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PROGRESS REPORT

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Role of Algae in Crust Formation in Desert Soils

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Abstract

Surface and subsurface soil samples, usually with visible algal and algal-lichen crusts have been collected from Desert Biome sites in the Jornada Range, New Mexico and at the Silver Bell and Santa Rita Experimental Range near Tucson, Arizona. These soil samples were analyzed for soil properties and kinds and, in some cases, abundance of algae present.

Objectives

The objectives of this study are to identify, characterize, and illucidate the role of algae in the formation of crusts and nitrogen fixation in desert soils. The parameters governing the growth of desert soil algae such as soil moisture, nutrients, and other chemical and physical factors are also of interest to the investigators.

Methods

Soil samples were analyzed for water soluble anions and cations using techniques of colorimetry, flame photometry and atomic absorption spectrophotometry.

Soil moisture was determined by drying samples to constant weight at 105 C ± 5 C and soil salinity was determined by electrical conductivity.

Culturing of the microorganisms present in the soil samples collected by Cameron was primarily carried out by incubating samples in moisture chambers (petrie dishes) containing filter paper moistened with dilute mineral salts media or by dilution tube methods. Infrared photography has also been employed to estimate viable algae present in soil crusts.

Samples handled in the Utah laboratory were cultured by placing about 0.5 to 1.0 centimeters of soil in 18 x 150 mm test tubes, adding five ml of glass distilled water and incubating at 25 C under constant light (500 ft. c.). Duplicate samples were cultured on filter paper, moistened with mineral salts solution, and incubated in a petri dish under the same light and temperature regime as the tube cultures.

A second group of samples was air dried in the light and cultured as above while a third group was cold shocked for one week at -5 C ± 2 C and then handled as previously described. In all cases, identification of microorganisms was based on microscopic examination.

Findings

Physical and Chemical Properties of Desert Soils Studied:

Soil measurements, carried out in the Pasadena laboratory, show that all soils examined were oxidized, weakly to moderately (Eh_2 + 10/180 mv to 350 mv), weakly to moderately saline (pH 5.5 to 8.7 and EC of 50 to 300 $mhos^{-6}/cm^2$ at 25 C), sandy or loamy, and brownish colored (7.5 YR to 5 YR) materials of medium bulk density (1.3 to 1.7 gm/cc) and porosity (35 to 51%). Moisture contents were typically low in drier areas (0.40 to 4.0 wt.%), and higher (5.0 to 10.5 wt.%) in the finer-textured, moister playa area.

All samples were primarily silicious, with lesser concentrations of aluminum, iron and potassium. None of the water-soluble concentrations of predominate cations and anions were at inhibitory or toxic levels, and all were at sufficient levels for growth of microorganisms, if moisture were available. In decreasing order of occurrence, the predominate cations and anions were generally:

Role of Algae in Crust Formation in Desert Soils -- continued

Cations	Anions
Ca^{++}	HCO_3^-
K^+	Cl^-
Na^+	NO_3^-
Mg^{++}	PO_4^{---}
NH^+	SO_4^{--}
Fe^{+++}	NO_2^-
Al^{+++}	CO_3^{--}

A higher concentration of both reserve and extractable (10 to 55 ppm) potassium was obtained in the samples than is usually found in desert soils. The concentrations of nitrate (15 to 85 ppm) were indicative of the moderate aridity of the areas and interruptions in the microbial nitrogen cycle. All soils possessed a moderate buffer capacity (4 to 9 me/100 gm) and a relatively favorable cation exchange capacity (as low as 4, but as high as 21 me/100 gm). As expected, organic matter levels were not high and the organic carbon was as low as 0.20 wt.% in subsurface soils, but some arid algal-lichen soil crusts contained as much as 1.3 wt.% organic carbon values. These soils, as well as those collected from California desert areas, contain more $CaCO_3$ than those obtained from similar arid areas in the Egyptian and Moroccan Sahara, which are predominately gypsic. The carbon to nitrogen (C:N) ratios varied from a low of 1.2 to 19.0, with an average of 9.5 for 33 samples. The C:N ratios did not vary significantly for the April collection of 16 samples (C:N = 9.3) versus the November collection of 17 samples (C:N - 9.6). Subsurface C:N ratios were usually slightly narrower than the surface crust ratios. The narrow C:N ratios (less than 10.0) are indicative of the microbial nature, decomposed or colloidal state of the organic matter in the samples. As a general rule, it would be available to higher plants or it would be lost through leaching and runoff.

Microorganisms from Desert Soils:

Soil samples, both surface (0cm-2 cm) and subsurface (2 cm-15 cm), yielded a rather wide variety of algal genera as well as a number of protozoans. Although most of the algal flora encountered has been identified to species, only generic designations are reported herein.

The algae encountered were predominantely filamentous, oscillatoroid forms. Schizothrix calcicola or its ecophenes, being the predominate blue-green alga of both surface or subsurface soils. Coccoid green and blue-green algae were usually of secondary occurrence, followed by diatoms. Flagellate or amoeboid protozoa were present in all of the algal cultures; Bodo sp. were typical. Only a few samples showed any likely nitrogen-fixing blue-green algae, and they were not present in large numbers as indicated by dilution tube cultures. Nitrogen-fixing blue-green algae which responded to culturing included several species of Nostoc, Scytonema, and Tolypothrix. A complete listing of algal genera encountered is given in Table 1.

Infrared photography has been utilized by Cameron to determine the presence of viable algae in very dry desert crusts. Such use of infrared photography may provide a useful tool for further work since positive correlations were found between viability, as indicated by cultured material, and the infrared photographs.

The authors feel that a greater abundance of viable algae should have been recovered from the samples. The prevalence of probable nitrogen-fixers is less than that indicated in collections of earlier years in similar areas of the Sonoran and Chihuahuan Deserts, but these reports are based on collections made during the summer "rainy season". Future collections will be made during the midsummer period of optimum moisture.

It has been suggested that many algae, having once undergone a period of dessication, require exposure to low temperatures before growth will resume even though other environmental conditions are favorable. To test this hypothesis and, hopefully, to increase our experimental resolution regarding numbers of viable algae present in air dried soil samples, we subjected slightly moist soils from the Jornada Experimental Range catchment basin and the Curlew Valley sites to three different incubation procedures.

Role of Algae in Crust Formation in Desert Soils -- continued

Table 1. Tabulation of sites sampled and genera observed. Data compiled from independent sampling by Cameron and Lynn.

Genera Observed	Sites Sampled				
	Curlew Valley near Snowville, Utah	Jornada Playa Experimental Range uplands New Mexico	Jornada Playa Experimental Range Catchment Basin New Mexico	Silver Bell Experimental Range Arizona	Santa Rita Experimental Range Arizona
Anacystis		+			+
Astasia	+		+		
Astrephomene			+		
Ceratium			+		
Chlamydomonas		+	+		
Chlorella	+		+	+	
Chlorococcum	+	+	+	+	+
Coccochloris		+			
Eudorina			+		
Euglena			+		
Fritchiella			+		
Gonium			+		
Merismopedia			+		
Microcoleus		+	+		+
Navicula		+	+	+	+
Neidium					+
Nostoc	+	+	+	+	+
Oxyrrhis					+
Oscillatoria	+	+	+	+	
Phormidium	+		+		
Porphyrosiphon		+	+		+
Protosiphon		+	+		
Schizothrix		+	+	+	+
Scytonema	+		+	+	+
Spirulina			+		
Spongiochloris		+			
Tolypothrix	+				
Volvox			+		
Volvulina			+		

The first method consisted of placing freshly collected soil in culture tubes or in filter paper and rewetting it with sterile, glass distilled water. The second procedure differed from the first in that the samples were allowed to air dry at 25 C for several days in the laboratory before rewetting. The third technique involved cold shocking of air-dried soils prior to rewetting.

The data (Tables 2 and 3), indicate that greater resolution is obtained using air dried, cold shocked samples and following the tube procedure. It should be noted, however, that nitrogen fixing blue-green algae were equally evident if air dried, cold shocked samples were incubated either on moist filter paper or rewet in culture tubes.

A rather large number of soil samples have been assayed for numbers of viable algae present per weight of soil. The data, however, is not yet complete and presentation of these is deferred until a later date.

Discussion

The habitat for algae, as expected, was predominately within the surface 2 cm of soil in areas of partial shade or in the open, and occasionally among tall grasses. In the vicinity of shrubs, where soil is frequently disturbed by rodents and other animals, algal incidence is very low. Algae were found in less than half of the subsurface soil samples.

Algal abundance in some of the crusts were more than 10 /gm of soil, and biomass was predominantly of algal material.

Not all samples yielded algae. However, it is suspected that modification of pre-culture treatment as presented in Tables 2 and 3 will increase the resolution of the culturing procedure.

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Table 2. Response of Curlew Valley Soil Algae to Preincubation Treatments

No pre-culture treatment		Air dried		Air dried-cold shocked	
Tube	Moist filter paper	Tube	Moist filter	Tube	Moist filter paper
Cynanophyta					
Oscillatoria	Oscillatoria	Oscillatoria	Oscillatoria	Oscillatoria	Oscillatoria
Phormidium	Phormidium	Phormidium	Phormidium	Phormidium	Phormidium
		Nostoc		Nostoc	
		Tolypothrix		Tolypothrix	
		Scytonema		Scytonema	Scytonema
Polycystis	Polycystis	Polycystis	Polycystis	Polycystis	Polycystis
Euglenophyta					
Astasia		Astasia		Astasia	
Chlorophyta					
Chlorella	Chlorella	Chlorella	Chlorella	Chlorella	Chlorella
Chlorococcum	Chlorococcum	Chlorococcum	Chlorococcum	Chlorococcum	Chlorococcum
Chrysophyta					
2 Diatoms (not identified)		1 Diatom (not identified)		4 Diatoms (not identified	

Table 3. Response of Curlew Valley Soil Algae to Preincubation Treatments

No pre-culture treatment		Air dried		Air dried-cold shocked	
Tube	Moist filter paper	Tube	Moist filter	Tube	Moist filter paper
Algae-Cynophyta					
Oscillatoria	Oscillatoria	Oscillatoria	Oscillatoria	Oscillatoria	Scytonema
Phormidium	Phormidium	Phormidium	Phormidium	Phormidium	Phormidium
		Nostoc		Nostoc	Nostoc
		Nostoc		Schizothrix	Schizothrix
Polycystis				Spirulina	
				Merismopedia	
				Polycystis	Polycystis
Algae-Euglenophyta					
				Astasia	
		Euglena		Euglena	
Algae-Chlorophyta					
	Chlamydomonas	Chlamydomonas		Chlamydomonas	Chlamydomonas
		Gonium		Gonium	
		Volvulina		Volvulina	
Volvox		Volvox		Volvox	
		Eudorina		Eudorina	
		Fritchiella			
		Astrephenmeme gubernaculiferum		Astrephemene	
Chlorococcum	Chlorococcum	Chlorococcum	Chlorococcum	Chlorella	Chlorella
Chlorella	Chlorella	Chlorella	Chlorella	Chlorococcum	Chlorococcum
Algae-Chrysophyta					
8 genera of Diatoms (not identified)		9 genera of Diatoms (not identified)		7 genera of Diatoms (not identified)	
				Ceratium	