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# Alpine soil crusts, the biocoenosis which braves the cold

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## Summary

In an interdisciplinary approach, soil crusts were studied in the vicinity of the Grossglockner road, in the area of Hochtor, at 2575 m a. s. l. The study is focused on organism composition, function and development of soil crusts in alpine altitudes. Within the soil crusts, eukaryotic algae are present with 42 taxa and Cyanoprokaryota with 3 taxa. The lichen flora includes 23 taxa with *Thoniniopsis obscura* being the most common species. The total number of bryophytes achieves up to 14 taxa, and approximately 40 different vascular plants are scattered throughout the soil crusts. Compared to bare soils, crusts accumulate more silt and clay, have higher contents of humus and nitrogen, and have higher water storage capacity. The specific biological, physical and chemical traits of the crust contribute to significant higher soil stability and to better establishment for vascular plants. However, soil crusts are extremely sensitive toward mechanical disturbances and thus they need rigorous protection.

## Keywords

Biological crusts, organism composition, soil characteristics, National Park of Hohe Tauern, Austria

## Introduction

Biological soil crusts (BC) are an intimate association between soil particles and cyanobacteria, algae, microfungi, lichens, and bryophytes which live within or on top of the uppermost soil (BELNAP & LANGE 2003). In contrast to the numerous studies from semiarid and arid regions, knowledge about BC in alpine ecosystems is fragmentary. With the exception of PÉREZ (1997) and GOLD et al. (2001), only HUBER et al. (2007) give a first description of alpine soil crusts. In continuation of this study, further investigations were done in 2007 and 2008. We included new sites in order to extend our knowledge about (i) the biotic (organism) composition of BC, (ii) the environmental conditions for BC, and (iii) their function within the alpine ecosystem. All our studies were kindly supported by the Glockner Öko-Fonds.

## Study area

The study area is situated in the mountains Hohe Tauern (Austria), close to the Hochtor-Tunnel at 2505 m elevation. The sample plots were set east of the Hochtor, where Rauwacke, dolomite and calc-marble prevail (Seidlwinkl Triassic), and west of the Hochtor with different bedrocks of the Brennkogel facies, such as black phyllites, mica-schists, quarzites, prasinites, and garnet chloritoide schists (Fig. 1). The climate is alpine; the mean air temperature ranges from -10 °C to -8 °C in January and from 2 °C to 4 °C in July. On an average, 250 frost days, 150 to 200 ice days and 80 to 90 frost alternation days occur per annum. The mean annual precipitation lies between 1750 mm and 2000 mm. 70 % to 80 % of the precipitation falls as snow, the snow cover lasts 270 to 300 days.

## Methods

Along 10 transects of 5 to 10 m length, abundance and frequency of lichens, bryophytes, and vascular plants were recorded in distances of one meter, using a frequency frame of 10 cm x 20 cm. The abundance of species was estimated as percentage groundcover. Additionally, soil types were described and classified according to the rules of the Austrian Society of Pedology and the World Reference Base for Soil Resources (FAO, 2006). Soil samples were taken both, from the crust layer and underlying/bare soil. The samples for microbiological analyses were collected at the sites of the sample plots, using metal cylinders (Ø 5 cm, length 1 cm). For methodical treatment of the algal culture see BISCHOFF & BOLD (1963). The soil analyses include: pH, particle-size distribution, Kjeldahl-nitrogen, organic matter content, heavy metals, water absorption capacity, and aggregate stability. ISO-standards on soils were applied. All analyses were done on 5 replicate samples. Taxon identification and nomenclature followed for Cyanoprokaryota and eukaryotic algae ETTL & GÄRTNER (1995), for mosses and liverworts FREY et al. (1995), and for lichens POELT (1969) and WIRTH (1995). Vascular plant nomenclature follows that in FISCHER et al. (2005). To compare the differences between soil crusts and underlying/bare soil, the non parametric Mann-Whitney U-Test was applied (SPSS-programs for Windows).

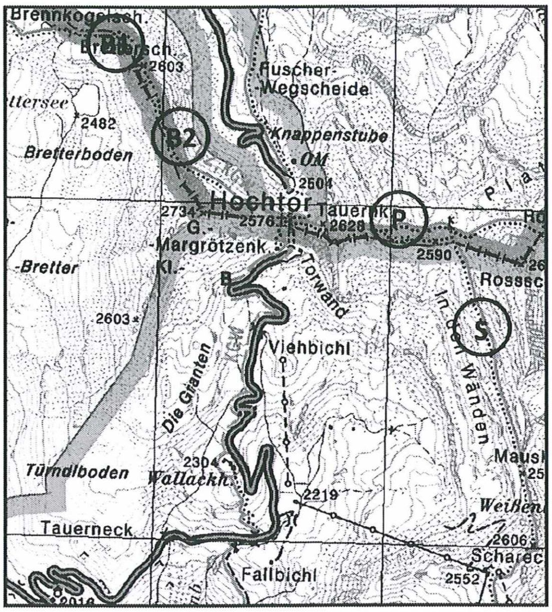


Figure 1: Localization of the sites from where the samples were taken (B1, B2 = Brennkogel, P = Plattenkar, S = Schareck)

## Results and discussion

Approximately 45 taxa of eukaryotic algae and Cyanoprokaryota were recorded in samples within transects. Green algae (Chlorophyta) are the biggest group with 35 taxa; yellow-green algae (Xanthophyta, Eustigmatophyta) exhibit 7 taxa, and blue-green algae (Cyanoprokaryota) 3 taxa. Within Cyanoprokaryota, the species *Nostoc punctiforme* is most frequent. The genera *Anabaena* and *Pseudanabaena* are filamentous algae and like *Nostoc* capable of nitrogen fixation. Cyanoprokaryota are also known to aggregate soil particles by producing extracellular polysaccharides. The yellow-green algae *Botrydiopsis constricta* and *Eustigmatos vischeri* have coccoid forms, whereas the species of *Xanthonema* (*X. hormidiodes*, *X. montanum*, *X. debile*) are filamentous. Filamentous forms are suitable to bind mineral particles together and thus to facilitate soil aggregation. Within green algae, the taxa *Stichococcus* sp., *Coelastrella* sp., *Chlorella* sp., *Cylindrocystis* (*brebissonii*), and *Klebsormidium* sp. are most common. In general, algae represent the first community to colonize bare soil, and together with aeolian deposits they contribute to a first pedogenesis.

The lichen flora includes 23 taxa with *Thoniniopsis obscura* being the most common species of biological crusts. *Toniniopsis obscura* forms dark coloured, granular crusts on carbonate soils, and contributes essentially to the fixation of the upper soil layer. *Buellia elegans* also forms solid crusts, which are firmly connected with the upper layer of the soil. As additional lichens of high frequency, *Cladonia symphycarpa, Collema fuscovirens, Dacampia hookeri, Solorina saccata*, and *Myxobilimbia lobulata* are to be found in the study area.

Compared to algae and lichens, bryophytes are of minor importance on our sites. This fact is probably linked with the competition pressure of lichens, primarily by the crust forming *Thoniniopsis obscura*. Approximately 14 taxa, among them 4 liverworts, were recorded in the study area. Most of them are ubiquists and exhibit a wide altitudinal range (colline to alpine). Within mosses, species of the genus *Bryum (B. argenteum, B. imbricatum, B. pallescens)*, and within liverworts, *Blepharostoma trichophyllum* and *Lophozia sudetica* are very common on our sites. Many mosses and liverworts were juvenile and in a gametophytic stage, thus an exact determination was partly impossible. In contrast to the low biomass of bryophytes on the soil surface, the subterranean moss protonemata and rhizoids are widespread and are likely to contribute to soil stability.

The total number of vascular plants with 40 species is relatively high, but only 11 species are frequent and have a higher abundance. Typical plants of the bare scree slopes are cushion plants, like *Saxifraga oppostifolia, S. rudolphiana* (both develop long runners), *Silene acaulis*, and *Minuartia sedoides.* Furthermore, *Salix serpillifolia* as a creeping plant, and *Oreochloa disticha* as a tuft-grass occur. Higher humidity and more favourable nutrient supply within the biological crust layer facilitate growing conditions for vascular plants, provided seeds can find suitable gaps to germinate. Within BC, the species *Carex atrata*, *Cerastium uniflorum*, *Euphrasia minima*, *Gentiana orbicularis*, *Minuartia gerardii*, *Persicaria vivipara*, *Primula minima*, *Saxifraga oppositifolia*, and *Silene acaulis* are frequent. Alpine grasslands with *Carex curvula* or *Elyna myosuroides* need deeper and better consolidated soils; between the alpine swards biological crusts are largely lacking. Many species colonize several habitats, and there is also a mix between calcicole and calcifuge plants, which could be caused by aeolian mineral deposits (originating from the heterogeneous parent material in the Grossglockner area), and/or is probably an indication of the wide ecological amplitude of those species.

Depending on parent material and the geomorphologic situation, pedogenesis varies in a wide range. On slopes, weakly developed soils prevail. The soil-depth is 15 cm to 25 cm and stones of different size intersperse the entire profile. Because of permanent slope movement, distinct horizon differentiation is generally lacking, but a slight brownish discoloration within the solum points to chemical weathering processes and the presence of Fe-oxides and clay-minerals as well. Therefore we classified the soils as Skeletic Regosols, Rendzic Regosols, Cambic Regosols, and Skeletic Cambisols. The two latter require an advanced pedogenesis. The texture ranges between loamy sand and silty loam, the crusts are provided with somewhat more clay and silt. Compared to bare soils, crusts have remarkable higher contents of organic carbon and organic nitrogen, and the accumulation of stabilizing substances like clay minerals and organic substances affects both, higher water absorption capacity and significantly higher aggregate stability. Furthermore, crusts are also effective captors for pollutants like Pb, Zn and Cd, probably originating from long distance transport and/or local traffic emissions (Tab. 1).

Table 1: Chemical and physical properties of crusts and bare soils. Differences tested by Mann-Whitney-U-test, * $p< 0{,}05$)

| | pH ($CaCl_2$) | clay | silt | sand | org. C | Kjeldahl-N | water abs. capacity | aggregate stability | Cu | Ni | Pb | Zn | Cd |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | % | % | % | % | % | ml/cm³ | % | mg/kg DM | | | | |
| crust (n= 21) | 6,6 | 8,6 | 24,0 | 67,3 | 4,5* | 0,17* | 0,57 | 85,28* | 11,07 | 22,38 | 87,93* | 50,07* | 0,33* |
| bare soil (n=21) | 6,9 | 8,1 | 22,3 | 69,5 | 2,3 | 0,06 | 0,49 | 36,16 | 13,09 | 25,38 | 42,55 | 31,24 | 0,12 |

## Conclusions

Alpine BC are composed mainly of lichens; bryophytes and algae are of minor importance. BC accumulate fine material, humus, nutrients and atmogenic heavy metals. BC protect underlying soil against erosion forces and improve conditions for plant growth. BC require fine weathering deposits, sufficient humidity during the entire year, and moderate steep slopes without any disturbances. Mechanical disturbances such as foot paths do crush the thin-layer and fragile crusts. It is necessary to intensify the research on alpine soil crusts, and to anchor the results in the minds of the general public.

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