in the vegetative season-station interaction. This is evident from the Curlew sites in the nonvegetative season where the values are higher than those from other stations, and it was probably influenced most by the wet January samples due to intermittent snowmelt.

Nitrification potential seems to be influenced greatly by moisture season in the playa (Jornada) site. However, Silverbell and playa (Jornada) nitrification potentials are not significantly different from each other during dry seasons. This was probably influenced most by the Silverbell December sample which was quite high in nitrification potential.

**Table 32.** Mean nitrification potential values from moisture season-station interaction

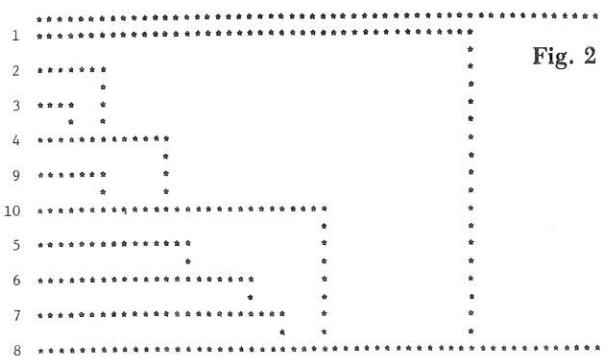
| Station | Wet | Dry |
|---|---|---|
| P | 797.91* | 226.86* |
| B-1 | 3.30 | 1.20 |
| B-2 | 1.30 | 2.60 |
| B-3 | 18.41 | 14.38 |
| S | 35.77 | 249.27* |
| RV | 17.14 | 1.90 |
| PV | 7.54 | 6.51 |
| C5 | 43.29 | 115.05** |
| C6 | 46.30 | 26.83 |
| C7 | 53.17 | 49.03 |
| | LSD ($\alpha$ = .10) = 92.80 | LSD ($\alpha$ = .10) = 92.80 |

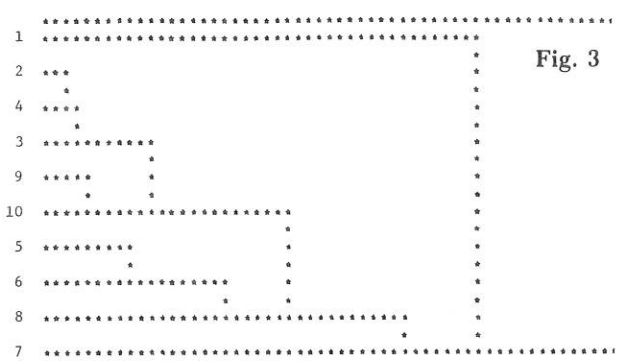
*Significantly different from all the rest within moisture season.

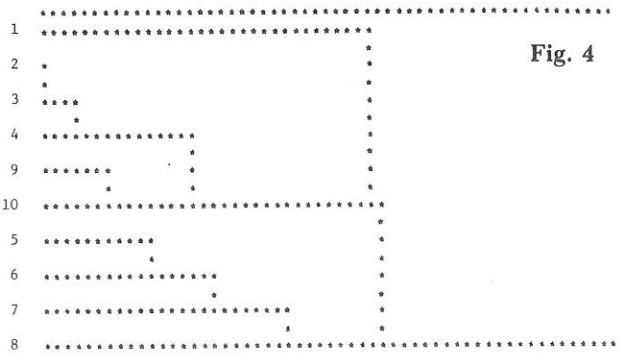
**Significantly different from all except C6 and C7.

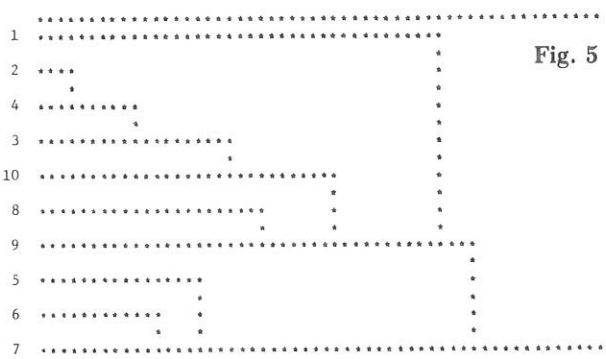
The cluster analyses phenograms are shown in Figures 2 to 5. The bottom of the tree corresponds to the start (first clustering cycle) where each individual is a separate cluster. The formation of clusters is defined by horizontal lines within the tree. The individuals contained within a cluster are defined by locating a horizontal line and then tracing all connecting lines back to the bottom of the tree, noting the numbers denoting the individuals placed at the bottom of the tree. The greater the height of the horizontal line as measured from the bottom of the tree (given by a similarity index scale with larger values denoting less similarity), the less is the similarity between the two joining clusters.

Figure 2 shows the phenogram of the All Attributes Cluster. From this analysis it can be concluded that the playa (Jornada) is the most distinct station and bajada 2 and bajada 3 (Jornada) are most similar. However, two clusters can be picked out, with playa being by itself. The two clusters seem to be bajada 1, 2 and 3 (Jornada) and Rock Valley; and Pine Valley, Curlew 5, 6, 7 and Silverbell. Examining the Soil Status Cluster in Figure 3 and the Potential Activities Cluster in Figure 4, the same clusters are discerned with greater similarity between the bajada (Jornada) stations noted when all attributes are broken down into two groups. Finally, the Nitrogen Attributes Cluster shown in Figure 5 shows three distinct clusters with playa (Jornada) again being excluded. The bajada stations (Jornada) form one, the Curlew stations form another, and Pine Valley, Rock Valley and Silverbell form another. A Principal Components analysis run subsequent to cluster analysis showed that 79.2% of the variability between sampling stations was explained by nitrogen fixation potential and ammonification potential, although nitrification potential probably resulted in the playa (Jornada) being distinct from other stations when it is grouped with general biological activity attributes. The playa (Jornada) bottom, where these samples were collected, is quite distinct from other sampling stations. The vegetation is quite dense (mostly *Panicum obtusum*) and the soil texture is a clay loam rather than a sandy loam or silt loam found at the other stations.




**Figures 2-5.** All Attributes Cluster analysis phenogram (Fig. 2); Soil Status Cluster analysis phenogram (Fig. 3); Potential Activities Cluster analysis phenogram (Fig. 4); Nitrogen Attributes Cluster analysis phenogram (Fig. 5).

1 = Jornada, playa; 2 = Jornada, bajada 1; 3 = Jornada, bajada 2; 4 = Jornada, bajada 3; 5 = Curlew Valley 5; 6 = Curlew Valley 6; 7 = Curlew Valley 7; 8 = Silverbell; 9 = Rock Valley; 10 = Pine Valley.

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