Microphytic Crusts: 'Topsoil' of the Desert

by Jayne Belnap

Deserts throughout the world are the home of microphytic, or cryptogamic, crusts. These crusts are dominated by cyanobacteria, previously called blue-green algae, and also include lichens, mosses, green algae, microfungi and bacteria. They are critical components of desert ecosystems, significantly modifying the surfaces on which they occur. In the cold deserts of the Colorado Plateau (including parts of Utah, Arizona, Colorado, and New Mexico), these crusts are extraordinarily well-developed, and may represent 70 - 80% of the living ground cover.

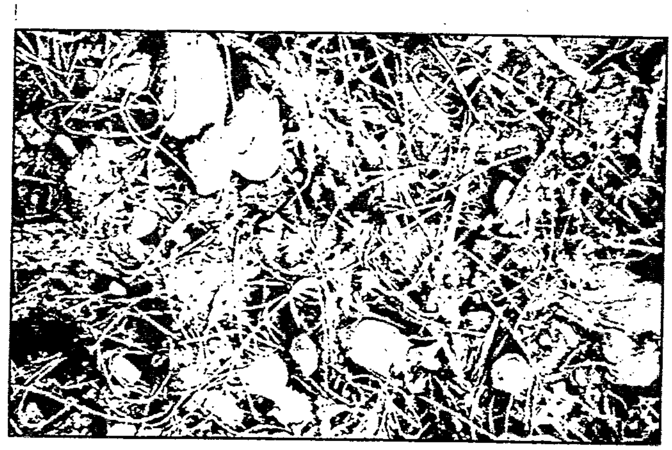
Cyanobacteria are the oldest form of life known, having been dated at more than 3.5 billion years. They are basically nutritionally independent, needing only light, atmospheric nitrogen, and a few minerals and water to survive. This enables them to colonize areas of bare rock and soil, (such as newly-formed land masses), one reason these organisms are thought to be the first land colonizers of earth's early land masses. It has been suggested that these marine organisms converted the earth's original carbon dioxide-rich atmosphere into the oxygen-rich atmosphere necessary for the evolution of life as we know it today.

Effect of Cyanobacteria on Desert Soils

Cyanobacteria occur as single cells or as filaments. The most common form found in desert soils is the filamentous type. Filaments are surrounded by a sticky mucilaginous sheath. When moistened, cyanobacteria become active, moving through the soil and leaving a trail of sticky mucilage behind. The sheath material sticks to rocks and soil particles, resulting in an intricate webbing of fibers joining soil particle to soil particle. This gives the soil great stability and tensile strength, and enhances resistance to erosional forces such as wind and water. Moreover, the binding action is not dependent on living filaments: layers of abandoned sheaths, built up over time, can be found clinging tenaciously to soil particles at depths greater than 15 cm in sandy soils.

The sheaths have other functions as well. They swell up to ten times their dry size when moistened, intercepting and storing water, an important feature in arid areas with intense, sporadic rainfall. This enables the cyanobacteria, which are active only when wet, to be active longer. Also, both the sheath and the adhered clay particles bind important nutrients, keeping them from being leached o·.: of the upper soil horizons or becoming bound in a form unavailable to plants, so vascular plants grown in crusted areas have much higher levels of essential nutrients than plants grown in areas without crusts. This nutrient-binding property benefits the crustal organisms as well. Like soil stability, it is not dependent on living filaments, but only on the presence of sheath material. Sheaths also protect the organism from abrasion and desiccation, especially important in dry, unstable soils. Finally, the sheaths and the organisms they surround contribute a great deal of organic matter to soils in which they occur.

Cyanobacterial structure, enlarged 700 times. Note sheath and filaments.



Magnified views of crust structure: above, dry crust in sandstone; below, wet crust in sandstone.

Many cyanobacteria are also nitrogen fixing. Since vascular plants are dependent on microbial organisms to reduce atmospheric nitrogen to a usable form, the presence of nitrogen-fixing organisms is especially important in desert ecosystems, where low nitrogen levels often limit productivity.

Human Impact on Crusts

Unfortunately, human activities are generally incompatible with the presence and well-being of cyanobacterial crusts, whether directly through construction and recreational activities, or indirectly through grazing animals and pollutants. The fibers that confer tensile strength are no match for the compressional stress of footprints (cows or people) or machinery, especially when the crusts are dry and therefore brittle. Air pollutants, both from urban areas and from coal-fired power plants, significantly affect the physiological functioning of these crusts. And the arid western United States, where these crusts play such a critical role, faces not only an expanding human presence, but also an ever-increasing pressure to provide energy resources such as coal, and oil shale; to provide locations for energy production such as coal and oil-fired power plants; and to provide locations for waste disposal, whether incinerators or landfills. All these activities threaten the crusts which are, in essence, the topsoil of most of the West.

No research has been done on recovery rates of crusts after physiological disturbance. However, there is information on recovery from mechanical disturbances. There are two types of mechanical disturbances: 1)trampling—from hoof or foot traffic—which breaks up the crust, but leaves pieces in place that may re-establish themselves, and 2)total removal, as by road construction.

Recovery from trampling depends on the extent of trampling, and when it occurs. Dry crusts are very brittle and easily broken up. While not much is killed, the area of impact is destabilized. Fiber connections are broken, both in sheaths containing living filaments and empty sheaths. For living filaments, repair and re-stabilization is possible only when moisture is present, so if impact occurs just before or during a dry time—of which there are plenty in the desert—re-establishment can be very difficult.

This is especially true when large areas are destabilized in a continuous strip, as by vehicular or bicycle tracks. Such areas are highly susceptible to wind and water erosion. Wind not only blows away pieces of the pulverized crust, thereby preventing their re-attachment, but it also blows the underlying loose soil around, covering nearby crusts. Since crustal organisms photosynthesize, burial can mean death. When large sandy areas are impacted in this way during dry periods, previously stable areas can become a series of moving sand dunes in a matter of only a few years. Such continuous strips are also highly susceptible to water erosion, as channels are quickly formed, especially on slopes. These areas may never fully recover.

Dry crusts cover the highly alkaline lower bajada above Willcox Playa in southeastern Arizona. When dry, they are an unobtrusive brown to black, but turn bright green when wet.

In situations where crusts have been removed, re-establishment is very slow and depends on the size of the disturbance. In sandy areas, under the best of circumstances, a thin veneer, 2-4 mm thick, consisting of one or two species of cyanobacteria may return in five to seven years. (Compare this to an undisturbed crust, 50-100 mm or more thick, with 10-15 species of cyanobacteria, as well as lichens, green algae, and other organisms.) It is not known how resistant this thin layer is to erosion, especially considering the tremendous overland flow of rainwater possible in the desert. Damage to the abandoned sheath material underneath the surface cannot be repaired, but must be rebuilt slowly through years of cyanobacterial growth.

Inoculation Strategies

Artificial inoculation can significantly increase recovery rates, and should be an integral part of recovery plans. There are several ways to do it:

1) *Use commercial innoculants*
  - Advantage:
    - •readily available in bulk without disturbing intact crust
  - Disadvantage:
    - •probably non-native, and are generally dominated by green algae instead of cyanobacteria

2) *Culture innoculum from local crusts using fresh water with micronutrients added*
  - Advantages:
    - •provides native bulk material with little disruption of intact crust
    - •allows treatment of large areas
  - Disadvantages:
    - •requires space and time for culturing
    - •green algae may dominate the culture unless cyanobacteria are cultured separately

3) *Use nearby crusts for innoculum by simply crumbling crust material collected from the edge of the disturbance on the area to be innoculated*
  - Advantage:
    - •simple and inexpensive
  - Disadvantage:
    - •inappropriate for large areas of disturbance

The amount of material used depends on the speed with which cover is desired, and the area to be covered. For cover within a year on small patches of southeastern Utah sandstones, crusts from an area totalling 5 - 10% of the disturbed area were crumbled onto the disturbance. This percentage would have to be much smaller for large disturbances to minimize the overall impact to the areas. Instead, 1 - 2% would be

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used; consequently, cover would take longer. Since the crustal organisms are only active when wet, watering at the time of treatment greatly enhances establishment, as it gives the organisms an opportunity to tack themselves to the surface. Otherwise they are highly susceptible to wind and water erosion. Additional watering later on will aid the spread of the crusts. For the same reasons, treatments done just before the wetter and cooler seasons of the year will be more effective.

Summary

It is critical that we re-assess our view of these microphytic crusts and expend more energy in assuring their continued presence and well-being in our desert ecosystems. This is especially important in disturbed areas already at great erosional risk. More research needs to be done with these crusts, especially in warm desert regions, where little is known about their structure and recovery potentials.

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