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Comparing Some Properties of Crusted and Uncrusted Soils in Alagol Region of Iran

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Abstract: The current research was carried out to study effects of biological soil crusts (lichens and mosses) on some soil attributes. The study was carried out in rangelands of Alagol region, in north of Golestan province, Northern Iran. Survey area is located near Iran-Turkmenistan border. In this research, soil samples were taken from two crusted and adjacent uncrusted areas, at one site along 4 transects. Environmental factors, soil texture and vascular plants vegetation of two areas were similar, but due to livestock repeated trampling and wind and water erosion over the last years, there were not lichens and mosses in non-crusted points. Soil sampling was done along each of two transverse 300m transects. Laboratory analyses were done on soil samples from the upper soil layer (0-5 cm). Soil properties included organic C, K, Na, N, and P. Using t-test, above mentioned properties were compared in crusted and uncrusted soils. Results showed that P, N, and organic C were significantly different at depth 0-5 cm.

Key words: Biological soil crust, crusted soil, soil characteristics, arid and semi-arid lands, rangeland

Introduction

The term microbiotic soil crust is synonymous with soil crust described as microflora, cryptogamic, biological organic, biocrust or biogenic, microphytic, biotic, and crypto biotic (Williams, 1994). The names are all to indicate common features of the organisms that compose the soil crusts. The most inclusive term is probably "microbiotic" (St. Clair and Johansen, 1993). Microbiotic crust develop in interspaces of open shrub and grass communities, from sagebrush steppe to salt brush steppe, and in woodlands of arid and semi-arid environments (Beymer and Klopatek, 1992; Harper and Marble, 1988; West, 1990). Crusts comprise a complex assemblage of organisms such as mosses, liverworts, cyanobacteria, algae, lichens, fungi, and bacteria growing on and within the uppermost layers of the soil (Eldridge, 2000). Since microbiotic crusts are formed by living organisms, so they are distinguishable from chemical and physical crusts such as salt crusts or gypsum crusts which are inorganic features.

Arid environments often support a low cover of vascular plants, which provide a niche for non-vascular plants such as mosses and lichens. In these environments, bryophytes and lichens are the principal visual components of biological soil crusts. These crusts and their constituent non-vascular plants are patchily distributed throughout the landscape, occupying areas of bare ground between individual vascular plants in some areas, completely dominating the ground flora (Eldridge and Tozer, 1996).

Biological soil crusts' close association with the soil surface means that they play vital roles in ecosystems processes. While the importance and ecological role of these crusts varies according to their composition (Belnap *et al.*, 2001a; Evans and Johansen, 1999). Available information indicates that biological soil crusts contribute to a variety of ecological functions, including soil stabilization, nitrogen fixation, nutrient availability, and vascular plants establishment (Belnap and Gardner, 1993; Belnap *et al*., 2001b; Harper and Belnap, 2001; Pendleton *et al*., 2003; West, 1990; Williams *et al*., 1995).

Because of high importance of biological soil crusts, during the past decades there has been increased interest in the roles of biological crust in soil and ecological processes. Recent reviews have reinforced the notion that crusts are essentially components of healthy, functional ecosystems (Eldridge, 2000). Soil crusts ecology has now moved from a phase of discovery to one of consolidation. However, it is little known about lichens and mosses of Iranian rangelands. While the lichen and moss flora of Iran, with a large variation in climate, geology, and topography, ranging from hot deserts to cool mountain forests and alpine meadows, is likely be very rich. The current research is the first one that has focused on biological crusts-soil relationships in rangelands of Iran. In this study, to characterize the role of biological crusts on soil

Table 1: Vascular and non-vascular species of study area

Vascular plants	Lichens	Mosses
Artemisia herba-alba	*Collema tenax*	*Barbula trifaria*
Artemisia scoparia	*Diploschistes muscorum*	*Barbula hourschuchiana*
Poa bulbosa	*Diploschistes sp.*	*Fumaria hygrometria*
Bromus sp.	*Squamarina cartilaginea*	*Hyophila sp.*
Erodium cicutarium	*Fulgensia bracteata*	*Tortula revolvens*
Veronica sp.	*Fulgensia subbracteata*	
Astragalus tribuloides	*Fulgensia fulgens*	
Helianthemum ledifolium	*Psora decipiens*	
Schismus barbatus	*Endrocarpon posillium*	
Plantago sp.	*Toninia cedifolia*	
Filago sp.		
Cymbolena sp.		
Trigonella monspeliara		
Scorzanera sp.		

environment, we focused on K, Na, P, organic C and N differences in crusted and uncrusted soils collected from one site in rangelands of Alagol, northern Iran, about 20 km from Iran-Turkmenistan border.

Materials and Methods

Site description: The study was carried out in the Alagol region, approximately 80 km north of Gorgan, in Golestan province, Northern Iran (37º 20 N and 54º 34 E). The survey area is located near Iran-Turkmenistan border in Turkman steppe. Alagol rangelands are comprised of loess hills. These hills commence near international Alagol wetland and continue in some parts along the border as far as Marave Tappeh. It is thought that these hills are originally from Qara Qum plain in Turkmenistan which have been transported by wind and deposited in Iran.

The climate of the study area can be classified as arid. A 20 year period meteorological data shows that the mean annual precipitation of area is less than 250 mm. January and February have the highest rainfall while the lowest rainfall occurs in June and July. Mean daily temperature is estimated 17.4^{o}C. Absolute maximum and minimum temperature are 42.8^{o}C and -5.36^{o}C, respectively.

Data collection and analysis: Data collection was performed in a typical part of the study area, where some parts were completely covered by vascular and non-vascular plants, while beside these parts, due to overgrazing and erosion (disturbance), non-vascular plants were absent. Different environmental characteristics such as climate and topography, soil texture, and vascular plants were similar in both areas. According to topographic variations and vegetation attributes, soil sampling was done along each of two transverse 300m transects. Along each of transects, with 20m intervals, soil samples were collected from the upper soil layer (0-5 cm), where soil is mostly affected by biological crusts. Arbitrarily, beside transect (left or right side), soil of the nearest non-crusted point to the sampled crusted point was taken.

Analytical methods included Walkley-Black for organic carbon (Black, 1979), Kjeldhal for nitrogen, Bray-I and Olsen for phosphorus, and flame photometer for soluble sodium and potassium.

t-test was used to compare soil properties in crusted and uncrusted soils, using SPSS ver.10.

Results

Higher plants vegetation at study site were dominated by *Artemisia herba-alba* and *Poa bulbosa.* In addition to these two species, there are different annual species which occur after rain season and are grazed by livestock in winter and spring. Total vegetation cover of survey site was estimated 34 percent, which of 9 and 6 percent of were related to mosses and lichens cover, respectively. Floristic list of vascular and non-vascular species, is given in Table 1.

In soil variables comparison between crusted and uncrusted areas, as it is shown in Table 2, some characteristics showed greatly significant differences, while no statistically significant differences were observed between some other properties. The most notable differences were higher levels of organic matter and nitrogen in crusted soils compared to non-crusted one. Crusted soils contained more nitrogen and organic matter ($p<0.001$) than uncrusted soils (Table 2). Nitrogen level in encrusted soils averaging about twice those of uncrusted areas (0.9 versus 0.5 mg g^{-1}). Organic matter was much higher in crusted soils and its level was more than twice compared to uncrusted soils (17.4 versus 7 mg g^{-1}). Phosphorus was the other soil factor that showed great difference ($p<0.01$) between two soil groups.

Although characteristics such as sodium and potassium, showed weak differences in crusted and uncrusted soils, but differences were so small that no

Table 2: Chemical properties of the surface 5 cm of soils in crusted and uncrusted areas

Properties	Crusted area	Uncrusted area	significant level
Organic matter (mg g^{-1})	17.4	7.0	***
Nitrogen (mg g^{-1})	0.92	0.51	***
Phosphorus (meq lit^{-1})	0.017	0.013	**
Potassium (meq lit^{-1})	0.47	0.5	NS
Sodium (meq lit^{-1})	0.76	1.48	NS

NS: not significant ** $p<0.01$ *** $p<0.001$

statistically significant difference was observed between two understudy soils in terms of above mentioned factors.

Discussion

In non-crusted soils, as noted before, lichens and mosses have been removed due to livestock repeated trampling and erosion over recent years. Land use by domestic livestock results in compaction and disturbance of microbiotic soil crusts (Kaltenecker and Wicklow-Howard, 1994). Kleiner and Harper (1972) observed increased floristic diversity and about 7 times the microbiotic crust cover in ungrazed versus grazed sites.

Nitrogen is the most important limiting factor, after C, H, and O, to plant growing in arid and semi arid systems (West, 1991). Nitrogen was strongly affected by biological crusts. Our result and those of many researchers provide clues to emphasize on biological crusts role in N fixation in arid and semi arid lands. Nitrogen occurs in the atmosphere as N_2, a form that is not useable by vascular plants. N_2 must first be "fixed", or reduce to ammonia by prokaryotic organisms such as eubacteria and cyanobacteria (Belnap, 2001). Atmospheric nitrogen fixed by many cyanobacterial, algal, and lichen species in microbiotic crusts has been well documented (Barger, 2003; Belnap, 1996; Evans and Lange, 2001; Johnson, 1982; MacGregor and Johnson, 1971; Skujins and Klubek, 1978). Nitrogen increment process is almost solely based on the cyanobacterial components of the crust, whether free living or as part of lichens (USDA, 1997) or as epiphytes on mosses (Peters *et al*., 1986). Evans and Ehleringer (1993) measured ^{15}N values in sites selected in a Utah Juniper woodlands (*Juniperus osteosperma*) interspersed with *Artemisia tridentate* shrubs without any nitrogen-fixing organisms other than those in microbiotic crusts. They concluded that microbiotic crusts were the source of nitrogen for this ecosystem. Belnap *et al.* (1994) found that compaction of microbiotic crusts by animals, vehicles, and disruption by raking all resulted in an immediate 80% reduction in nitrogen fixation. Evans and Ehleringer (1993) concluded that disturbance to microbiotic crusts ability to fix nitrogen, potentially affect changes in the coverall plant community due to impaired plant growth and production. Evidences indicate that lichens release nitrogen into the surrounding environment when repeatedly wetted and dried (Millbank, 1978). Nitrogen fixation begins rapidly within five minutes after wetting cyanobacterial crusts (Richter and Skujins, 1974). Jefferis *et al.* (1992) reported relatively low input estimates (0.7-3.6 kg N_2 ha^{-1} / year relict site, 0.4-2 kg N_2 ha^{-1} / year lightly grazed site, and 0.02-0.17 kg N_2 ha^{-1} / year in heavily grazed site) by cyanobacterial dominant crusts in a blackbrush community in southern Utah.

Organic matter of crusted and uncrusted soils were markably different. In addition to higher plants litter, mosses and lichens remnants are added to soil, too. Because of the activity of associated autotrophic microbiota, much more content of organic matter is expected in crusted soils (Belnap and Harper, 1995). Harper and Pendleton (1993) attributed higher levels of organic matter and nitrogen to the presence of microbiota. Rozanov (1951) noted that microbiota crust components are important to the breakdown of humus. Also, most of the organisms associated with the biological soil crusts are photosynthetic, particularly during cold, wet seasons when most plants are dormant. This means that the biological crust increase the length of the time during which organic carbon is added to topsoil.

Phosphorus was significantly higher in crusted soils compared to soils from non crusted points. This shows the potential role of biological crusts on betterment of soil phosphorus levels. Greater concentrations of extractable phosphorus have been reported in microbiotic crusts-influenced soils compared to nearby non crusted soils (Kleiner and Harper, 1977). Increase of phosphorus is accomplished by the binding of soil fines, which are relatively high in phosphorus content (Harper and Marble, 1988).

No significant differences were observed between sodium and potassium of collected soil samples from two areas. Different researches demonstrate that microbiotic crusts can increase nutrients in soil. This is mainly due to bonding of positively charged nutrient cations (Na^+, K^+, Ca^{++}, and Mg^{++}) to negatively charged clay particles (Belnap and Gardner, 1993; Belnap and Harper, 1995). In our study area, clay fraction is not considerable (8.57% clay versus 48.5% sand). A number of nutrients, Ca, Cu, Na, and to a lesser extent Mg and Zn, are bonded to the exterior cell walls of lichens (Brown and Brown, 1991). When dessicated lichen is wetted, these nutrients are washed from lichen and absorbed by clay particles. As noted above, because of little fraction of clay in soil texture, washed nutrients from lichens are washed downward by percolating water, so are not available in upper soil horizons. Notedly, in some clues greater concentrations of nutrients have been attributed to soil textural differences rather than crusts existence (Harper and Pendleton, 1993). Since soils of two areas were texturally similar, hence cations did not show any significant difference in crusted and uncrusted soils.

Conclusion: In Alagol, the land, where crusts occur on loess hills, is very sensitive to wind and water erosion. On the other hand, this area is frequently used for grazing. So, according to positive roles of biological soil crusts on some chemical properties of soils in this area, suitable management strategies are needed to protect crusts from disturbance and develop them.

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