BIOLOGICAL SOIL CRUSTS AND NATIVE SPECIES FOR NORTHERN MINE SITE RESTORATION

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ABSTRACT

The nitrogen cycle is highly sensitive to pollutants and restoration of this biogeochemical pathway is essential to ensure long-term sustainable ecosystems. In a greenhouse trial, the growth and nitrogen fixation rates of *Dryas drummondii*, *Hedysarum alpinum*, *Oxytropis campestris* and *Lupinus arcticus* were determined in both tailings and cover soils with amendments of rhizobia and biochar. In a growth chamber trial, Pure *Nostoc commune* culture, Dried *Nostoc* spp. and biological soil crust (BSC) slurries derived from mature soil crusts were applied with and without biochar to tailings. *L. arcticus* had the highest biomass and all species with the exception of *D. drummondii* showed nitrogen fixation after 3 months, with higher rates observed in cover soils. Nodulation and nitrogen fixation only occurred in herbs given a rhizobia innoculum, indicating the need for microbial amendments. All mature BSC treatments had significantly higher rates of nitrogen fixation compared with other treatments. Inclusion of biochar did not significantly increase the rates of nitrogen fixation for BSCs, but did influence nitrogen fixation by native herbs. Including local native nitrogen-fixing species in seed mixes and establishing nitrogen-fixing BSCs may reduce the application rates of artificial fertilizer and promote plant community growth while establishing primary successional processes.

Key Words: Biochar, Cryptogamic Crusts, Indigenous Species, Nitrogen Fixation, Revegetation, Soil Amendments.

INTRODUCTION

Metalliferous mine tailings are often a source of heavy metal pollution as a result of removal by wind and water, as well as, leaching of products of mineral weathering into nearby watercourses (Liu et al. 2012; Shu et al. 2001). Physical and chemical techniques provide a means to reduce dust and water erosion, however phytostabilization can provide a relatively simple and cost effective way to reduce these risks (Bradshaw 1997; Lan et al. 1998; Liu et al. 2012; Ye et al. 2002). Natural recolonization of plants on mining impacted soils is often limited since these degraded materials often have no aggregate structure or organic matter and are deficient in nutrients (N and P), as well as having high toxicity associated with metals and metalloids (Pb, Zn, Cu, Cd, Mn, Ni and As), requiring intensive use of amendments and chemical fertilizers (Huang et al. 2011; Petrisor et al. 2004; Ye et al. 2002).

Establishment of native pioneer species can not only improve soil characteristics by enhancing organic content and supplying needed nutrients, but may also reduce long-term soil toxicity, so that more sensitive plants can establish leading to a healthier more diverse ecosystem (Chan et al. 2003). Indigenous or native species are preferable to exotic species because they are most likely to fit into fully

functional ecosystems and are climatically adapted (Chaney et al. 2007; Li et al. 2003; Sheoran et al. 2010). This may be particularly important in harsh climates typical of northern Canada.

The nitrogen cycle is highly sensitive to pollutants and restoration of this biogeochemical pathway is essential to ensure long-term sustainable ecosystems. Nitrogen fixing plants may be important in soil restoration due to the addition of C and N and a more favourable balance between the production and immobilization of inorganic N (Myrold and Huss-Danell 2003; Rhoades et al. 2001; Wurtz 1995). In highly disturbed N-limited ecosystems biological nitrogen fixation is important for plant growth and nitrogen fixing legumes are often used in restoration efforts (Bradshaw 1997; Broos et al. 2004; Liu et al. 2012; Reichman 2007; Tordoff et al. 2000). However, these legumes are often not native to the area of restoration.

Biological Soil Crusts (BSCs) are early successional communities, composed of bacteria, cyanobacteria, algae, mosses, liverworts, fungi and lichens. BSCs are found to occur naturally throughout northern Canada and these crusts may act as keystone communities in establishing primary successional processes and returning disturbed ecosystems to a desirable trajectory (Bowker 2007). A few studies have shown inoculation of mine tailings with BSCs may be a means to accelerate the restoration process (Liu et al. 2012; Spröte et al. 2010). BSCs may play several important roles in restoration processes, including reduction of soil erosion, increased soil organic matter, carbon and nitrogen content and positively influencing local hydrology and vascular plant establishment (Li et al. 2012; Zhao et al. 2006, 2010).

Due to the lack of organic matter, low pH and high metal content the conditions on many mine sites may be too harsh for establishment of vegetation. Hence, the use of soil amendments may be necessary to allow for successful germination and growth. Several studies have found biochar, a product that results from the oxygen limited pyrolysis of various biological ingredients, can result in significant decreases in the bioavailability of heavy metals associated with mine impacted soils (Beesley and Marmiroli 2011; Fellet et al. 2011; Namgay et al. 2006) and simultaneously improve physical, chemical and biological soil properties (Laird et al. 2010).

The objective of this study is to examine native herb and biological soil crust species and biochar soil amendments to determine optimal formulations that improve soil conditions and promote long term re-vegetative success and nitrogen input in northern mining impacted soils.[5]

METHODS

Nitrogen-Fixing Herb Greenhouse Trial

Soil amendments and nitrogen-fixing herb species were examined in a greenhouse trial at the Yukon Research Centre, Whitehorse, Yukon. Tailings and mining impacted soils for the greenhouse trial were taken from the Keno Hill Silver District located 330 km north of Whitehorse, Yukon, Canada (63°55'26.4N, 135°29'76.1W). The tailings are highly variable with a pH ranging from 5.7 to 8.4 and texture varying from silt loam to sand. The tailings exceed the Canadian Council of Ministers of the

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Environment (CCME) industrial soil quality guidelines for allowable levels of Antimony (Sb), Arsenic (As), Cadmium (Cd), Copper (Cu), Lead (Pb), Silver (Ag), Titanium (Ti) and Zinc (Zn). Mining impacted soils from Husky SW (63°54'18.9 N, 135°31'45.1W) were also collected on-site. The Husky SW soil is currently being used in an engineered cover design trial as a cover soil. Cover soils pH was 8.0 to 8.4 with a loam texture and organic carbon content of 47%. The soils exceed the CCME industrial soil quality guideline for As.

We used a full factorial design with 2 soil types (Cover and Tailings), 4 local native nitrogen-fixing species (*Dryas drummondii* (Richardson ex Hook.), *Hedysarum alpinum* (L.), *Oxytropis campestris* (L.) and *Lupinus arcticus* (S. Watson)) and 4 soil amendments. Each treatment combination had 12 replicates for a total of 384 samples. Each sample comprised an individual container that was 3.8 cm in diameter with a volume of 164 ml (Ray-Leach Tubes, Stuewe & Sons, Tangent, Oregon).

Seeds from the 4 local native nitrogen-fixing species were collected throughout August 2012. In addition, for each species the belowground systems of a number of plants were excavated, examined and sampled for rhizobia or frankia nodules.

Three different soil amendments and a control treatment were used: biochar (BC), rhizobia (R), biochar and rhizobia (BCR) and a control with fertilizer only (C). The biochar (BC) was a Phosphorus-rich bonemeal biochar (2-14-0). The biochar (1 kg/m^2) was mixed with deinonized (DI) water and 5 ml of biochar slurry was added to each container. Nodules previously collected were masticated in DI water to create rhizobia slurries or for *D. drummondii* a Frankia slurry. Seeds receiving the R and BCR treatments were soaked for 3 hours in the slurry prior to planting. Slurries contained 1.4 mg/ml of masticated nodules (wet weight). Containers receiving the R treatment were given 2.5 ml of slurry and 2.5 ml of DI water. All containers received 2 seeds of one of the 4 species and fertilizer (19:19:19) at a rate of 110 kg/ha. The trial was initiated on September 11, 2012.

The greenhouse conditions and watering were controlled to reflect typical summer growing conditions in the Keno area. Temperature was 11°C with no light from 22:00 to 4:00 and 16°C with 175 $\mu mol/m^2/s$ of light from 4:00 to 22:00. Each replicate was watered every second day with 6 ml of DI.

From December 6 to 13, 2012 containers were sampled for germination rate, number of observable nodules, above and belowground biomass and nitrogen fixation. Measurements of N_2-fixation were made using acetylene reduction assays (ARA) (Stewart et al. 1967). Plants were harvested from each container (with belowground systems kept intact) and placed in a separate 60 ml amber glass vial with a Teflon septa cap. Each amber vial was injected with 10% (v/v) acetylene gas (C_2H_2) and incubated in the dark at 20°C for 4 hours. Ethylene concentrations were measured with a portable gas chromatograph (SRI 8610A, Wennick Scientific Corporation, Ottawa, ON, Canada) fitted with a Porapak column (Alltech Canada, Guelph, ON, Canada) and a flame ionization detector.

Biological Soil Crust Growth Chamber Trial

Both the cover soils from Husky SW and Valley Tailings used in the greenhouse trial were used in the growth chamber trial. The substrates were collected throughout the summer of 2012 and were autoclaved

at 120°C for 1 hour prior to use to provide a sterile medium free of any pre-existing soil microorganisms. Autoclaved soils were lightly packed into petri dishes (1.2 cm height, 60.82 cm^2 surface area) leaving 0.5 cm for addition of slurry treatments to the surface.

Six different treatments were applied as slurries to the Valley Tailings (T): Pure *Nostoc commune* (Vaucher ex Bornet & Flahault) culture (UTEX Culture Collection of Algae, University of Texas) with biochar (NC BC T) and without biochar (NC T), Dried *Nostoc* spp. collected from grassland near Haines Junction, Yukon with biochar (ND BC T) and without biochar (ND T) and biological soil crust slurry from mature soil crusts collected at Husky SW with biochar (S BC T) and without biochar (S T). Only two treatments were applied to the Husky SW cover soils (C): Biological soil crust slurry from mature soil crusts collected at Husky SW with biochar (S BC C) and without biochar (S C). Each treatment on each soil type had 10 replicates (i.e., petri dishes) for a total of 80 samples. For treatments receiving bonemeal biochar, biochar was added at a rate of 1 kg/m^2. All treatments also received a commercial fertilizer (19:19:19) that was pulverised with a mortar and pestle and added at a rate of 110 kg/ha (i.e., 5.9 g per petri dish). For each treatment, slurries were created by adding nitrogen fixers/crust, biochar and fertilizer to 100 ml of DI water and 10 ml of slurry was added to each replicate.

All samples were placed in a growth chamber (Conviron Adaptis A1000, Winnipeg, MB, Canada) on September 10, 2012 which had a diurnal cycle of temperature ranging from 9.9 to 19.3°C, relative humidity from 47 to 81% and light from 0 to 200 $\mu/m^2/s^1$ with darkness from 22:00 to 4:00 hrs. DI water (6 ml) was added to each petri dish every second day for the duration of the experiment.

From December 19 to 22, 2012 petri dishes were randomly selected and net photosynthesis, dark respiration and nitrogen fixation were measured for each replicate. Each petri dish was placed within a 450 ml clear glass incubation chamber and sealed with high vacuum grease. Rates of net photosynthesis and dark respiration were calculated from changes in CO_2 concentration within incubation chambers over approximately 30 minutes (LI-840A CO2/H2O analyzer, Li-Cor, Lincoln, Nberaska, USA). Nitrogen fixation was measured immediately after photosynthesis and respiration using the same ARA method as described above except that samples were incubated for 4 hours under at 20°C and 200 $\mu/m^2/s^1$ of light.

Data from the greenhouse and growth chamber trials were examined to ensure the assumptions of Analysis of Variance (ANOVA) were met and log transformations were performed on some variables. Greenhouse trial data was analyzed using a full factorial ANOVA. All analyses were conducted in R (R package version 2.1.50).

RESULTS

Nitrogen-Fixing Herb Greenhouse Trial

Overall cover soils had significantly lower germination rates (42% vs. 53%, $p<0.01$), but higher rates of nodulation (3.8 nodules vs. 0.3 nodules, $p <0.001$) and nitrogen fixation (209 µmol ethylene/m^2/hr vs. 23 µmol ethylene/m^2/hr, $p<0.001$) compared with tailings. Aboveground and belowground biomass were not significantly different between the two substrate types ($p = 0.47$ and $p = 0.63$ respectively).

O. campestris had significantly lower germination rates (28%) compared with all other species (*D. drummondii* = 52%, *H. alpinum* = 51%, *L. arcticus* = 59%), which did not differ significantly from each other. The BC treatment (34%) had lower germination compared with all other soil amendment treatments (BCR = 54%, F = 51%, R = 52%, ANOVA, $p<0.001$ for all comparisons).

L. arcticus (62 g/m^2) had significantly higher average aboveground biomass and belowground biomass compared with all other species (ANOVA, $p<0.001$ and $p<0.05$ for above and below comparisons respectively) (Figure 1). *H. alpinum* had significantly higher average belowground biomass than *D. drummondii* and *O. campestris* ($p<0.05$ for both comparisons). The BC soil amendment treatment had lower average aboveground biomass (8.7 g/m^2) compared with all other soil amendments (BCR = 24 g/m^2, R = 19g/m^2, F = 26 g/m^2, $p<0.05$ for all comparisons). The BC soil amendment treatment (28 g/m^2) had significantly lower average belowground biomass than the BCR (61 g/m^2) and R (56 g/m^2) treatments ($p<0.05$ for both comparisons).

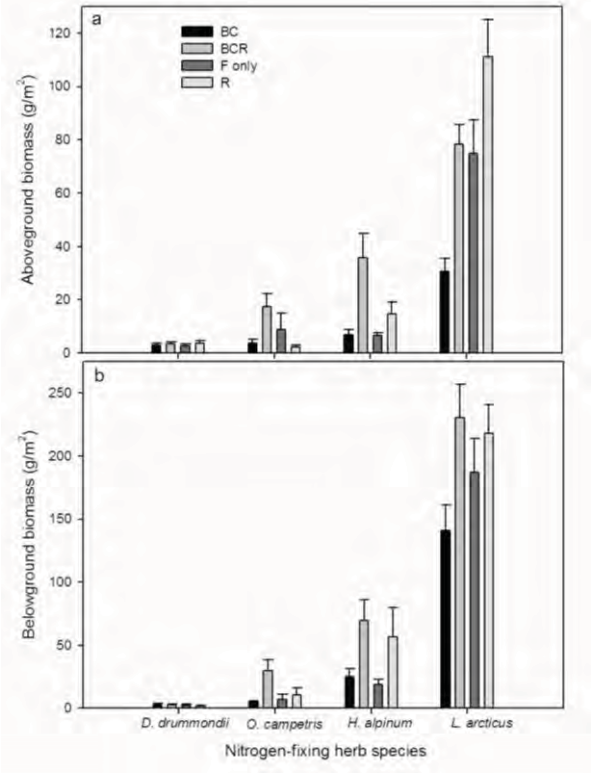

Figure 1. Aboveground (a) and belowground (b) biomass of four native nitrogen-fixing herb species after 12 weeks of growth in a greenhouse trial. All species were fertilized and four soil amendment treatments were applied to each species: biochar (BC), biochar and rhizobia (BCR), fertilizer only (F only) and rhizobia (R). Bars are means with SE.

The R and BCR treatments had higher average rates of nodulation (4.7 and 3.6 nodules respectively) than the BC and F treatments (0 and 0.02 nodules respectively, $p<0.001$ for all comparisons). *L. arcticus* had the highest average rate of nodulation (3.9 nodules) and was significantly higher than both *O. campestris* (1.3 nodules) and *D. drummondii* (0 nodules) ($p<0.05$ and $p<0.001$ respectively). *H. alpinum* had the second highest average rate of nodulation (3.1 nodules).

All species with the exception of *D. drummondii* demonstrated nitrogen fixation after 3 months. Only those samples treated with the rhizobia innoculum (i.e., CR, TR, CBCR and TBCR) had nitrogen fixation above our detection limit (10 µmol ethylene/m^2/hr) (Figure 2). *H. alpinum* had significantly higher mean rates of nitrogen fixation (288 µmol ethylene/m^2/hr) compared with both *O. campestris* (50 µmol ethylene/m^2/hr) and *L. arcticus* (11 µmol ethylene/m^2/hr) (ANOVA, $p<0.001$). Average nitrogen fixation was significantly higher for the BCR treatment (188 µmol ethylene/m^2/hr) than the R treatment (45 µmol ethylene/m^2/hr) ($p<0.001$). The highest rates of nitrogen fixation occurred in cover soils with the BCR treatment (Figure 2). Specifically, *H. alpinum* (*) had higher nitrogen fixation than *L. arcticus* (*) in CBCR and *O. campestris* had higher nitrogen fixation in cover soils ($) than in tailings ($) for the BCR treatment (Figure 2).

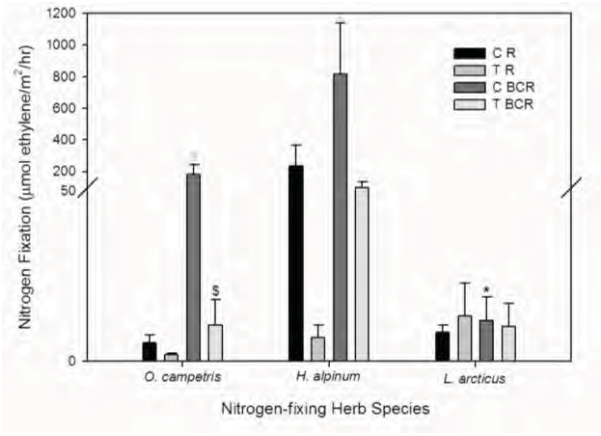

Figure 2. Nitrogen fixation by three herb species in four different treatments after 12 weeks for growth in a greenhouse trial. The treatments are cover soils with rhizobia (CR), tailings with rhizobia (TR), cover soil with biochar and rhizobia (CBCR) and tailings with biochar and rhizobia (TBCR). Bars are means with SE.

Biological Soil Crust Growth Chamber Trial

Establishment and growth of biological soil crusts derived from mature crusts on-site (S) were highly successful on both tailings and cover soils within the growth chamber. Lichens, mosses, *Nostoc* spp. and the occasional recruitment of naturally occurring grasses were observable after 10 weeks of incubation (Figure 3).

Figure 3. Establishment and growth of biological soil crust from a slurry derived from mature crust found at Keno Hills on cover soils immediately after application (a) and following 10 weeks of incubation in the growth chamber (b).

There were no significant differences in net photosynthesis or dark respiration between the different cyanobacterial soil amendments (ANOVA, $p=0.47$ and $p=0.17$ respectively). However, biochar may influence both photosynthesis and respiration, although these differences are likely strongly influenced by the substrate type and cyanobacterial amendment. When only treatments in tailings were considered, treatments with biochar tended to have higher rates of net photosynthesis (ANOVA, $p=0.09$). Slurry amendment treatments with biochar had lower rates of dark respiration on both tailings and cover soils (ANOVA, $p<0.05$).

All slurry treatments created from biological soil crusts harvested from Keno (*) had significantly higher rates of nitrogen fixation compared with both the pure *Nostoc commune* culture (*) and dried *Nostoc* sp. slurries (*) (ANOVA, $p<0.001$ for all comparisons; Figure 4), with the exception of the ND T and S T treatments which were not significantly different ($) (ANOVA, $p=0.09$).

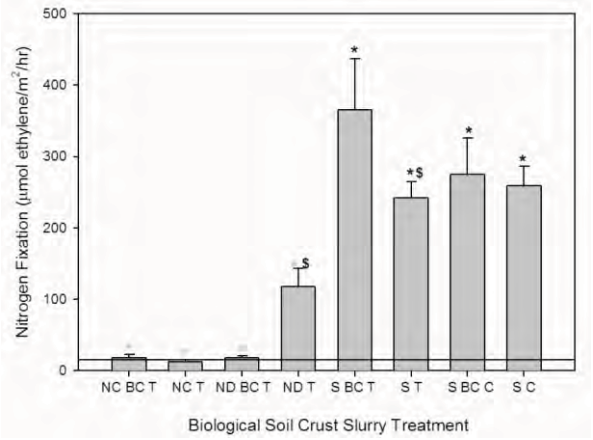

Figure 4. Nitrogen fixation rates of biological soil crust slurry treatments after 101 days in a growth chamber experiment. Treatments are Nostoc commune with biochar (NC BC T) and without biochar (NC T) on tailings, Nostoc spp. dried with biochar (ND BC T) and without biochar (ND T) on tailings, Biological soil crust slurry with biochar (S BC T) and without biochar (S T) on tailings and on cover soils (S BC C and S C) respectively. Bars are means with SE. Reference line indicates the nitrogen fixation detection limit.

Both the NC and ND treatments were generally below our detection limit for nitrogen fixation with the exception of the ND T treatment. Inclusion of biochar in the ND treatment resulted in significantly lower nitrogen fixation rates ($p<0.001$). There were no significant differences in nitrogen fixation between the substrate types (tailings versus cover) for the slurry treatment (S) ($p = 1.00$) or for the slurry treatment with biochar (S BC) ($p = 0.99$). Comparison of biochar treatments within each substrate type were also not significantly different (tailings, $p = 0.99$; cover soils, $p = 1.00$).

DISCUSSION

Nitrogen-Fixing Herb Greenhouse Trial

The main limiting factors for establishment of vegetation on mining impacted soils, especially on tailings, are high levels of acidity, low nutrient content, especially nitrogen, low water-holding capacity, low organic matter and excess salinity (Chan et al. 2003; Petrisor et al. 2004; Ye et al. 2002). Identification of northern native species that are able to overcome these limitations is needed. We had relatively high germination rates with the exception of *O. campestris*, which is likely due to limitations in our seed preparation procedure. *L. arcticus* had the highest above and belowground biomass and no differences in biomass were observed between the tailings and cover soils. In addition, we found *L. arcticus* to have the highest rate of nodulation compared with the other species examined. Therefore, of the species examined here, *L. arcticus* may be an important species to consider in restoration efforts aimed at promoting biomass accumulation and N input.

Nodulation and nitrogen fixation only occurred in samples that were given a rhizobia innoculum, indicating that nodulation in these soils is unlikely to occur naturally within a few months and the use of nitrogen-fixing species in northern reclamation may require microbial amendments. Nodulation may play a critical role in the growth and biomass accumulation of plants. Chan et al. (2003) observed that the nitrogen fixing *Sesbania* spp. had more nodules when they were inoculated and inoculated plants generally produced higher biomass.

Surprisingly, in our greenhouse trial we found the biochar only treatment (BC) had lower rates of germination, aboveground and belowground biomass. Under less harsh environmental conditions (i.e., watered every second day) and in soils with higher water-holding capacity, biochar may play a less important role in promoting germination. We found nitrogen fixation for both the R and BCR treatments, but the BCR treatment had significantly higher rates. Therefore, a combination of both a rhizobia innoculum and biochar may best promote nitrogen fixation and hence N input on mine impacted sites. Robertson et al. (2012) did not find any differences in the rate of nodulation of *Pinus contorta* or *Alnus viridis ssp. sinuata* in sub-boreal forest soils amended with biochar. However, nitrogen fixation was observed to continue for longer in biochar-treated systems versus non-biochar treated systems.

Most nitrogen-fixing microorganisms are thought to have an optimum soil pH near 7 and a higher diversity of free-living nitrogen fixers has been detected in tailings with a more neutral pH (Zhan and Sun 2011). In another study conducted *in-situ* on the Valley Tailings we found that the combined treatment of dolomite lime (54.6% $CaCO_3$, 41.5% $MgCO_3$) and bonemeal biochar resulted in higher germination and aboveground biomass of native grasses (Stewart et al. 2013) indicating that bonemeal biochar may reduce

the availability of toxic heavy metals. Under suitable pH conditions inoculation can increase plant resistance to some toxic metals by reducing plant uptake, while also stimulating the absorption of nutrients (Petrisor et al. 2004).

Biological Soil Crust Growth Chamber Trial

The establishment, growth and nitrogen fixation of BSCs applied as slurries derived from mature crusts on-site (S) was highly successful with establishment of lichens, mosses and *Nostoc* spp. globules within 3 months. Xiao and Zhao (2008) also demonstrate that it is feasible to inoculate and cultivate artificial BSCs using a method of crushing and broadcast sowing natural BSC collected on-site. In their study, artificial crust coverage reached 30 to 60% and the main BSCs components were the same as the collected crusts. Nitrogen fixation from dried *Nostoc* sp. (ND) and pure *N. commune* culture (NC) were very limited. Nitrogen fixation rates for NC were below our detection limits and it is likely that these cyanobacteria were unable to survive and/or fix nitrogen on the tailings and cover soils. The rapid transition from an aqueous (i.e., growth medium) to solid (i.e., tailings and soils) environment may account for the low success rate with this type of amendment.

N. commune form macroscopic colonies that consist of extracellular polysaccharides (EPS) and filamentous cells embedded in EPS (Tamaru et al. 2005). Extracellular polysaccharides of *N. commune* are crucial for the stress tolerance of cellular functions, including photosynthesis, respiration and nitrogen fixation and may serve as a sink for excess energy during desiccation and during freezing and thawing (Tamaru et al. 2005). In the environment these cyanobacteria are exposed to natural drying and wetting cycles and *Nostoc* cells produce EPS in response to stress conditions. However, laboratory cultures that have not been exposed to these desiccation cycles generally have only small amounts of EPS and therefore, may be highly sensitive to desiccation (Tamaru et al. 2005).

We did not observe any significant differences in net photosynthesis, dark respiration or nitrogen fixation between the different biochar treatments. However, we did observe slight increases in net photosynthesis with biochar on tailings and slightly higher nitrogen fixation for slurries (S) with biochar, which may be related to increased moisture availability for cyanobacteria in this more porous well-drained substrate. Studies indicate that the variability of carbon fixation and nitrogen fixation are largely dependent on the amount of time BSCs are wet and the successional stage of crust development (Li et al. 2012; Zielke et al. 2002, 2005). Nitrogen fixation changes with crust succession due to changes in species composition, increases in biomass during BSCs development and increasing polysaccharide material, which slows water loss and lengthens activity time (Belnap 1996; Zhao et al. 2010). Although, our slurry treatment (S) would represent a later successional stage of crust development (i.e., dominance of lichens and mosses), all of our crust treatments were of the same age and all had the same moisture treatment (i.e., watered every second day), which may in part account for why we did not detect any significant differences in photosynthesis between our different BSC treatments. Field studies are needed to examine the establishment, growth and nitrogen fixation rates with biochar under natural conditions. In addition, further studies are required to determine if biochar does increase moisture availability to cyanobacteria.

CONCLUSIONS

Development and identification of soil amendments and native species directly impacts eco-restoration revegetation success while simultaneously helping to remediate soils affected by pollutants. Currently there are very few native species available for restoration in northern Canada. Our study indicates that native nitrogen-fixing herbs and biological soil crusts demonstrate a strong potential for use in restoration efforts in the North.

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Overcoming Northern Challenges

Proceedings of the 2013 Northern Latitudes Mining Reclamation Workshop and

38th Annual Meeting of the Canadian Land Reclamation Association

Whitehorse, Yukon September 9 – 12, 2013

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Polster	Natural Processes: An Effective Model For Mine Reclamation
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NORTHERN LATITUDES MINING RECLAMATION WORKSHOP

The Northern Latitudes Mining Reclamation Workshop is an international workshop on mining, land and urban reclamation and restoration methods. The objective of the workshop is to share information and experiences among governments, industry, consultants, Alaska Natives, northern First Nations and Inuit groups which undertake reclamation and restoration projects, or are involved in land management in the north or in comparable environments.

The first Workshop was held in Whitehorse, Yukon Territory, Canada in 2001 and it has been held every two years since, alternating between Canada and Alaska. The primary sponsors of the Workshop include the Yukon Geological Survey, Indian and Northern Affairs Canada, Natural Resources Canada, US Department of the Interior Bureau of Land Management, and the State of Alaska Department of Natural Resources.

CANADIAN LAND RECLAMATION ASSOCIATION

The CLRA/ACRSD is a non-profit organization incorporated in Canada with corresponding members throughout North America and other countries. The main objectives of CLRA/ACRSD are:

- To further knowledge and encourage investigation of problems and solutions in land reclamation.
- To provide opportunities for those interested in and concerned with land reclamation to meet and exchange information, ideas and experience.
- To incorporate the advances from research and practical experience into land reclamation planning and practice.
- To collect information relating to land reclamation and publish periodicals, books and leaflets which the Association may think desirable.
- To encourage education in the field of land reclamation.
- To provide awards for noteworthy achievements in the field of land reclamation.

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- The Conference Organizing Committee: Alissa Sampson, Andrea Granger, Bill Price, David Polster, Diane Lister, Justin Ireys, Linda Jones, Mike Muller, Neil Salvin and Samantha Hudson.
- The Conference Papers and Posters Committee: Andy Etmanski, Bill Price, Chris Powter, David Polster, Diane Lister and Scott Davidson
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- Dustin Rainey, Jocelyn Douheret and Brian Geddes for permission to use their photos on the Cover, Papers and Posters pages, respectively

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