ESTABLISHMENT OF NATIVE BOREAL PLANT SPECIES ON RECLAIMED OIL SANDS MINING DISTURBANCES

Ann Smreciu, Kimberly Gould and Stephanie Wood

Wild Rose Consulting, Inc.
15109 77 Ave
Edmonton, Alberta T5R 3B5

ABSTRACT

Current revegetation strategies for disturbed oil sands sites include values such as biodiversity and sustainability. As a result, a wide range of species are sought for inclusion in revegetation programs. A trial was initiated in 2007 to evaluate emergence of 41 boreal vascular and provide definitive strategies for establishment.

Emergence of 24 species was observed by the second year. Many species responded differently depending on site characteristics while others established consistently over the three locations. We documented two species that emerge in higher percentages from whole fruit than from cleaned seed. We have also determined a number of species that benefit from either spring or fall sowing.

Direct sowing information, seed metrics and other culturally information on all 41 species was gathered to create 'Propagation and Establishment Profiles'. These 2 to 5 page fact sheets will be publically available through the Oil Sands Research and Information Network (OSRIN).

Key Words: Boreal, Emergence, Oil Sands.

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We are grateful to each of the former and current members of this project's ERRG (Environmental and Reclamation Research Group) Steering Committee for their encouragement and ongoing discussions regarding all aspects of the project (Syncrude Canada Ltd., Suncor Energy Inc., Shell Albian, Canadian Natural Resources Ltd., Imperial Oil and Total C&P).

INTRODUCTION

Revegetation of disturbed mined oil sands sites has, historically, focused primarily on forest productivity. More recently, the focus of revegetation has widened to include values attributed to other end land uses, such as wildlife habitat, aboriginal land uses, recreation, biodiversity and sustainability.

A comprehensive field trial was initiated under ERRG in 2007 to encompass a large number of boreal species and provide more definitive strategies for establishment. The objectives were:

1. To determine the effect of sowing season and propagule type on emergence and establishment of up to 40 native boreal plant species under field conditions,
2. To provide site specific information regarding the establishment of individual species, and

3. To fill knowledge gaps in the literature used by practitioners to efficiently and effectively grow and establish locally harvested native boreal plant species (i.e., phenology, propagule harvest and cleaning methods, germination and pre–treatment requirements, seed and fruit metrics).

This field trial is ongoing and all results presented are preliminary.

PROJECT METHODOLOGY

Seeds are harvested from areas within 100 km of the actively mined oil sands of northeastern Alberta. Seeds are cleaned by hand, with methods documented (Table 1). Seeds are stored dry until the following fall and spring, at which time they are direct–seeded in field trials. Fruit (for species that produce fleshy fruit or berries) are also harvested and frozen until being sown the following fall and spring.

Seed weights are recorded and/or calculated for each species (Table 2). Sub-samples of 100, 500 or 1000 cleaned seeds (depending on size) are weighed and averaged. Fruit metrics are recorded for accessions with fleshy fruits: number of seeds/fruit (average), average number of fruit per litre, weight of fruit per litre. From this, the average number of seeds per kilogram of fruit is calculated.

Germination of individual species is tested using standard methods (Table 3). Germination trials are conducted on fresh seeds (within six to eight months of harvest) and again in the following year (12 to 18 months after harvest). Four samples of 25 seeds from each accession are counted and placed into petri dishes on Whatman #1 filter paper. Plates are placed in a refrigerator at 2 to 4°C for cold stratification, the length of which was determined based on literature and previous experience. Plates removed from stratification are randomized with control plates placed at room temperature (19 to 23°C) in ambient room light. Germinants are counted twice weekly for at least four weeks. Germination is considered complete when the radicle emerges.

All information regarding the methodologies (cleaning, germination, emergence) are used to populate Propagation and Establishment profiles. These fact sheets are intended for use by all levels of industry: growers, reclamation operators, harvesters. These profiles will be published by OSRIN (Oil Sands Research and Information Network) and should be available publicly by the end of 2013.

The three trial locations selected (Table 1) represent a diversity of environments in which to test emergence and establishment.

Target boreal plant species are divided into two broad categories – those that have dry seeds and those that produce a fleshy fruit (e.g., drupes or berries). The primary treatment for the dry-seeded species is sowing season (i.e., fall vs. spring). Whereas, there are two primary treatments for fleshy fruited species: propagule type (seed vs. fruit) and sowing season (fall vs. spring). Each category is replicated four times at each of three sites over two sowing years.

Table 1. Experimental site locations and descriptions

Site	Location	Description of Reclamation
Suncor – Steepbank Sand Pit Area	N 56° 53' 56.8" W 111° 24' 7.27"	Reclaimed 2003 to d1 Ecosite; overburden; soil depth 28 cm – directly placed peat/mineral; fertilized in 2003 with 23.5-25-8 (NPK) at a rate of 200 kg/ha. Although planted in 2004, the site was ploughed in 2007 to provide a relatively open site for this experiment.
Syncrude Mildred Lake – W1	N 57° 1' 3.7" W 111° 43' 47.6"	Capped with 110 cm of peat-mineral mix (top 14 cm organic material) in 2005. *Populus tremuloides* and *Picea glauca* were planted at 1360 and 670 stems/ha respectively in 2007. In addition, *Alnus viridis* was planted at 250 stems/ha.
Syncrude Aurora – Fort Hills	N 57° 9' 49.4" W 111° 31' 58.4"	Capped with 90 cm of peat-mineral mix in 2005. In 2006, *Picea glauca* and *Populus tremuloides* were planted at 1218 and 882 stems/ha respectively. In addition, *Rosa acicularis* was planted at 230 stem/ha and *Amelanchier alnifolia* was planted at 321 stems/ha.

Thirty species plots are delineated on each site. There are thirty-two individual subplots (each 1 m x 1 m) within each, enough for one species with fleshy fruit, and buffers of 2 m between subplots. A 4 m buffer lies between species plots. For dry-seeded species, two species are included in a single species plot.

Sowing occurs in the fall a year after seeds are first harvested and again in the following spring. Soil/substrate is scuffled with a garden rake and seeds or fruit are broadcast. Soil is then raked and pressed to incorporate propagules and ensure good propagule/soil contact. Seeding rates are based on previous experience, seed size and seed availability. For fleshy-fruited species, the seeding rates are adjusted to obtain the same number of seeds in each plot for the two propagule types (e.g., for *Aralia nudicaulis* with a fruit sowing rate of 50 fruit/m^2 the seed sowing rate would be 250 seed/m^2 as each fruit bears approximately five seeds).

Plots are monitored for emergence/survival and vigour annually for up to five years. Many plots have been observed for three years, but a few have only been monitored once. Hence, results are tentative. In spring of 2012, light meter readings were taken in each sub-plot and these data used as a covariate in the analysis of variance. In this way, the reduced light availability due to competition from other vegetation is taken into account, making differences from other effects, such as season of sowing, more apparent among sites.

RESULTS

Each species is unique and emergence of one species isn't directly comparable to that of another, therefore we did not compare emergence percentages among species. However, it was possible to group species by their preferred establishment conditions.

Seven dry seeded species emerged equally well regardless of season. *Castilleja raupii* and *Symphyotrichum laeve* (purple paintbrush and smooth blue aster) emerged in similar proportions on all three experimental sites. Both *Solidago* species (*S. canadensis* and *S. simplex* – Canada and mountain goldenrod) as well as *Hesperostipa curtiseta* (western porcupine grass) emerged best on Aurora. *Vicia americana* (American vetch) was the only species to emerge best at Mildred Lake and *Anemone multifida* (cut-leafed anemone) emerged equally well on Aurora and Suncor, but in lower proportions on Mildred Lake.

The remaining dry-seeded species showed a preference for sowing season. *Bromus ciliatus* (fringed brome) and *Dasiphora fruticosa* (shrubby cinquefoil) emerged best from fall seed while *Anemone patens* (prairie crocus) emerged in greater proportions from spring sowing. *A. patens* and *D. fruticosa* emerged best on Aurora, but *B. ciliatus* showed no preference for site.

None of the fleshy fruited species showed a preference for sowing season alone, but propagule type was significant for seven species. Only *Viburnum edule* (lowbush cranberry) and *Shepherdia canadensis* (buffaloberry) emerged in higher proportions from entire fruit.

Amelanchier alnifolia (Saskatoon), *Arctostaphylos uva-ursi* (bearberry), *Prunus pensylvanica* (pin cherry), *Rosa acicularis* (prickly rose) and *Symphoricarpos albus* (snowberry) emerged best from cleaned seed. Of these, only *A. alnifolia* and *S. canadensis* emerged equally well on all the sites. The rest preferred Aurora.

There were also four species that emerged best under specific propagule/season combinations. *Fragaria virginiana* (wild strawberry) and *Rubus idaeus* (red raspberry) both emerged best from fall sown cleaned seed, whereas *Cornus sericea* (dogwood) and *Prunus virginiana* (chokecherry) preferred spring sown seed. *P. virginiana* and *R. idaeus* emerged best at Aurora, and *F. virginiana and C. sericea* emerged equally well on all three sites.

Betula papyrifera (paper birch), *Campanula rotundifolia* (harebell), *Cornus canadensis* (bunchberry) and *Sibbaldiopsis tridentata* (three-toothed cinquefoil) have emerged on one or more sites, but too few plants are available for statistical analysis.

The remaining 16 species have not emerged to date:

Alnus incana (river alder)
Alnus viridis (green alder)
Apocynum androsaemifolium (dogbane)
Aralia nudicaulis (sasparilla)

Cypripedium acaule (pink lady's slipper)
Geocaulon lividum (bastard toadflax)
Lilium philadelphicum (wood lily)
Lonicera caerulea (blue-fly honeysuckle)
Maianthemum canadense (lily of the valley)
Mitella nuda (bishop's cap)
Rhododendron groenlandicum (Labrador tea)
Rumex aquaticus (wild sorrel)
Schizachne purpurascens (false purple melic)
Trientalis borealis (northern starflower)
Vaccinium myrtilloides (dwarf blueberry)
Vaccinium vitis-idaea (bog cranberry)

CONCLUSIONS

These emergence trends can be used to broadcast seed or fruit at the appropriate time for the greatest chance at emergence and survival.

Although species can be grouped by their preferred season of sowing or propagule emergence, these trends bear no relation to how a species responds to a given experimental site. Each species is individual and often need to be treated differently from one another. By compiling emergence information alongside cleaning (Table 2), seed metrics (Table 3), and germination (Table 4) information, a proper establishment/revegetation plan can be made based on the species selected for revegetation.

There is a general trend toward greater emergence (both number of species as well as number of individuals) occuring at Aurora and Suncor than at Mildred Lake. This is probably, in part, a response to the warmer average soil temperatures recorded at these two sites in early June (Aurora – 16°C, Suncor – 15°C and Mildred Lake – 13.5°C) and likely throughout the season. Temperature differences can be attributed to various factors including soil type, slope and aspect. Greater vegetation cover at Mildred Lake may also cause cooler soil temperatures as well as compete for nutrients and water.

Table 2. Seed cleaning methods for native boreal species.

Cleaning Methods	Species
For achenes or caryopsis or for seeds formed in capsules that dry as they mature. Air-dry fruits in paper or Tyvek bags at 15-25˚C. Crush material or remove large chaff and crush remaining material. Sieve to remove seeds from chaff using appropriate size screens. Small chaff and dust can be removed by winnowing. If capsules are intact merely open capsules and empty seeds; sieve or winnow to remove chaff and dust. For awned species – break off awns with a de–awner or by hand.	*Alnus incana* *Alnus viridis* *Anemone patens* *Betula papyrifera* *Bromus ciliatus* *Campanula rotundifolia* *Castilleja raupii* *Hesperostipa curtiseta* *Lilium philadelphicum* *Mitella nuda* *Rumex aquaticus* *Rhododendron groenlandicum* *Schizachne purpurascens* *Trientalis borealis* *Vicia americana*
For small seeds enclosed in succulent fruit. Place pulpy fruits in water (use about 3:1 water with fruit) and place in a blender on low speed until fruits are fully macerated. Pour through sieve(s) to remove chaff smaller than seeds. Re-suspend residue in water and mix; allow seeds to settle and decant water with floating and suspended larger chaff. Repeat re-suspension step until seeds are clean; sieve and place seeds on paper towelling or cloths to dry. Dry at room temperature or up to 25˚C over a moving air stream.	*Amelanchier alnifolia* *Aralia nudicaulis* *Cornus canadensis* *Fragaria virginiana* *Geocaulon lividum* *Lonicera caerulea* *Maianthemum canadense* *Rubus idaeus* *Shepherdia canadensis* *Vaccinium myrtilloides* *Vaccinium vitis-idaea* *Viburnum edule*

Cleaning Methods	Species
For small seeds enclosed in dry, pulpy fruit Rub fruit between corrugated rubber in a box or on a large size sieve to remove pulp. Winnow the chaff off or suspend seeds and remaining chaff in water and mix. Allow the seeds to settle and decant off the lighter chaff. Repeat the suspension if necessary. Dry at room temperature or up to 25˚C preferably over a moving air stream.	*Arctostaphylos uva-ursi*
For seeds with an attached pappus Pull seeds from seed heads by hand or rub seeds with pappus between corrugated rubber in a box. Sieve to remove seeds from chaff using appropriate size screens. Small chaff and dust can be removed by winnowing. Alternately, pappus with attached seeds can be placed on a sieve with opening size large enough to let seeds through stacked on a sieve that will catch the seeds. Place a smaller sieve over the top sieve and direct a strong flow of air (such as that produced by a reversed vacuum) through the top sieve. Seeds will be removed from the pappus and lodge in the small mesh sieve.	*Anemone multifida* *Apocynum androsaemifolium* *Dasiphora fruticosa* *Sibbaldiopsis tridentata* *Solidago canadensis* *Solidago simplex* *Symphyotrichum laeve*
For large, round, hard seeds in pulpy fruits Mash fruits by hand or using a potato masher, apple-saucer, or ricer, or run through a hand meat grinder. Alternatively, use a food processor on low speed with blunt mashing blade (not a sharp blade) or use a blender with blades covered by plastic tubing or duct tape. Suspend residue in water and mix; allow seeds to settle and decant water with floating and suspended larger chaff. Repeat this step until seeds are clean; sieve and place seeds on paper towelling or cloths to dry. Dry at room temperature or up to 25˚C preferably over a moving air stream.	*Cornus sericea* *Prunus pensylvanica* *Prunus virginiana*
For large, irregular-shaped, hard seeds in pulpy fruits Process fruits through a tomato de-seeder (several times if necessary) to remove juice and some fruit pulp. Suspend residue in water and mix; allow seeds to settle and decant water with floating and suspended larger chaff. Repeat this step until seeds are clean; sieve and place seeds on paper towelling or cloths to dry. Dry at room temperature.	*Rosa acicularis* *Symphoricarpos albus* *Viburnum edule*

Table3. Seed and fruit metrics.

Species	Average Seeds/g	# of samples/ accessions	g/1000 seeds	Average Seeds/ fruit	Average # of Fruit/L	Average # of Fruit/kg
Alnus incana	2 013	23/7	0.51			
Alnus viridis	5 582	26/10	0.1996			
Amelanchier alnifolia	334	17/9	3.02	9	1 590	3 350
Anemone multifida	1 152	6/2	0.95			
Anemone patens	1 136	6/2	1.08			
Apocynum androsaemifolium	6 295	9/3	0.16			
Aralia nudicaulis	198	6/2	0.90	5	3 320	5 650
Arctostaphylos uva-ursi	168	67/20	6.31	6	1 690	3 720
Betula papyrifera	6 375	18/10	0.17			
Bromus ciliatus	586	18/6	0.19			
Campanula rotundifolia	31 810	9/3	0.03			
Castilleja raupii	13 970	26/7	0.07			
Cornus canadensis	151	3/1	6.65	1	2 780	7 890
Cornus sericea	38	9/6	26.71	1*	2 460	4 900
Dasiphora fruticosa	5 353	21/8	0.20			
Fragaria virginiana	2 598	24/8	0.39	35	2 370	3 940
Geocaulon lividum	23	6/2	42.83	1	2 310	3 110
Hesperostipa curtiseta	81	15/5	12.38			
Lilium philadelphicum	1 340	10/6	1.21			
Lonicera caerulea	1 900	11/4	0.54	10	2 450	4 350
Maianthemum canadense	111	9/3	9.05	1.3	8 370	14 700
Mitella nuda	3 606	9/3	0.28			
Prunus pensylvanica	26	14/7	39.64	1	1 620	3 310
Prunus virginiana	15	10/6	69.67	1	1 200	2 090
Rhododendron groenlandicum	53 230	10/6	0.03			
Rosa acicularis	104	13/7	9.88	23	630	1 130

Species	Average Seeds/g	# of samples/ accessions	g/1000 seeds	Average Seeds/ fruit	Average # of Fruit/L	Average # of Fruit/kg
Rubus idaeus	1 243	18/6	1.23	37	808	1 160
Rumex aquaticus	1 096	18/6	0.95			
Schizachne purpurascens	591	5/2	1.70			
Shepherdia canadensis	165	42/12	6.13	1	5 640	8 090
Sibbaldiopsis tridentata	2 611	6/2	0.39			
Solidago canadensis	11 740	15/5	0.11			
Solidago simplex	10 020	12/4	0.13			
Symphoricarpos albus	208	11/7	4.89	2	3 220	10 000
Symphyotrichum laeve	5 048	13/7	0.20			
Trientalis borealis	2 269	16/6	0.45			
Vaccinium myrtilloides	6 810	46/16	0.15	37	2540	5 240
Vaccinium vitis-idaea	4 880	52/17	0.21	12	3 190	7 050
Viburnum edule	46	32/14	22.07	1	1 770	3 030
Vicia americana	77	6/2	13.13			

Table 4. Germination recommendations.

Species	Germination recommendations
Alnus incana	Cold stratify fresh or year old seeds for at least 4 weeks.
Alnus viridis	Cold stratify fresh or year old seeds for at least 4 weeks.
Amelanchier alnifolia	Cold stratify fresh or year old seeds for 16 weeks.
Anemone multifida	No pre-treatment required.
Anemone patens	Cold stratify fresh seed for 4 weeks or allow one year after-ripening.
Apocynum androsaemifolium	Fresh seed require no pre-treatment.
Arctostaphylos uva-ursi	Seed germination is highest when year-old seeds are soaked in concentrated sulphuric acid for a period of four and a half hours and subjected to at least 8 weeks of warm stratification followed by at least the same length of cold stratification.
Betula papyrifera	4 weeks stratification of fresh or 1 year old seeds.
Bromus ciliatus	Cold stratify fresh seeds for at least 4 weeks.

Species	Germination recommendations
Campanula rotundifolia	No pre-treatment required.
Castilleja raupii	Cold stratify fresh, 1 year or 2 year old seeds for at least 4 weeks. Seeds lose little viability for at least six years.
Cornus canadensis	Cold stratify seed for 20 weeks.
Cornus sericea	Cold stratify fresh, 1 year or 2 year old seeds for 4 weeks.
Dasiphora fruticosa	No pre–treatment required.
Fragaria virginiana	Cold stratify fresh or year old seeds for up to 12 weeks.
Hesperostipa curtiseta	Cold stratify year old seeds for 4 weeks.
Lilium philadelphicum	No pre–treatment required.
Lonicera caerulea	Cold stratify fresh seeds for at least 4 weeks.
Maianthemum canadensis	Cold stratify fresh seed for 8 or 12 weeks.
Rhododendron groenlandicum	Stratify fresh or one year old seeds for 4 weeks.
Rubus idaeus	Acid scarify seeds for one minute prior to 16 weeks warm stratification followed by 8 weeks cold stratification.
Rumex aquaticus	Cold stratify fresh or year old seeds for 4 weeks.
Schizachne purpurascens	Fresh seeds require no pre-treatment
Shepherdia canadensis	Cold stratify mechanically scarified seed for 8 weeks.
Sibbaldiopsis tridentata	Cold stratify fresh seeds for at least 4 weeks.
Solidago canadensis	No pre–treatment required.
Solidago simplex	Fresh seeds require no pre-treatment.
Symphyotrichum laeve	No pre-treatment required.
Trientalis borealis	Warm stratify year old seeds for 16 weeks.
Vaccinium myrtilloides	Cold stratification did not improve germination but greater germination was found when tested for period of 60 days or more.
Vaccinium vitis-idaea	Cold stratify fresh or 1 year old seeds for at least 12 weeks.
Viburnum edule	Warm stratify seed for 16 weeks followed by cold stratification for 12 weeks.
Vicia americana	Mechanically scarify seeds.

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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Northern Latitudes Mining Reclamation Workshop

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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
Pedlar-Hobbs, Ludgate and Luchinski	Key Factors in Developing and Implementing a Successful Reclamation Plan
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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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