BIOCHAR APPLICATION FOR REVEGETATION PURPOSES IN NORTHERN SASKATCHEWAN

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ABSTRACT

Our research was focused on biochar application for revegetation purposes under northern Saskatchewan conditions. The Gunnar Mine Site, located on the northern shore of the Athabasca Lake, was used as a case study to test the effectiveness of biochar as a soil amendment. Greenhouse and field trials were run to study the effect of biochar and peat application on the growth and establishment of native plant species.

The greenhouse trials showed that both peat and biochar had a positive effect on plant growth, but different plant species had individual responses to each organic amendment. The field trials showed that peat promotes vegetation cover establishment better than biochar. Nevertheless, biochar also showed a positive effect on vegetation recovery through both establishment of seeded plants and self-establishment of natural invaders (plant species not seeded during the experiment). It was also determined that different plant species have a preference for organic amendment. In general, both peat and biochar can be used to promote plant establishment and growth, but biochar's effect on plant growth can vary widely depending on its properties.

Key Words: Exotic Species, Native Species, Organic Amendment, Peat, Mine Remediation.

INTRODUCTION

The establishment of vegetation cover on disturbed mine sites is one of the prime tasks of mine closure to protect the soil surface from wind and water erosion, restore wildlife habitats, and create opportunities for sustainable development of local Aboriginal communities. Properties of vegetation growth media is a most significant factor defining revegetation success. In northern environments, the fertile soil layer (topsoil) of uplands is very thin, with low organic matter and nutrients. It also can be easily destroyed or lost in during mining activities. Soil organic amendments and mineral fertilizers are, therefore, usually applied to improve topsoil properties and increase effectiveness of revegetation activities. Transportation of organic media in remote northern areas is very expensive because of their low density, but local harvesting for organic materials (e.g. peat) destroys natural habitats (e.g. wetlands). As a result, there is an emerging need for alternative organic soil amendments.

Biochar is a solid material obtained from the carbonisation of biomass through pyrolysis (Lehman and Joseph 2009). Addition of biochar to the soil can improve both its chemical and physical properties (Lehman and Joseph 2009; Verheijen et al. 2009). It has also been shown that biochar application creates favorable conditions for soil microbiota, promotes plant growth, and increases plant resistance to disease (Biederman and Harpole 2012; Elad et al. 2012; Verheijen et al. 2009). Therefore, this type of organic amendment can be beneficial for site restoration purposes. Potentially, biochar can be produced on-site or in nearby communities from local feedstock (e.g. organic wastes), which makes its attractive substitute for conventional organic amendments (Roberts et al. 2009). On the other hand, most biochar research is focused on its effect on cultivated crops and few research studies have considered its impact on native plant species (Adams et al. 2013; Elad et al. 2012; Sovu et al. 2013). Thus, there is a gap in understanding as to whether biochar can be used in ecological restoration and which trades off can be associated with its application.

The purpose of our research was to test effectiveness of biochar as a soil amendment for mine site restoration in northern Saskatchewan. The Gunnar Mine Site, located on the northern shore of the Athabasca Lake, was selected as a case study for the research, since one of the project tasks is to establish self-sustaining vegetation on the engineered cover that will be installed on the Gunnar tailings areas (SRC 2013). The cover material is to be taken from the local airstrip and/or neighboring areas. The proposed borrow material is coarse sand with gravel inclusions and relatively low content of organic matter (less than 0.1%), and has a limited capacity to support plant establishment and growth. As a result, application of organic amendments and mineral fertilizer is necessary to enhance its properties as a growth medium. During 2011 and 2012 two organic amendments (i.e. peat and biochar) and mineral fertilizer were tested under greenhouse and field conditions to study the response of native plant species to the soil treatments.

METHODS

Greenhouse Trials

The greenhouse trials comprised growing four plant species (i.e., Slender Wheatgrass (*Elymus trachycaulus* (Link) Gould ex Shinners), Rocky Mountain Fescue (*Festuca saximontana* Rydb.), American Vetch (*Vicia americana* Muhl. ex Willd.), Common Yarrow (*Achillea millefolium* L.)) in pots containing combinations of the borrow material with mineral fertilizer and two organic amendments (peat and biochar). The experiment had a completely randomized design with five replicates of each soil mixture and plant species.

Borrow material for the trials was collected from the borrow area at the Gunnar airstrip. The borrow material was sampled from the depth below 20cm to exclude top soil with its seed bank from the experiment. The borrow material was poor in organic carbon, nitrogen, and plant available phosphorus and potassium. It was poor in silt and clay, and composed mostly of coarse sand with a high proportion of gravel and big stones. Prior to the trial start-up, the borrow material was sieved through 1 cm sieves to remove the stones.

Sphagnum peat and willow dust biochar were used as organic amendments for the greenhouse trials. Both peat and biochar were purchased from commercial suppliers. Both organic amendments had low contents of plant available nitrogen, phosphorus, potassium, and sulfur. The organic matter content was higher in peat compared to biochar (93% vs. 76%). The water holding capacity of the peat was 509%, while that of the biochar was 454%. The application rate of organic amendments was targeted to achieve 2% of the organic matter in the soil mixture, so application rates for peat and biochar were 80 t/ha and 95 t/ha, respectively.

Borrow material and organic amendments were mixed by hand and used to fill 2 L pots (18 cm in diameter). All the pots were placed in the enclosed greenhouse in random order. The greenhouse conditions were adjusted to the Gunnar average monthly temperature during the growing season (i.e., 20ºC average air temperature during the 16 hours of light and a 10ºC average air temperature during the 8 hours of darkness).

Seeds for the greenhouse trials were obtained from commercial seed suppliers. Burton and Burton's (2003) recommendations on growing selected plant species were used as a basis for seeding rates and seeding depth, as follows:

- Slender Wheat Grass – 6 pure live seeds (PLS) per pot at the depth of 1.5 cm
- Rocky Mountain Fescue – 22 pure live seeds (PLS) per pot at the depth of 1 cm
- American Vetch – 4 pure live seeds (PLS) per pot at the depth of 1 cm
- Common Yarrow – 11 pure live seeds (PLS) per pot on the soil surface

Before seeding, all pots were excessively watered to imitate spring snowmelt conditions. Fertilizer was applied to the corresponding pots after seeding. Saskatchewan Forage Council (1998) recommendations on slender wheatgrass cultivation were used as a basis for fertilizer rates, which were 45 N kg/ha, 84 P_2O_5 kg /ha, and 112 K_2O kg/ha for soils with poor nutrient content.

The trial time period was 12 weeks, which is close to the growing season at Gunnar. During the trial period, the pots were rotated weekly to avoid the edge effect, and were watered every third day at a rate imitating the Gunnar average monthly precipitation that varied from 38 mm (week 1 to 4) to 53 mm (week 5 to 12). During the trials, the seedling number in every pot was measured weekly. On the third week of the trials, it was noticed that direct sunlight might overheat the soil mixtures with biochar because of its black colour, impeding seed germination and growth. To avoid such undesirable effects, the greenhouse shades were closed. No other changes in temperature or the water regime were made. At the end of the experiment, the aboveground biomass from each pot was harvested, dried, and weighed.

The experimental data were further processed and analyzed to quantify the following indices: plant establishment rate, seedling emergence rate, seedling survival rate, and aboveground biomass dry weight.

All data were tested for normality using the Shapiro-Wilk test. If data did not fit a normal distribution, the Kruskal-Wallis test, followed by the Conover-Iman test, was used to assess statistical differences in response of the investigated indices to the soil treatments. If data were normally distributed, analysis of variance (ANOVA), followed by the Tukey's HSD test (honestly significant difference), was applied. XLSTAT was used to run the above statistical tests for all data groups. The significance level for all tests was 0.05.

<u>Field Trials</u>

The field trials comprised the sowing of a native species seed mix on different combinations of the borrow material, two soil organic amendments (three rates), and mineral fertilizer (two rates). The experiment had a factorial design with 4 replicates of each combination of borrow material with organic amendment or/and mineral fertilizer.

The study area is located within the Taiga Shield Ecozone and the Tazin Lake Upland Ecoregion. The trials were set up on the abandoned side of the Gunnar airstrip in the middle of June 2012. Before the trial set up, the research area was cleared of vegetation. Due to high compaction of the airstrip material and high content (up to 50% by volume) of big stones in it, we constructed 7 wooden bottomless boxes (frames). Each box was 0.3 m x 4 m x 6 m and was divided into twelve 1.5 m x 1.5 m cells. The boxes were half-buried below the soil surface. One box was filled with the pure borrow material and six boxes were filled with mixture of borrow material with two organic amendments at three different rates. Boxes for the soil mixtures were assigned on a random basis.

Borrow material for the trials was collected from a borrow area at Gunnar. The borrow material was sampled at the depth below 20 cm to exclude top soil with the seed bank from the experiment. The borrow material was poor in organic carbon, nitrogen, plant available phosphorus, and potassium. It was composed mostly of sand with a high inclusion of gravel and big stones and poor of silt and clay. Prior to the trial start-up the borrow material was screened through 5 cm steel mesh to exclude large stones.

Sphagnum peat and pine chunky biochar were used as organic amendments for the field trials. Both peat and biochar were purchased from commercial suppliers. Both types of organic amendments had low contents of plant available nitrogen, phosphorus, potassium, and sulfur. Organic matter content was higher in peat and lower in biochar (94% vs. 78%). Water holding capacities of the peat and biochar were 523% and 68%, respectively. The application rate of organic amendments was targeted to achieve 2%, 4% and 6% of organic matter in the soil mixture, so application rates for organic amendments were 80, 160, and 240 t/ha of peat (hereafter, peat rates referred as "peat at low, medium, or high rate") and 90, 190, and 280 t/ha of biochar (hereafter, biochar rates referred to as "biochar at low, medium, or high rate").

After the boxes were filled with soil treatments, as described above, native plants were seeded by hand broadcasting on 1 m^2 plots placed in the centre of the box cells. The seed mixture comprised eight grasses, five forbs, and one shrub. Its composition in percentage of pure life seeds by weight was as follows:

- Rocky Mountain Fescue (*Festuca saximontana* Rydb.) – 20%
- American Vetch (*Vicia americana* Muhl. ex Willd.) – 20%
- Streambank Wheatgrass (*Elymus lanceolatus ssp. riparius*) – 10%
- Slender Wheatgrass (*Elymus trachycaulus* (Link) Gould ex Shinners) – 10%
- Violet Wheatgrass (*Elymus violaceus* (Hornem.) Feilberg) – 10%
- Tufted Hairgrass (*Deschampsia caespitosa* (L.) P. Beauv.) – 7%
- Rough Hair Grass (*Agrostis scabra* Willd.) – 7%
- Canada Buffaloberry (*Shepherdia canadensis* (L.) Nutt) – 6%
- Canadian Milkvetch (*Astragalus Canadensis* L.) – 4%
- Marsh Reed Grass (*Calamagrostis canadensis* (Michx.) P. Beauv.) – 3%
- White Bluegrass (*Poa glauca* Vahl) – 1%
- Alpine Milkvetch (*Astragalus alpinus* L.) – 1%
- Prairie Crocus (*Anemone patens* L.) – 1%

- Fireweed (*Chamerion angustifolium* (L.) Holub) – 0.1%

The seeding rate was 2000 PLS/m^2 or 15.6 PLS kg/ha.

After seeding, the mineral fertilizer was applied by the hand broadcasting. Fertilizer rates were designed in line with the lowest and highest agronomic rates recommended by the Saskatchewan Forage Council for slender wheatgrass cultivation (SFC 1998). The low fertilizer rate was 22 N kg/ha, 56 P_2O_5 kg /ha, 56 K_2O kg/ha, and 10 S kg /ha. The high fertilizer rate was 45 N kg/ha, 84 P_2O_5 kg /ha, 112 K_2O kg/ha, and 20 S kg/ha. Plots for fertilizer application were assigned within each box on a random basis.

A vegetation survey of the trial plots was carried out two months after seeding. For each sampling quadrat, the vegetation cover was assessed using the modified Daubenmire method (Bayiley and Poulton 1968). As vegetation on the plots was presented by both seeded plants and natural invaders, the effectiveness of soil treatments was assessed on the basis of their impact on total vegetation cover, seeded plant cover and cover of dominant invaders (i.e., rough cinquefoil and strawberry blite). The Kruskal-Wallis test, followed by the Conover-Iman procedure, was used to assess the statistical significance of the response of the investigated indices to the soil treatments. XLSTAT was used to run the above statistical tests for all data groups. The significance level for all tests was 0.05.

RESULTS

Greenhouse trials

Figure 1 shows the aboveground biomass dry weight (ABDW), seedling emergence rate (SER), seedling survival rate (SSR), and plant establishment rate (PER) for each species on the tested soil mixtures.

Mineral fertilizer addition to the borrow material promoted slender wheatgrass growth, increasing ABDW by a factor of 1.6 (from 62 to 110 mg per pot; $p = 0.036$), but had no effect on the growth of other plant species (p varied from 0.065 to 0.258, depending on the species). This treatment also fostered seedling survival of American vetch, increasing SSR by a factor of 1.7 (from 35 to 59%; $p = 0.048$), yet its impact on seedling emergence was not strong enough ($p = 0.432$) to provide a statistically significant overall positive effect on the plant establishment ($p = 0.843$). There was no significant effect of fertilizer application on the plant establishment, seedling emergence, and seedling survival of the other three plant species (p varied from 0.144 to 0.977, depending on the index and plant species).

Addition of peat to the borrow material fostered growth of all four plant species, increasing ABDW by a factor of 3 for slender wheatgrass (from 62 to 209 mg per pot; $p<0.001$), 6 for rocky mountain fescue (from 62 to 373 mg per pot; $p<0.001$), 14 for American vetch (from 8 to 111 mg per pot; $p<0.001$), and 73 for common yarrow (from 2 to 131 mg per pot; $p<0.0001$). This treatment had an overall positive effect on establishment of rocky mountain fescue and common yarrow, increasing SER by a factor of 1.2 ($p = 0.001$) for rocky mountain fescue and 2 ($p = 0.001$) for common yarrow. SSR increased by a factor of 1.3 ($p<0.001$) for rocky mountain fescue and 8 ($p<0.001$) for common yarrow, while PER increased by a factor of 1.6 ($p<0.001$) for rocky mountain fescue and 19 ($p<0.001$) for common yarrow. The favorable effect of peat on American vetch resulted in an increase in the SSR by a factor of 3 ($p<0.001$) and PER by a factor of 4 (p = 0.001). There was no significant effect of peat application on slender wheatgrass seedling emergence (p = 0.602), seedling survival (p = 0.532), or plant establishment (p = 0.974).

a) b)

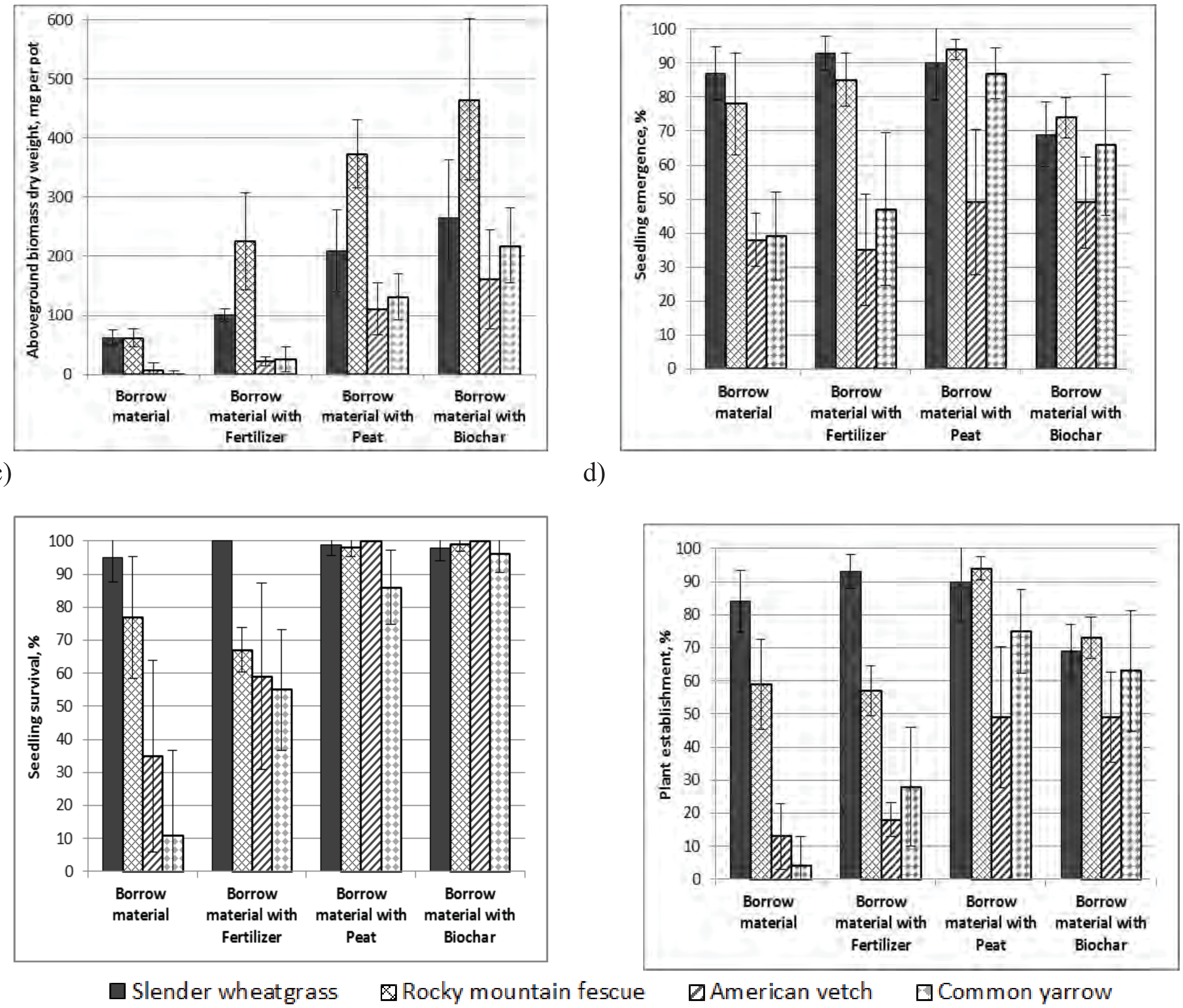

Figure 1. Effect of mineral fertilizer, biochar, and peat on the aboveground biomass dry weight (a), seedling emergence (b), seedling survival (c), and plant establishment (d) of the plant species tested during the greenhouse trials. Error bars indicate standard deviation.

Biochar addition to the borrow material fostered the growth of all four plant species, increasing ABDW by a factor of 4 for slender wheatgrass (from 62 to 265 mg per pot; p<0.001), 8 for rocky mountain fescue (from 62 to 465 mg per pot; p<0.001), 20 for American vetch (from 8 to 161 mg per pot; p<0.001), and 121 for common yarrow (from 2 to 218 mg per pot; p<0.001). This treatment also promoted common yarrow seedling emergence and seedling survival, increasing SER and SSR by factors of 1.7 (from 39% to 66%; p = 0.037) and 9 (from 11 to 96; p<0.001), respectively, which resulted in an increase of PER by a factor of 16 (from 4% to 63%; p<0.001). The favorable effect of biochar on mountain fescue and American vetch resulted in increases in SSR by factors of 1.3 (from 77 to 99%; p<0.001) and 3 (from

35% to 100%; $p<0.001$), respectively, for these species, which resulted in an increase of PER by a factor of 1.2 (from 59% to 73%; $p = 0.013$) for rocky mountain fescue and 4 (from 13% to 49%; $p=0.001$) for American vetch. Biochar application, however, impeded slender wheatgrass seedling emergence, decreasing SER by a factor of 1.3 (from 87% to 69%; $p = 0.006$), yet it had no pronounced effect on the seedling survival ($p = 0.532$) or plant establishment ($p = 0.107$).

In general, a favorable effect of organic amendments on the investigated plants was more pronounced than the effect of mineral fertilizer, except for the following cases:

- Peat and mineral fertilizer had similar effects on slender wheatgrass seedling emergence, seedling survival, and plant establishment (p = 0.498, 0.454, and 0.974, respectively) and American vetch seedling emergence ($p = 0.229$)
- Biochar and mineral fertilizer had similar effects on seedling emergence of American vetch and common yarrow (p = 0.229 and 0.149, respectively) and seedling survival of slender wheatgrass ($p = 0.393$).

Comparing the effects of peat and biochar on the tested plant species, we obtained the following results:

- Both amendments had similar effects on the establishment of American vetch and common yarrow (p = 1 and 0.136, respectively) and the growth of slender wheatgrass, rocky mountain fescue and American vetch (p = 0.657, 0.288, and 0.165, respectively)
- Peat addition to the borrow material resulted in better establishment of rocky mountain fescue in comparison with the biochar addition (94% on peat vs. 73% on biochar; $p = 0.001$)
- Biochar addition to the borrow material resulted in higher ABDW of common yarrow than addition of peat (218 mg per pot on biochar compared to 131 mg per pot on peat; $p = 0.014$)
- Biochar addition to the borrow material had a negative effect on the SER of slender wheatgrass, while peat addition did not affect this index (87% on borrow material compared to 90% on peat and 71% on biochar; $p = 0.002$ for peat compared to biochar).

Field Trials

Two months after the trial start-up, vegetation was observed on all the plots. A total of 30 vascular plant species were found within the overall research area (all plots together; Table 1). Of this total, 14 species were seeded during the trial startup and 16 species were natural invaders that were incorporated into the plots with the borrow material or were transported from nearby areas by wind.

Table 1. List of plant species observed during the field trials.

Seeded species	**Invading species**
Agrostis scabra Willd. – Rough Hair Grass (native) *Astragalus alp*inus L. – Alpine milkvetch (native)	*Achillea millefolium* L. – Common yarrow (native)
Astragalus canadensis L. – Canada milkvetch (native)	*Arabis hirsuta* (L.) Scop. – Hirsute rock cress (native)

Seeded species	Invading species
Brassica napus L. – Canola (exotic, seeded by accident)	*Arabis holboellii* Hornem – Reflexed rock cress (native)
Calamagrostis canadensis (Michx.) P. Beauv. – Marsh Reed Grass (native)	*Artemisia campestris* L. – Sagewort wormwood (native)
Chamerion angustifolium (L.) Holub – Fireweed (native)	*Chenopodium album* L. – Lamb's quarter (exotic)
Deschampsia cespitosa (L.) P. Beauv. – Tufted hairgrass (native)	*Chenopodium capitatum* (L.) Ambrosi – Strawberry blite (native)
Elymus trachycaulus (Link) Gould ex Shinners – Slender Wheatgrass (native)	*Crepis tectorum* L. – Annual hawksbeard (exotic)
Elymus lanceolatus ssp. riparius – Streambank Wheatgrass (native)	*Geranium bicknellii* Britton – Bicknell's geranium (native)
Elymus violaceus (Hornem.) Feilberg – Violet Wheatgrass (native)	*Matricaria matricarioides* L. – Pineapple weed (exotic)
Festuca saximontana Rydb. – Rocky Mountain Fescue (native)	*Plantago major* L. – Common plantain (exotic)
Poa glauca Vahl – White Bluegrass (native)	*Polygonum aviculare* L. – Prostrate knotweed (native)
Shepherdia canadensis (L.) Nutt – Canada buffaloberry (native)	*Potentilla bimundorum* Soják – Staghorn cinquefoil (native)
Vicia americana Muhl. ex Willd. – American vetch (native)	*Potentilla norvegica* L. – Rough cinquefoil (native)
	Rorippa palustris (L.) Besser – Bog yellowcress (native)
	Salix spp. – Willow (native)
	Taraxacum officinale F.H. Wigg. – Common dandelion (exotic)

Figure 2 shows the total vegetation cover (TVC), seeded plant cover (SPC), rough cinquefoil cover (RCC) and strawberry blite cover (SBC) on the tested soil mixtures.

Plant establishment on the borrow material without any amendments (control) was very poor (TVC = 2%, SPC = 0.5%, RCC = 0.4%, and SBC = 0.3% in average). Organic amendments alone had very low or no impact on plant establishment (the average increment of TVC did not exceed 6% for biochar and 4% for peat). Fertilizer alone applied at the high rate promoted plant establishment to a larger extent than organic amendments (the average increment of TVC was 16%).

In comparison with the control, peat/fertilizer combinations had the most positive impact on all TVC, SPC, and RCC. All three indexes were the highest when:

- peat at the low rate was combined with fertilizer at the high rate (TVC = 33%, $p<0.001$; SPC = 10%, $p<0.001$; RCC = 15%, $p<0.001$)
- peat at the medium rate was combined with fertilizer at the high rate (TVC = 39%, $p<0.001$; SPC = 10%, $p<0.001$; RCC = 15%, $p<0.001$)

- peat at the high rate was combined with fertilizer at the low rate (TVC = 44%, p<0.001; SPC = 8%, p<0.001; RCC = 44%, p<0.001) and the high rate (TVC = 28%, p<0.001; SPC = 10%, p<0.001; RCC = 25%, p<0.001).

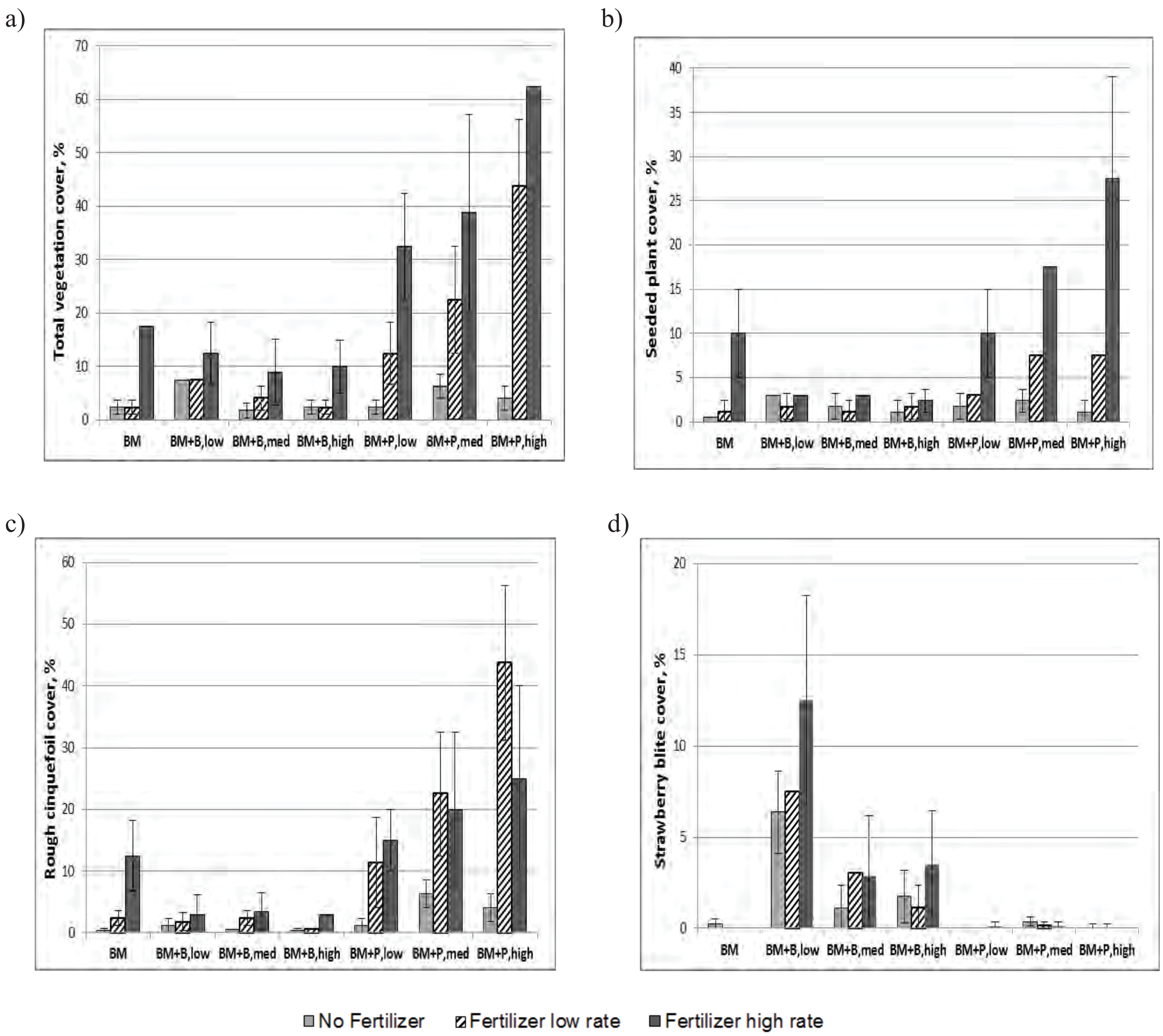

Figure 2. Effect of mineral fertilizer, biochar, and peat on the total vegetation cover (a), seeded plant cover (b), rough cinquefoil cover (c), and strawberry blite cover (d), at field trials. Error bars indicate standard deviation (absence of error bar means that the standard deviation is zero). BM – borrow material; B, low/med/high – biochar added at low/medium/high rate; P, low/med/high – peat added at low/medium/high rate.

There was no statistically significant difference for TVC, SPC, and RCC data for the above treatments (p varied from 0.059 to 0.761).

All biochar/fertilizer treatments increased SBC, while peat application did not affect this parameter. SBC varied from 1% on the plots with biochar at the high rate and fertilizer at the low rate to 13% on the plots with biochar at the low rate and fertilizer at high rate, which is significantly higher compared to control plots (p = 0.001 and p<0.001, respectively). Biochar/fertilizer combinations also promoted TVC (up to 13%), SPC (up to 3%), and RCC (up to 4%), but these effects were significantly lower than effects from the above peat/fertilizer treatments (p <0.001 in all cases).

Interestingly, when biochar was applied alone, the increase of its rate from low to high resulted in a significant decrease of TVC (from 6% to 2%, p<0.001), SPC (from 3 to 1%, p = 0.006) and SCC (from 6% to 2%, p = XX). When biochar was applied with fertilizer at the low rate, the same trend was observed, only for TVC. The latter decreased from 8 to 2% when the biochar rate was increased from low to high (p<0.001). There was no significant difference between the indexes when biochar at different rates was applied with fertilizer at the high rate (p varied from 0.092 to 1.000).

DISCUSSION AND CONCLUSION

While the greenhouse trials demonstrated that biochar is a good substitute for peat as a soil amendment, the field trials showed that peat promotes plant establishment and growth to a larger extent than biochar. The contradictory outcome from our research can be explained by the variability of biochar, which is not a standardized material; as a result, its properties vary depending on feedstock and the pyrolysis process used for the biochar production (Biederman and Harpole 2012; Lehman and Joseph 2009; Verheijen et al. 2009). In our case, the willow dust biochar that was used for the greenhouse trials had a water holding capacity similar to the peat, while the water holding capacity of the pine chunky biochar used for the field trials was eight times lower than that of the peat. Therefore, borrow material mixed with biochar during the greenhouse trials had a higher capability to retain water and nutrients compared to borrow material mixed with the same amount rate of biochar used for the field trials. This demonstrates that water holding capacity is likely an important factor in the benefit gained from a given soil amendment.

Our research also showed that peat and biochar had different effects on the establishment and growth of different plant species. The greenhouse trials showed that establishment of rocky mountain fescue was promoted by peat application to the larger extent than by biochar, but growth of common yarrow was fostered by biochar application to the larger extent than by peat. The slender wheatgrass establishment was impeded by biochar application. As a result of the field trials, biochar had a positive effect on the growth of strawberry blite, while peat promoted growth of rough cinquefoil. A better understanding of these finding would require a separate study including a literature review and specially designed experiments.

In case of the field trials, the effect of the organic amendment on the plant community composition can be explained by species competition traits, as follows. Peat has higher ability to hold and retain water and nutrients than biochar; therefore, its presence in the borrow material was more favorable for the those plants normally found in wetter areas, such as rough cinquefoil, tufted hairgrass, marsh reed grass or streambank wheatgrass. Faster development of these plants under favorable conditions made them stronger competitors for the resources, e.g. they could develop faster than other species, thereby impeding the development of the latter. Addition of biochar to the borrow material also improved its properties, but to a lower extent than peat. For the treatments with biochar, those plant species adapted for moist conditions were less competitive than other species. Thus, biochar addition to the borrow material created better conditions for ruderal species, such as strawberry blite, which is known as a pioneer species on disturbed areas relatively depleted of water and nutrients, but is not a strong competitor under more favorable conditions.

It should be noted that higher rates of biochar application had a negative impact on both vegetation establishment and development. This phenomenon is in line with the results of other researchers who suggested an idea of "biochar loading capacity" (Verheijen et al. 2009). Biochar loading capacity (BLC) is the maximum amount of biochar that can be added to a soil without compromising its other properties and, therefore, impeding plant growth. BLC can vary from a few tens to a few hundreds of tonnes per hectare, depending on soil properties, biochar properties and plant species. In our case, BLC is likely to be within the interval of 90 to 190 tonnes of biochar per hectare and increases in proportion to fertilizer rates.

However, unlike peat, biochar can be produced locally, which may save cost on the transportation of soil amendments to remote sites, create local job opportunities, provide opportunities for organic waste recycling, and also reduce the anthropogenic footprint (since no wetlands will be destroyed due to peat harvesting). Biochar is also a very stable material, since decomposition takes decades, so it can serve as a carbon sink addressing global warming issues (Biederman and Harpole 2012; Montanarella and Lugato 2013; Verheijen et al. 2009). Thus, biochar application can provide a more sustainable approach to land reclamation.

In conclusion, although both biochar and peat treatments showed a significant positive effect on plant establishment and growth, peat appears to be a more suitable organic amendment for revegetation projects. On the other hand, biochar application can assist in achievement of other sustainable remediation goals, such as carbon sequestration or waste management enhancement. Therefore, assessment of biochar and peat effectiveness under sustainable remediation framework is a focus of our next research.

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REFERENCES

Adams M.M., T.J. Benjamin, N. C. Emery, S. J. Brouder and K. D. Gibson. 2013. The effect of biochar on native and invasive prairie plant species. Invasive Plant Science and Management 6(2): 197-207.

Bailey, A.W. and C.E. Poulton. 1968. Plant communities and environmental relationships in a portion of the Tillamook burn, Northwest Oregon. Ecology 49: 1-13.

Biederman, L.A. and W.S. Harpole. 2012. Biochar and its effects on plant productivity and nutrient cycling: A meta-analysis. GCB Bioenergy 5: 202-214..

Burton, C.M., and P.J. Burton. 2003. A Manual for Growing and Using Seed from Herbaceous Plants Native to the Interior of Northern British Columbia. Symbios Research & Restoration, Smithers, B.C. 168 p.

Elad, Y., E. Cytryn, Y. Meller Harel, B. Lew and E.R. Graber. 2012. The biochar effect: plant resistance to biotic stresses. Phytopathologia Mediterranea 50(3): 335-349.

Lehmann, J. and S. Joseph. 2009. Biochar for environmental management: an introduction. IN: Biochar for Environmental Management (Lehmann J. and S. Joseph eds). Earthscan, London. pp. 1–12.

Montanarella, L. and E. Lugato. 2013. The application of biochar in the EU: Challenges and opportunities. Agronomy 3(2): 462-473.

Roberts, K., B. Gloy, S. Joseph, N. Scott and J. Lehmann. 2009. Life cycle assessment of biochar systems: Estimating the energetic, economic and climate change potential. Environment Science and Technology 44: 827-833.

Saskatchewan Forage Council (SFC). 1998. Seed production of Slender Wheatgrass. 12 pp.

Sovu, T.M., P. Savadago and P.C. Odén. 2012. Facilitation of forest landscape restoration on abandoned swidden fallows in Laos using mixed-species planting and biochar application. Silva Fennica 46(1): 39-51.

SRC (Saskatchewan Research Council). 2013. http://www.src.sk.ca/about/featured-projects/pages/gunnar-uranium-mine-and-mill-site.aspx

Verheijen, F., S. Jeffery. A.C. Bastos, M. van der Velde, and I. Diafas. 2009. Biochar Application to Soils - A Critical Scientific Review of Effects on Soil Properties, Processes and Functions. EUR 24099 EN, Office for the Official Publications of the European Communities, Luxembourg, 149 pp.

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

CLRA | ACRSD
Canadian Land Reclamation Association
Association canadienne de réhabilitation des sites dégradés

Northern Latitudes Mining Reclamation Workshop

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Knight	Galena Hill, Yukon, Ecosystem Mapping Project
Polster	Natural Processes: An Effective Model For Mine Reclamation
Dustin	Implementation of contaminated water management system upgrades to allow for dewatering of two open pits at the Vangorda Plateau, Faro Mine Complex, Yukon
Kempenaar, Marques and McClure	Tools for Arctic Revegetation: What's in Your Toolbox?
Smreciu, Gould, and Wood	Establishment of Native Boearl Plant Species On Reclaimed Oil Sands Mining Disturbances
Keefer	Twin Sisters Native Plant Nursery
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Chang, et.al	Effects of Soil Aggregates Sizes (paper not attached)
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Janin	Passive treatment of drainage waters: Promoting metals sorption to enhance metal removal efficiency
Stewart and Siciliano	Biological Soil Crusts and Native Species for Northern Mine Site Restoration
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Simpson	Defining Disturbance and Recovery - the influence of landscape specific ecological responses to oil and gas linear disturbances in Yukon

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
- The Conference Sponsors (see next page)
- The Conference paper and poster presenters
- 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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