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Disturbance and recovery of Biological Soil Crusts (BSCs) in the high alpine region of the Hochtor (Grossglockner, Austria)

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Abstract

Based on preliminary results of BSCs recovery in the SCIN project, we assessed the succession of recovery by recording cyanobacteria, seedlings, lichens, bryophytes and vascular plants within the treatment plots from 2013 to 2017 on the Hochtor. The results indicate a very fast re-colonisation of cyanobacteria, a high seedlings emergence in summer, and a first attempt of colonisation by vascular plants. However, cryptogams (lichens, bryophytes) hardly contribute to the recovery of BSCs so far. Soil nutrients also did not show significant increase over the study period. The strong soil erosion and the extreme climate conditions are the two main factors which hamper the regeneration process.

Keywords

Recovery, cyanobacteria, seedlings, vascular plants, soil nutrients

Introduction

Long-term observation programmes are of high importance for protected areas by giving insight into the complex ecological interactions over a long time, providing knowledge about long-term effects like climate change or soil disturbance. Biological Soil Crusts (BSCs) have been recognized to contribute to erosion control and nutrient cycling, and to be very important in arid and semi-arid areas as well as in alpine environments (Belnap & Lange 2003). To estimate the ecological functions of alpine BSCs, first analyses on the Hochtor were performed (Huber et al. 2007; Peer et al. 2010; Zheng et al. 2014). Actually, with the start of the SCIN-project (Soil Crust Inter National) in 2012, which was integrated in the network of Biodiversa (www.biodiversa.org), the alpine BSCs on the Hochtor have been examined in a broader geographical context (Büdel et al. 2014; Williams 2017). In this study we confined our presentation on recovery traits: (i) the building of a 'new crust', (ii) the presence of new established seedlings, (iii) the presence of new-established higher vascular plants and lichens, and (iv) the change in physic-chemical properties of soil.

Methods

The study area was located in the central part of Hohe Tauern, near the Grossglockner High Alpine Route. It belongs to the north facing 'Plattenkar', in the east of the Hochtor at an altitude of 2.576 m a.s.l. (47,0456N; 12,5052E), and is a part of the National Park Hohe Tauern. The bedrock consists of calcareous Rauwacke, belonging to the Seidlwinkl Triassic. Ten control plots and ten treatment plots were established in 2012 and investigated until 2014 on soil properties, and until 2017 in respect of seedlings, vascular plants, and lichens. Seedlings were always recorded at the end of July, except of 2015 (September). For this procedure, we used a frequency frame at 1m x 1m, which was further sub-divided into quadrats at 10cm x 10cm. The other methods and first results are described in Büdel et al. (2014), Maier et al. (2014), and Williams et al. (2017). The 'new crust' was also illustrated by vertical sections embedded in resin (Körapox 439).

Results

Compared to the control plots, the treatment plots on the Hochtor were not significantly different in cyanobacteria abundance and composition, but showed a very fast re-colonisation in the first year (Maier et al. 2014; Williams et al. 2017). Bryophytes were largely missing in treatments, and also in controls. They had only a cover degree of less than 10%. A few small thalli of lichens could be detected in treatments in 2014 (e. g. *Buellia elegans* and *Bilimbia lobulata*), not any in 2016, and again, some few small thalli of *Psora decipiens* in 2017. In controls, lichens often dominate, developing coverage up to 50%. In treatments, the number of seedling ranged from 141 to 312 after one year and this number doubled after 2 years, as well as in 2016 and 2017. Most of them were distributed compacted inside of gritty cracks and in layers adjacent to edge of controls. In autumn 2015 the number of seedlings had drastically reduced, and most seedlings did not survive the harsh winter time. The number of re-established higher plant species ranged from 14 to 51 (2016) and from 18 to 48 (2017). The cover degree was generally below 1%. However, the species composition was quite similar in both years. *Braya alpina*, *Minuartia gerardii*, *Persicaria vivipara*, *Silene acaulis*, and *Salix herbacea* were among the most common species. Some individuals of *Braya alpina* and *Minuartia gerardii* had already flowered in 2017.

As shown in the vertical sections from control plots, hyphae of lichens formed a dense web that tightly bound soil particles (Fig. 1A). In addition, a dark layer of cyanobacterial filaments covered the surface of BSC (Fig. 1B). In treatment plots, a dark but fragmentary layer of cyanobacterial filaments has been developed after 2 years (Fig. 1C, Fig. 1D).

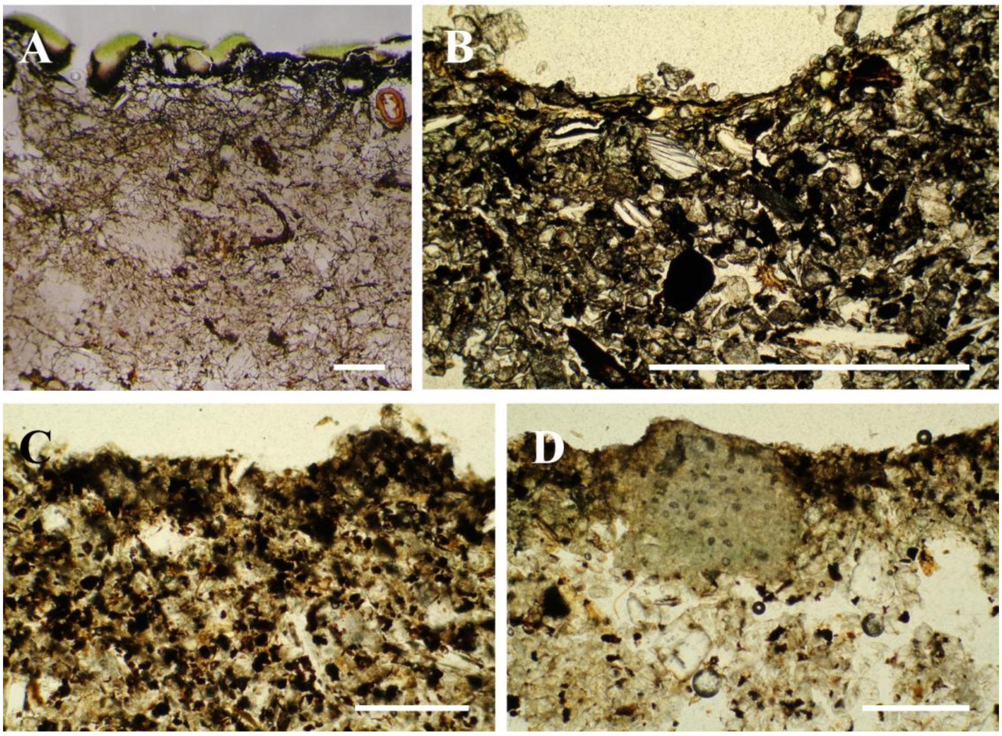

Figure 1: Vertical sections on Hochtor samples, collected in 2014. A: Control plot with lichen; B: Control plot with cyanobacteria layer; C, D: Treatment plot with fragmentary cyanobacteria layer. Bar: 0,5mm.

Total organic carbon content (TOC) and total nitrogen content (TN) in BSCs were generally low, the controls contained distinct more TOC and TN than the treatments (Fig. 2). This also applied to the availability of phosphorus (P) and potassium (K). The content of the other elements hardly changed from 2012 to 2014, with the exception of TN. Higher values were achieved in Ca und Mg, without great differences between controls and treatments, and also over time. All elements varied markedly within and between plots, a distinct recovery was therefore not shown. The particle size distribution was not significantly different between controls and treatments, and over time. pH and EC showed a temporal change by increasing in treatments and decreasing in controls.

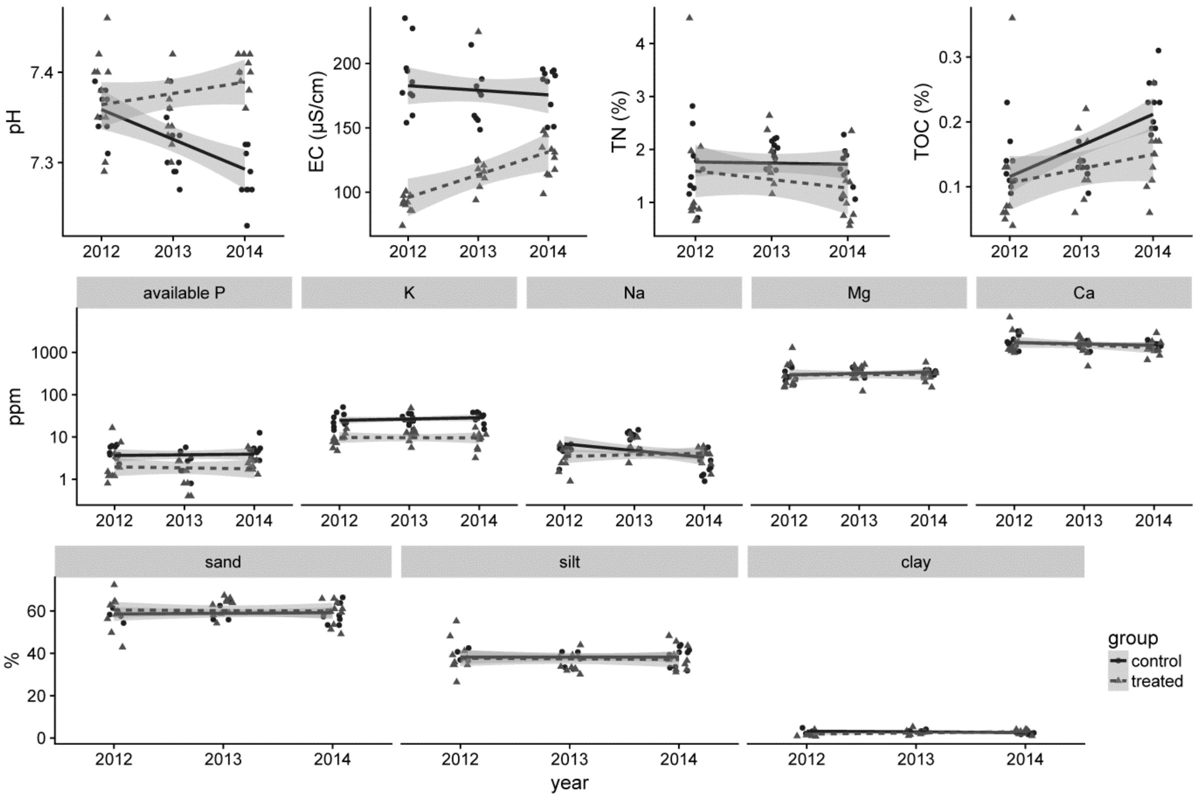

Figure 2: Physical and chemical parameters in control and treatment plots from 2012 to 2014.

Discussion

Cyanobacteria are often the first and fastest colonizers in disturbed areas (BELNAP & ELDRIDGE 2003; WEBER et al. 2016). Even on the high alpine Hochtor, the harsh climate, with 7 months snow cover, coldness, and heavy rainfall at all times, seems not to be a barrier for cyanobacteria growth (ZHENG et al. 2014 and references therein). On the other hand, high soil erosion in all open treatment plots obviously hampers the establishment of bryophytes, lichens and vascular plants. Nevertheless, an initial settlement of vascular plants, which have invaded from the surrounding BSC communities or have arisen from casually deposited fragments, can already be seen. Some seedlings may also be able to grow further. The resettled plants tent to be cushion-forming (e. g. *Silene acaulis, Minuartia gerardii*) or produce runners (*Salix herbacea, Saxifraga oppositifolia, Persicaria vivipara*), and are thus able to better withstand erosion. The reproduction of *Persicaria vivipara* is often by the bulbils, which are numerously dispersed on the open surface. The high surface inhomogeneity of the gravely scarped treatment plots has resulted in an extremely high standard deviation of the single soil measurements. The presented data do therefore not give a clear picture about the recovery process during the short observation time. Only electrical conductivity and nitrogen may indicate to a slight improvement in treatment plots. We suppose that if microorganisms and cryptogams have stabilized the bare surface over a longer period (10 years and more), and have thereby increased the availability of nutrients, cryptogams and vascular plants will become more widespread (BELNAP & ELDRIDGE 2003; LANGHANS et al. 2010; WEBER et al. 2016).

Conclusions

Our results provided interesting insights into the dramatic consequences of BSC destruction in a high alpine environment, and the subsequently protracted recovery process. For further investigations on recovery process, the National Park Authority should ensure that the treatment plots would be further monitored and new programmes could be started. Active soil inoculation with biocrust microorganisms and cryptogams can significantly accelerate biocrust recovery, including increasing lichen and moss cover, and cyanobacteria colonization. The mosaic-like placement of small mats of vascular plants may also facilitate the rehabilitation process of disturbed areas (e.g. BOWKER 2007; CHIQUOINE et al. 2016; WEBER et al. 2016). It is also important to ensure that hiking outside the marked trail is not allowed. A reduction in trampling on the soil surface will result in the re-establishment of BSCs and their associated organisms, and ultimately lead to lower levels of water and wind erosion.

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