THE EFFECT OF SITE PREPARATION ON THE ESTABLISHMENT OF NATIVE GRASSLAND SPECIES IN SOUTHERN INTERIOR, BC

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ABSTRACT

New Gold's New Afton Mine, located near Kamloops in the BC southern interior grasslands, is committed to ecosystem restoration through stakeholder consultation and research, including restoration of native grassland. Our objective was to study restoration potential of 24 selected native species from the BC interior grasslands, including those of cultural significance to First Nations. We applied a controlled experimental manipulation on the top of a flattened top soil stockpile to test germination and establishment of 12 native forb and 12 native graminoid species seeded on plots that were raked, hydroseeded or seeded with no manipulation. Raking resulted in greater establishment and count data for both native forb and graminoid species; however, it also increased the number of 'volunteer' non-native forbs. Hydroseeding had a negative effect on native graminoid species overall and on non-native forb species. Plant diversity, calculated as Shannon's diversity index, was greatest in the seeded plots that had been hydroseeded and hydroseeded + raked. As well, species richness was highest in the raked + seeded treatments. In terms of management, raking appears to result in positive seed germination for many native species; whereas hydroseeding was less effective.

KEY WORDS: Diversity, species richness, hydroseeding, raking, grassland restoration, mine reclamation

INTRODUCTION

Mining is an important economic driver of British Columbia's economy. The gross mining revenue in British Columbia in 2011 amounted to $9.9 billion and spin offs from the mining industry provided a further $3 billion in direct industry expenditures ("The Mining Association of BC" 2013). However, mining causes disturbances on the landscape through the building of infrastructure and the extraction of minerals and ores (Vickers et al. 2012). To offset these ecological disturbances, the BC mining industry has made environmental protection a priority during the development, operation and closure of mines. Mining regulations in BC are governed by both federal and provincial governments, and regulatory and monitoring processes occur throughout the life of the mine, including closure. Legislation requires mines to either reclaim or restore these disturbed sites to pre-disturbance productivity levels.

Reclamation and restoration are two different objectives for managing disturbed sites. Reclamation is the process of returning a disturbed site back to its pre-disturbance productivity level using a combination of species which may include non-native agronomics. Restoration, is the process of returning a site back to its natural, self-sustainable state (Alday et al. 2011). To attain either of these goals, seeding is often undertaken to mitigate erosion from wind and water and to assist site recovery in terms of the types of desirable species (Baasch et al. 2012). Historically, industries used agronomic species for reclamation because of their ability to colonize quickly thus reducing erosion and making the area aesthetically pleasing (Carrick and Krüger 2007, Prach and Hobbs 2008). However, agronomic species can become invasive and thus reduce species richness and diversity within nearby native communities (Christian and Wilson 1999). With restoration, the addition of native seed has been shown to affect the path and speed of succession (Martin and Wilsey 2006, Baasch et al. 2012). Research in this area is important as ecosystems differ and methods of restoration must be altered to match the biotic and abiotic factors and stresses of the area (e.g. arid grassland versus forested wetland). As degraded sites are in an altered state, the impact restoration will have on the path of succession is unknown and hard to predict (Suding et al. 2004), thus research should be an integral part of a mine's restoration strategy.

Grasslands present a unique set of problems when it comes to restoration. In BC, grasslands are predominantly found in the 'rain-shadow' east of the Coast and Cascade Mountains, where the climate is dry and summers are hot ("Grasslands Conservation Council" 2012). Restoring grasslands in semi-arid systems is difficult due to environmental and economic limitations (Prach and Hobbs 2008). Low precipitation rates in grasslands can reduce germination, establishment and growth (Josa et al. 2012). Adding a disturbance stress to the system can reduce the availability of nutrients (Brady and Weil 2012), disrupt the microbial community (Wanner and Dunger 2001), increase compaction where heavy equipment is used thus decreasing water and root penetration (Brady and Weil 2012), and increase the potential for invasion by exotic species (Yurkonis et al. 2008). Microclimates created by topography as well as plant biomass, including litter, play an important role in the amount of sun or shade an area receives, the intensity of wind experienced, the amount of precipitation that can be sequestered and the amount of evaporation and transpiration that occurs at a site. Economically the lack of or low availability of and high cost of seed (Rowe 2010) can make restoration goals difficult to obtain. Together these factors make finding techniques to ensure successful restoration challenging.

Raking and tilling have been used in an effort to increase the success of grassland restoration (Wilson and Gerry 1995, Pywell et al. 2002, Carrick and Krüger 2007). Wilson & Gerry (1995) found that low disturbance and high disturbance tilling resulted in higher densities of native species. Although tilling can reduce soil compaction (Burke 2003) and increase microclimates by roughening the soil surface (*An Integrated Approach to Establishing Native Plants* 2007), whether it decreases or increases invasion by exotics is controversial as studies have shown both outcomes (Wilson and Gerry 1995, Montalvo et al. 2002, Kiehl et al. 2010). Litter and hydroslurry have been used to reduce erosion, maintain moisture levels, add nutrients and increase germination and seedling establishment (Matesanz et al. 2006, Dunifon et al. 2011, Oliveira et al. 2012). A meta-analysis on the effects of litter on seedling emergence by Loydi et al. (2013), revealed seedling emergence in dry grasslands was affected by the amount of litter. Hydroslurry which may create a similar environment to plant litter, is often used for re-vegetating slopes in an attempt to reduce erosion (Matesanz et al. 2006), increase moisture availability and increase germination. As some studies have found little value to hydroseeding, the writer feels the benefit to hydroseeding is somewhat controversial.

Hypotheses

1) Hydroseeding will result in increased germination and establishment rates for native species while suppressing non-native forb species.
2) Site preparation, such as raking, will increase germination and establishment of native flora indigenous to the interior of BC, but will also increase invasion by exotics.
3) Seeding native grassland species will result in higher species richness and diversity.

Many studies have shown planting native seeds results in germination and establishment as well as increased species richness and diversity over one or more years (Montalvo et al. 2002, Martin and Wilsey 2006, Martínez-Ruiz et al. 2007, Yurkonis et al. 2008, Dornbush and Wilsey 2010, Kiehl et al. 2010). As the BC Interior grasslands are water limited, using species adapted to the area should result in native vegetative cover. Hydroseeding has been successful at re-establishing road banks with native seed mixes in countries like Spain (Tormo et al. 2007), but has been less successful in re-vegetating slopes in the Mediterranean where it is semiarid (Bochet and Garcıa-Fayos 2004), we expect to see increased germination on a non-sloped site. We also expect to see increased establishment on sites that have been raked as has been seen in previous studies which looked at tilling (Wilson and Gerry 1995, Montalvo et al. 2002).

MATERIALS AND METHODS

Site Description

The study took place at New Gold's New Afton Mine (NAM) site west of Kamloops, British Columbia (50°38'54.92" N 120°29'59.67" W, elevation 775m). The NAM is an underground working, copper-gold mine situated on a historical open pit. The mine is located in the Ponderosa Pine and Interior Douglas-fir biogeoclimatic zone and the surrounding grasslands are a northern extension of the Pacific Northwest Bunchgrass grassland (*The ecology of the Interior Douglas-fir zone* 2014). This area has a short, warm summer season (May – September) with average temperatures ranging from 8°C to 29°C respectively. Winter mean annual temperatures range from -6°C to 5.6°C. The average yearly precipitation is ~278mm with 81% of the moisture coming as rainfall and 19% coming as snowfall ("Cimate Data, Environment Canada" 2014).

Experimental Design

Plant species selected for sowing were chosen based on their presence in the interior grasslands of British Columbia and their cultural importance to the local First Nations. Seeds were either handpicked or sourced from local seed companies. For those species which were handpicked, the populations were followed through the 2012 summer season and harvested once seeds had set and matured. Seeds were collected from a number of populations whenever possible. Exceptions were *Mentzelia laevicaulis* and *Oxytropis campestris*. *M. laevicaulis* was collected from a single population found on the New Afton Mine site and *O. campestris* was picked from a single population found at Teck's Highland Valley Copper Mine site. After collection, all seeds were sealed in plastic ziploc bags and stored in a chest freezer.

A topsoil stockpile located north of the tailings pond at NAM was levelled and a grid of 80 plots was created on the east end in October, 2012. Each plot measured 2 m^2 with a half meter between each plot to allow for movement between the treatments for watering and assessment. Each row (rep) had 8 treatments; four soil preparation treatments: raking, hydro-slurry, hydro-slurry and raking, and a control where no soil preparation was completed; and each of these treatments had a seeded and unseeded component (4 x 2 x 10; n=80). Treatments were randomized within each rep using a computer generated randomization plan (random.org) ("Random.org" 2014).

In the fall of 2012 seed packets were prepared for fall planting. Coin envelopes were labelled and filled with 45 ml of sand, a carrying agent, for each treatment (80 in total). The study plan was to seed each plot with 1200 seeds/m^2 (Fraser and Grime 1999). However some of the species collected by hand did not have enough seeds to obtain the 4800 seeds per plot needed and so the number was reduced to 200 seeds per species or 600 seeds/m^2 which is considered a high density planting by Carter & Blair (2012). In October 2012 when the grid was set up it was determined the stockpile in the area chosen had areas that were compacted. To reduce the effect of compaction on raked treatment plots, a shovel was used to loosen the dirt on the plots and dirt from the edge of the stockpile was added to help simulate a tilled/raked treatment. Three 12L buckets of soil were added to each of the raking treatments to maintain consistency throughout the study grid.

Seeding took place in November 2012 when temperatures were low enough to ensure early germination would not occur (Martínez-Ruiz et al. 2007). Seeds were hand-seeded on all seeded treatment plots except those designated for hydro-slurry. Hand-seeding was conducted by only two people to reduce bias. For hydro-seeded plots, seeds were mixed into 2 – 12L buckets. Half of the seed mixture was mixed into each bucket. Control packages which contained just the sand were also mixed into the hydro-slurry, ½ into each bucket to stay consistent with the seeded packages. The hydro-seed mixture was then spread over the plots by pouring the two buckets evenly over the treatment area. All control plots were hydro-slurried first to ensure no contamination occurred between control sites and seeded treatment sites. In the spring of 2013, plots were watered with 4mm of water twice a week beginning in May using watering cans with a disperser spouts. Watering continued until the June rains began and then was only completed when no rain occurred on watering days. Plots were watered until the water pooled on the soil surface. This moisture was allowed to seep through the soil before the remaining water was added. Plot assessments were carried out the second week of July 2013. A 1m^2 grid was placed in the center of each treatment plot and all species within the grid were counted and recorded.

<u>Statistical Analysis</u>

Statistical analysis of vegetation count data was conducted using R Studio (R version 2.15.3; 2012 R Foundation for Statistical Computing). A Filgner test for homogeneity of variances was completed for all data sets. Data was square root transformed to satisfy assumptions of a normal distribution, and a two-way analysis of variance (ANOVA) was used to determine differences between treatments and a Tukey post hoc analysis was conducted when there was a significant statistical difference ($p<0.05$).

RESULTS

At the species level, there were effects of site management and seeding on the number of individuals (Table 1). With respect to native forbs, there was a greater number of *Achillea millefolium* plants in sites that were raked or undisturbed compared to the hydro-slurry. *Balsamorhiza sagittata* had greater numbers on sites that had been both raked and hydro-slurried. *Gaillardia aristata* had the greatest number of individuals on sites that had either been raked or hydro-slurried and raked. Non-native forbs showed very little preference to treatments, however *Salsola tragus* had greater numbers of individuals in the raked plots, while hydro-slurry caused a negative response when the plots were not raked. Looking at the graminoid species, *Elymus trachycaulus* and *Pseudoroegnaria spicata* exhibited a positive response to raking as a soil preparation and a negative response to hydro-seeding resulting in fewer seedlings on these sites. Non-native graminoids, *Agropyron. cristatum* and *Bromus tectorum*, showed no significant differences between soil treatments, but *A. cristatum* did show a positive trend in the hydro-seeded + raked sites.

Some non-native species responded to both the seeding treatments and the soil preparation treatments. *Kochia scoparia* responded positively towards raking and negatively towards the hydro-slurry. The hydro-slurry reduced the number of plants by approximately 85% on the seeded sites and 75% on the non-seeded sites. *Sisymbrium loeselii* also responded positively to raking, but was suppressed by the hydro-slurry. For the sites that were hydroseeded, *S. loeselii* was suppressed by approximately 83% and the hydro-slurry with no seed reduced *S. loeselii* by 41%. A slight trend was seen for *Salsola tragus* where the hydro-slurry showed some negative impact on the number of plants counted.

Both non-native and native species as groups reacted similarly to the raking and hydroseeding treatments (Table 1; Figure 3). Raking significantly increased the number of seedlings counted, while the hydroslurry suppressed the number of seedlings counted overall. When raking and hydroseeding were integrated the number of non-native seedlings was not significantly different between the raked and raked + hydroseeded sites. However, the native species count overall was still significantly depressed by the hydroslurry even when raking was added to the treatment.

The Shannon Diversity Index revealed significance between the seeded and non-seeded treatment plots (Table 1), such that seeded plots had a higher diversity (Figure 1). Site preparation as a main effect did not influence diversity; however, the interaction between seeding and site preparation was significant. Seeded hydroslurry and seeded hydroslurry plus raking treatments had higher diversity than non-seeded raked treatments (Figure 1).

Species richness (*S*) was also highest in the seeded treatments (Table 1; Figure 2). The raked and raked + hydro-seeded sites had higher *S* than the control sites. Whereas the seeded and hydro-seeded treatments were not significantly different from the control treatments.

Table 1: Results from 2-way ANOVAs, soil preparation (Soil Prep) and seeding (Seed/No Seed) on numbers of native and non-native species on stockpiled topsoil at New Gold's New Afton Mine Site. Soil preparation included control (no manipulation), raking, and hydro-slurry, while seeding treatments were either seeded or unseeded.

Species	**Soil Prep**		**Seed/No Seed**		**Soil Prep + Seed**	
	F-value	**P-value**	**F-value**	**P-value**	**F-value**	**P-value**
Native forbs (seeded)						
Achillia millefolium	**9.772**	**1.74e-05**	**41.308**	**1.24e-08**	**9.772**	**1.74e-05**
Balsamorhiza sagittata	**6.075**	**9.59e-04**	**20.764**	**2.07e-05**	**6.075**	**9.59e-04**
Erigeron filifolius	1.411	0.247	1.244	0.268	1.244	0.300
Fritillaria pudica	0.667	0.575	2.000	0.162	0.667	0.575
Gaillardia aristata	**4.313**	**0.007**	**28.738**	**9.54e-07**	**2.806**	**0.046**
Mentzelia laevicaulis	0.668	0.575	**4.475**	**0.038**	0.668	0.575
Native forbs (volunteer)						
Artemisia tridentate	1.320	0.275	3.240	0.076*	1.320	0.275
Artemisia frigidata	2.364	0.078*	0.896	0.347	0.299	0.826
Astragalus tenellus	0.333	0.801	0.333	0.566	1.222	0.308
Calocortus macrocarpus						
Non-native forbs						
Berteroa incana	0.667	0.575	2.000	0.162	0.667	0.575
Camelina microcarpa	0.667	0.575	1.000	0.321	0.333	0.801
Centaurea stoebe	1.000	0.398	1.000	0.321	1.000	0.398
Chenopodium album	0.736	0.534	0.093	0.762	1.058	0.372
Descurainia sophia	0	1.000	**4.000**	**0.049**	0	1.000
Kochia scoparia	**14.345**	**2.02e-07**	0.093	0.761	1.595	0.198
Lactuca serriola	1.000	0.398	1.000	0.321	1.000	0.398
Lepidium densiflorum	1.222	0.308	0.333	0.566	0.333	0.801
Medicago lupulina	1.112	0.350	0.135	0.714	1.453	0.235
Melilotus alba	**3.565**	**0.018**	1.870	0.176	0.178	0.911

Species	Soil Prep		Seed/No Seed		Soil Prep + Seed	
	F-value	**P-value**	**F-value**	**P-value**	**F-value**	**P-value**
Myosotis sp.	1.222	0.308	0.333	0.566	0.333	0.801
Polygonum aviculare L	0.901	0.445	0.025	0.875	1.100	0.355
Rumex acetosella	1.000	0.398	1.000	0.321	1.000	0.398
Salsola tragus	**4.194**	**0.009**	0.094	0.760	0.636	0.594
Sisymbrium loeselii	**8.666**	**5.53e-05**	0.113	0.738	1.807	0.154
Taraxacum officinale	0.667	0.575	0.000	1.000	1.333	0.270
Thlaspi arvense	1.000	0.398	1.000	0.321	1.000	0.398
Native grasses						
Elymus glaucus	0.708	0.550	**5.287**	**0.0244**	0.708	0.550
Elymus trachycaulus	**3.980**	**0.011**	3.578	0.0626*	**5.971**	**0.001**
Festuca sp	1.134	0.341	14.148	**2.95e-04**	1.134	0.341
Poa sandbergii	1.000	0.398	1.000	0.321	1.000	0.398
Pseudoroegneria spicata	**13.190**	**5.90e-07**	**23.140**	**8.02e-06**	**10.280**	**1.03e-05**
Sporobolus cryptandrus	2.250	0.090*	2.250	0.138	2.250	0.090*
Non-native grasses						
Agropyron cristatum	0.792	0.502	1.499	0.225	2.649	0.055*
Bromus squarrosus	0.667	0.575	2.000	0.162	0.667	0.575
Bromus tectorum	1.086	0.360	0.125	0.725	0.391	0.760
Elymus repens	1.000	0.398	1.000	0.321	1.000	0.398
Poa sp.	1.222	0.308	0.333	0.566	0.333	0.801
Poa compressa	1.000	0.398	1.000	0.321	1.000	0.398
Triticum sp	**3.240**	**0.027**	0.360	0.550	0.360	0.782
Shannon diversity index	**2.518**	**0.065**	**11.593**	**0.001**	1.909	0.136
Species richness	2.060	0.113	**31.272**	**3.79e-07**	**2.877**	**0.0419**
Native plants	**7.457**	**0.000**	**66.797**	**7.29e-12**	**4.990**	**0.003**
Non-native plants	**11.552**	**2.88e-06**	0.276	0.601	1.466	0.231

Species	Soil Prep		Seed/No Seed		Soil Prep + Seed	
	F-value	**P-value**	**F-value**	**P-value**	**F-value**	**P-value**
Native graminoid	**5.630**	**0.002**	**15.902**	**0.000**	**6.522**	**0.001**
Non-native graminoid	0.699	0.556	0.139	0.710	1.765	0.161
Native forb	**4.758**	**0.004**	**24.229**	**5.25e-06**	**3.480**	**0.0202**
Non-native forb	**9.395**	**2.56e-05**	0.098*	0.755	1.765	0.161

* trend

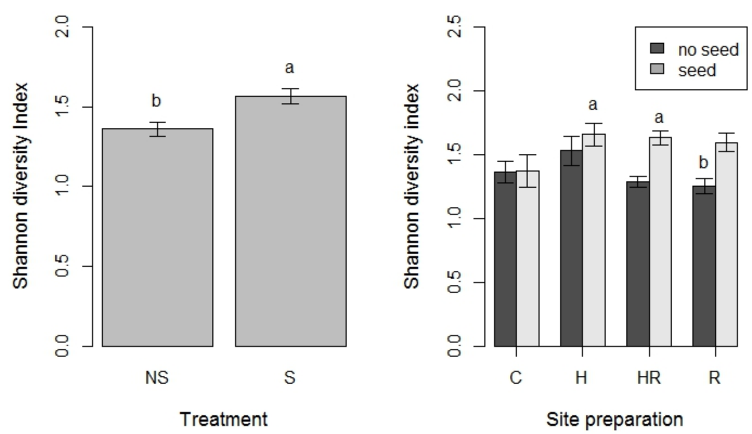

Figure 1: Analysis of Shannon diversity on stockpiled topsoil in the summer of 2013 at New Gold's New Afton mine site near Kamloops, BC. Treatments included seed (S), no seed (NS), raking (R), hydroslurry (H), and no manipulation (control (C)). Treatments labelled with different letters are significantly different ($p<0.05$).

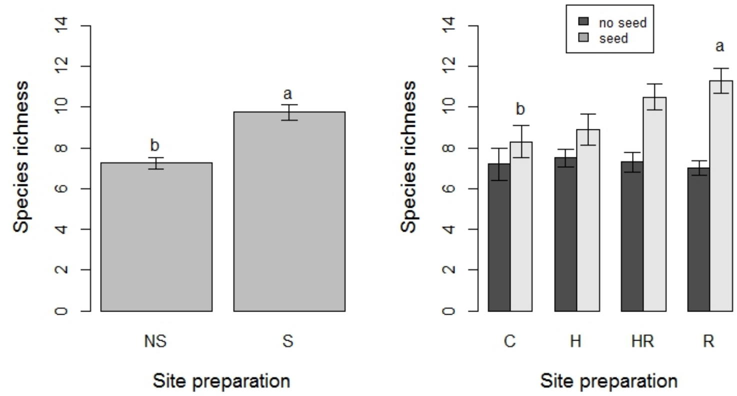

Figure 2: Species Richness based on seeded (S) and unseeded (NS) treatments as well as treatments that consisted of hydro-slurry (H) and/or raking (R). All treatments were carried out within a grid block located on stockpiled topsoil at New Gold's New Afton Mine site. Treatments labelled with different letters are significantly different (p<0.05).

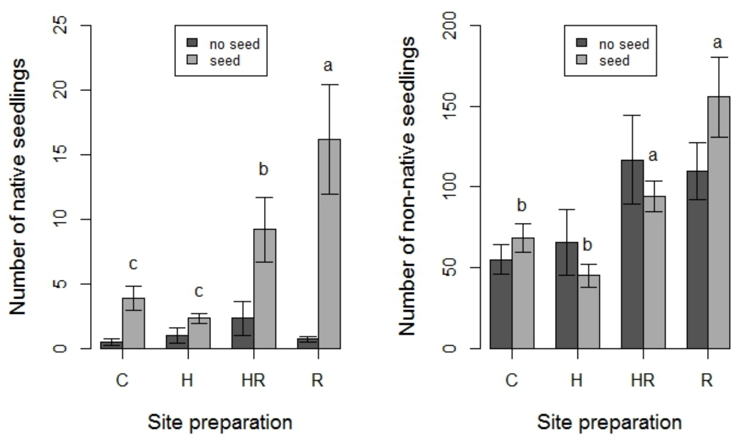

Figure 3: Results of seeding and soil preparation on stockpile topsoil at New Gold's New Afton Mine in the summer of 2013. Overall seedling count on plots treated with either raking (R), hydroslurry (H), both raking and hydroslurry (HR), control or no manipulation (C) and each of these treatments was either seeded or not seeded. Treatments labelled with different letters are significantly different (p<0.05).

Looking at the treatments from a group functional level (native forbs, native graminoids, non-native forbs and non-native graminoids), there were treatment effects for all groups except for the non-native graminoids (Table 1). Neither hydro-slurry nor raking had significant positive or negative effects on the germination of non-native grasses. However, there appears to be a slight increase in the number of non-native seedlings found on hydro-slurried sites when comparing it to raked sites. Raking did significantly increase the establishment of native graminoids, while adding hydro-slurry decreased the number of established native graminoid seedlings (Figure 4). The addition of raking to hydro-slurry did not result in a significant increase in the number of seedlings established. The non-native and native functional grouping of forbs revealed a positive response to raking for both groups and hydro-slurry resulted in a significant negative response for both native and non-native forbs. When hydro-slurry and raking were combined the result was a slight decrease in the number of seedlings counted for both non-native and native forbs as compared to the raked only sites (Figure 5). The control sights showed a slightly higher seedling count than the hydro-slurry treatment, but there was no significant difference between these two soil preparation methods.

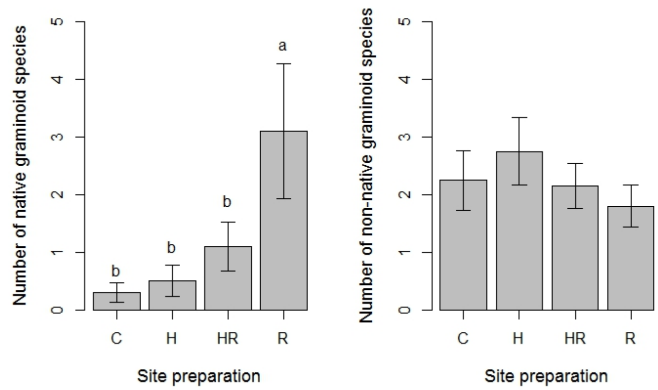

Figure 4: Native (left) and non-native (right) graminoids are depicted above showing the response to soil preparation carried out in a study looking at seedling establishment on stockpiled topsoil. C = control, H = Hydro-slurry, R = Raking. Treatments labelled with different letters are significantly different ($p<0.05$).

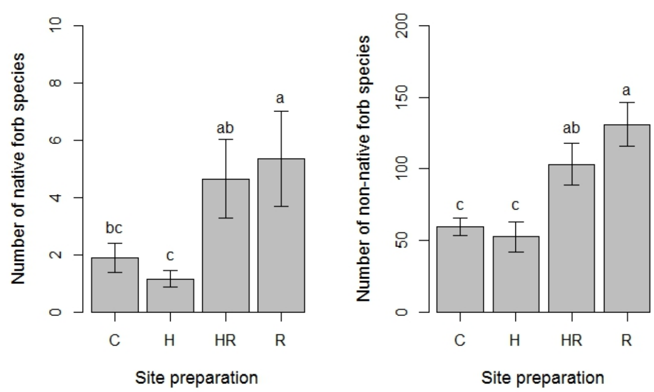

Figure 5: Response of native (left) and non-native (right) forb species to different soil preparations on stockpiled topsoil (C = control, H = hydro-slurry, R = Raking). Note the scale for the non-native forbs is 20x greater than for the native forb species. Treatments labelled with different letters are significantly different ($p<0.05$).

DISCUSSION

We hypothesized that raking would increase the number of native seedlings established on a site and results did show a positive response for both native graminoids and forbs. The positive effect of raking was most likely due to seed soil contact, which is enhanced by roughing up the surface of the soil (*An*

Integrated Approach to Establishing Native Plants 2007). As well, the crevices created by raking create areas of higher moisture, humidity, wind protection and shade from the sun (Montalvo et al. 2002). However, our method of raking only created ridges approximately two centimeters in height. Even though we attempted to loosen the soil with shovels the effect of roughing and loosening the soil to enhance seeding establishment, may diminish as the seedling roots reach below this loosened area into more compact soil. Certainly some of our plots were more compact than others. This was indicated by the difficulty in putting in our grid stakes as well as the difficulty we had in penetrating our shovels into the topsoil to loosen and roughen the raked sites.

Our objective with the hydro-slurry was to suppress unwanted/non-native species. In our study the hydro-slurry did not have the intended negative effect on non-native graminoids, but there was a negative effect on the native graminoids. Both native and non-native forbs were suppressed by the addition of hydro-slurry. Forbs overall, however, responded positively to the raking treatment. As one of the objectives to hydro-seeding was to suppress non-native species; the hydro-slurry treatment did have the intended effect. Unfortunately, the hydro-slurry also suppressed native forbs. In terms of management, hydro-slurry will make it difficult to re-establish native graminoids and forbs while controlling the non-native species.

At a species level, we found responses to the different treatments were selective. *A. millefolium* responded positively to either no soil management or raking, while hydro-slurry resulted in a negative response. *B. sagittata* and *G. aristata* shared a positive response to the double treatment of hydro-seeding and raking together. This could possibly be due to their larger seed size. *A. millefolium* seeds are small (~0.14 mg) and it’s possible they get trapped in the hydro-slurry which may result in desiccation when the slurry dries out. It’s also possible that as the hydro-slurry dries it shrinks inhibiting newly formed roots from making contact with the soil. The fibre and tackifying agent within the slurry may also create a mat which allows little light penetration thus reducing germination. A review by Moles and Westoby (2006) found studies indicated the increased survival rate of large seeded species through such conditions as shade, drought, competition and defoliation. Large seeds have the capacity to withstand short-term environmental stresses due to their stored reserves (Westoby et al. 1996). However, smaller seeded species like *A. millefolium* may not have the carbon reserves needed in times of short-term stress such as being able to penetrate the hydroslurry and access both the light above and soil below the slurry. Being of larger size the *B. sagittata* and *G. aristata* seeds may have the carbon stores needed to penetrate the hydro-slurry.

Unlike the native forbs, native graminoids responded positively only to raking. Raking resulted in a significantly positive response from *E. trachycaulus* and *P. spicata*. Hydroseeding native grasses has a negative effect and the non-native graminoids *A. cristatum* and *B. tetorum* showed no significant response to any of the treatments. As the hydro-slurry does not significantly inhibit the growth of non-native grasses and does not benefit native grasses, it is the researcher’s opinion that hydroslurry is not feasible in terms of the restoration of native grasses in the BC Interior.

Some non-native forb species that appear to be primary successional species showed some negative response to hydro-slurry, e.g. *K. scoparia,* a Eurasian species. Mustards also appear in the first year after disturbance. Both of these species appear to be ephemeral and as the site ages they become less common. These non-native species hold little threat to the native species trying to re-establish themselves. In fact, these ephemeral species may, in some ways, help native species take hold by creating areas of shade and reducing wind and water erosion. They may also play an important role in changing the soil parameters to better suit native species. For example, *K. scoparia* is a halophyte and may remove salinity from the disturbed soils. These factors may outweigh the resources these plants use in the short-term. Other species, such as *S. tragus,* are considered invasive, noxious species and stay around long term making it difficult for native species to establish.

Raking may create micro-climates on the soil surface. The loosening and roughing up of soil may form pockets thus protecting seeds from wind and water erosion that may otherwise remove them from the site. These microclimates may create areas of more or less moisture, warm and cool zones as well as increase the boundary layer between the soil and the atmosphere lowering the effects of wind reducing the amount of evaporation from the soil surface. Seed radicles may benefit from the loosening of soil creating better seed soil contact. The loosened soil may improve root penetration thus helping to anchor the young seedlings as well as allowing them better access to water, nutrients and oxygen below the soil surface.

CONCLUSION/MANAGEMENT

This study showed that hydroslurry can reduce the number of non-native species, however raking will somewhat negate this effect. Hydroslurry was also found to inhibit native species. *B. sagittata* benefitted from the hydro-slurry only when raking was also done. These results indicate that the use of hydroslurry in the restoration of BC interior grasslands is not feasible in terms of successful reintroduction of native species and therefore it is also not economically feasible. Our study supported similar studies in which raking or roughening up the soil, before seeding native species, resulted in increased diversity and species richness. However, it also increased the number of non-native species. It would be valuable to further study this effect in terms of deep tilling. The hollows created may allow for the accumulation of water, organic matter and seeds. It may also be beneficial to set up shade netting vertically in rows to reduce wind erosion and thus slow water evaporation from newly establishing sites (Carrick and Krüger 2007). Further research should be carried out in this area. Transplanting native woody species may also help with shading, soil stability, wind erosion, and the capture of precipitation especially snow in the winter months. A phased approach to planting (Burke 2003) may also be warranted as some species like *B. sagittata* appear to need litter in order to successfully germinate. Restoration may be more successful if seeding were to take place in intervals, thereby creating a facilitated succession. It is recommended that further studies be done in this area.

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