Pin cherry in bloom. (See Table 1 for taxonomic nomenclature.)

Field emergence of native boreal forest species on reclaimed sites in northeastern Alberta

Ann Smreciu and Kimberly Gould

ABSTRACT

Direct sowing is an underutilized technique for establishing native species on reclaimed land in the mineable oil sands region of northeastern Alberta. This study evaluated the effect of sowing season (spring versus fall) and propagule type (clean seeds versus whole fruit) on emergence of 41 species. Species were sown on 3 disparate sites, each prepared in the standard method for that operation and time and having differing slopes and aspects. Of 41 species, 27 emerged at some level, and of these, 9 species established and were reproducing by seeds, tillers, or rhizomes. These 9 species were smooth blue aster (*Symphyotrichum laeve* (L.) Á. Löve & D. Löve [Asteraceae]); shrubby cinquefoil (*Dasiphora fruticosa* (L.) Rydb. [Rosaceae]) and wild strawberry (*Fragaria virginiana* Duchesne [Rosaceae]), which emerged best from fall-sown seeds; fringed brome (*Bromus ciliatus* L. [Poaceae]); Canadian needle grass (*Hesperostipa curisetia* (Hitchc.) Barkworth [Poaceae]); Canada goldenrod (*Solidago canadensis* L. [Asteraceae]); Raup's Indian paintbrush (*Castilleja raupii* Pennell [Orobanchaceae]) and prickly rose (*Rosa acicularis* Lindl. [Rosaceae]), which emerged equally well from seed broadcast during the fall as during the spring; and Mt Albert goldenrod (*Solidago simplex* Kunth [Asteraceae]), which emerged best from seed broadcast in the spring.

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KEY WORDS

direct sowing, broadcast sowing, oil sands, revegetation, Asteraceae, Orobanchaceae, Poaceae, Rosaceae

NOMENCLATURE

USDA NRCS (2015)

ITIS (2015)

CONVERSIONS

m × 1.1 = yd

cm × 0.4 = in

m² × 10.2 = ft²

ha × 2.5 = ac

kg × 2.2 = lb

(°C × 1.8) + 32 = °F

Photos courtesy of Wild Rose Consulting Inc

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Oil and gas extraction is a major component of the Canadian economy, and is especially so in the province of Alberta. Some of the largest oil reserves are found in the oil sands of northeastern Alberta, with extraction resulting in disturbance of large tracts of boreal forest. Reclamation of these disturbances is ongoing, progressively reclaiming older areas as new areas are mined. The primary aim of reclamation efforts is to restore functioning communities and ecosystems on the reconstructed landscape that are similar to those that existed prior to disturbance. A wide range of species and deployment methods are necessary to meet the diverse conditions resulting from changes to hydrology, soils, and elevations and aspects. Although planting nursery-grown seedlings is the most common way currently used to establish native species on reclaimed sites in the oil sands, broadcasting seeds results in greater spatial diversity due to random scattering and uneven emergence over time. Within the Canadian Oil Sands Network for Research and Development Environmental and Reclamation Research Group (CONRAD ERRG), a study of 41 native boreal species was conducted.

Many woody species are currently harvested and banked for inclusion in reclamation efforts in northeastern Alberta. Very few non-woody species are used in these operations, however, despite their importance to the vegetation community structure and function. Additionally, many native boreal species, woody and herbaceous, are of particular importance to local First Nations and also play a role in nurturing wildlife. To address these concerns, this study selected an array of species: early seral species, those found under closed canopy, those with edible parts, those that provide browse for wildlife, and species of interest for other ecological considerations.

Seeds of boreal species often require stratification prior to germination (Baskin and Baskin 2001) as a reflection of their adaptation to colder climates. Some may emerge more quickly or more completely from fall sowing. For some biennial species, establishment following early spring seed set is common. There may be a difference in emergence from cleaned seeds and whole fruit for species with fleshy fruit. Some fruits contain inhibitors that prevent germination (Mayer and Poljakoff-Mayber 1982; Hassan and others 2013), and some seeds require scarification as would occur when digested. And for other species, the intact fruit may provide the seeds with an initial source of moisture and nutrients (Smreciu and Barron 1997).

Studies have explored direct sown seed for reclamation of prairie (Brown 1974; Pahl and Yeung 1998) and alpine (Haeussler and others 1999; Macyk 2001) regions as well as northern latitudes (Helm 2001; Mougeot and Withers 2001). These studies looked primarily at native grasses and legumes. In prairies, the sowing was generally successful; however, in alpine and northern climes, the resulting cover was an impediment to shrub and tree species. Some of this information can be applied

to disturbances in the oil sands, but complications unique to the area and to the type of disturbance, as well as the scale of disturbance, warrant a closer examination.

The goal of this experiment was to evaluate the effect of sowing season on the emergence and survival of 41 native shrub and forb species. For the 18 species that bear fleshy fruit, a second variable was added. Emergence was compared between plots sown with seeds that had been extracted (cleaned) versus plots sown with intact fruits. Each treatment was tested at the 3 experimental sites described below.

METHODS

Species Selection

Table 1 lists species included in this trial. Fleshy-fruited species are highlighted in blue. Many of these species have profiles on the USDA NRCS PLANTS database (2015). Most are included in the USDA Forest Service's Fire Effects Information System (2015), and all of them have profiles in Boreal Plant Species for Reclamation of Athabasca Oil Sands Disturbances (Smreciu and others 2013).

Site Description

Seeds were broadcast at 3 experimental sites selected in reclaimed areas within oil sands mining leases. Two of the experimental sites were on Syncrude Canada Ltd leases; the first near the original mine at Mildred Lake (ML) and a second farther north on their Aurora lease (AFH). The third site was at Suncor Energy Inc on the east side of the Athabasca River (SS). Sites differed by aspect, slope, reclamation material, and substrate depths. All were typical of reclamation practices of the time: placement of overburden material mixed with peat up to 1 m thick (peat-mineral mix) and planted with trees and shrubs. They were further colonized by native pioneers, nonnative weeds, and agronomic species. At ML, these were primarily agronomic legumes, such as sweetclover (*Melilotus* Mill. spp. [Fabaceae]), which formed a very dense cover. At AFH, the cover was sparse, consisting of a mix of colonizing native and nonnative species. SS, unlike the other 2, was harrowed prior to plot installation, which exposed the site to agronomic weeds, primarily sowthistle (*Sonchus* L. spp. [Asteraceae]) and legumes, in this case cicer milkvetch (*Astragalus cicer* L. [Fabaceae]). Thick swards of native grasses emerged in discrete areas within 1 or 2 y of sowing. Although the substrates were not analyzed specifically for this study, a general soil texture and pH were provided by the leasing company as part of their ongoing monitoring. Details regarding these soil properties, specific depth of capping material, planting prescription, aspect, and slope are summarized in Table 2, and site overviews are in the composite photograph.

Experimental site was a third, uncontrolled, independent variable. We included the effect of experimental site in our

TABLE 1

Species included in direct sowing establishment trial.

Common name	Genus, species, authority	Family
American vetch	<i>Vicia americana</i> Muhl. ex Willd.	Fabaceae
bare-stem bishop's cap	<i>Mitella nuda</i> L.	Saxifragaceae
bearberry	<i>Arctostaphylos uva-ursi</i> (L.) Spreng.	Ericaceae
blue honeysuckle	<i>Lonicera caerulea</i> L.	Caprifoliaceae
Canada bunchberry	<i>Cornus canadensis</i> L.	Cornaceae
Canada goldenrod	<i>Solidago canadensis</i> L.	Asteraceae
Canadian needle grass	<i>Hesperostipa curisetia</i> (Hitchc.) Barkworth	Poaceae
chokecherry	<i>Prunus virginiana</i> L.	Rosaceae
common snowberry	<i>Symphoricarpos albus</i> (L.) S.F. Blake	Caprifoliaceae
common red raspberry	<i>Rubus idaeus</i> L.	Rosaceae
cut-leaf anemone	<i>Anemone multifida</i> Poir.	Ranunculaceae
eastern pasqueflower	<i>Anemone patens</i> L.	Ranunculaceae
false lily-of-the-valley	<i>Maianthemum canadense</i> Desf.	Asparagaceae
false melic	<i>Schizachne purpurascens</i> (Torr.) Swallen	Poaceae
false toadflax	<i>Geocaulon lividum</i> (Richardson) Fernald	Santalaceae
fringed brome	<i>Bromus ciliatus</i> L.	Poaceae
gray alder	<i>Alnus incana</i> (L.) Moench	Betulaceae
green alder	<i>Alnus viridis</i> (Chaix) DC.	Betulaceae
Labrador tea	<i>Rhododendron groenlandicum</i> (Oeder) Kron & Judd	Ericaceae
lingonberry	<i>Vaccinium vitis-idaea</i> L.	Ericaceae
Mt Albert goldenrod	<i>Solidago simplex</i> Kunth	Asteraceae
northern star flower	<i>Trientalis borealis</i> Raf.	Primulaceae
paper birch	<i>Betula papyrifera</i> Marshall	Betulaceae
pin cherry	<i>Prunus pensylvanica</i> L. f.	Rosaceae
pink lady's slipper orchid	<i>Cypripedium acaule</i> Aiton	Orchidaceae
prickly rose	<i>Rosa acicularis</i> Lindl.	Rosaceae
Raup's Indian paintbrush	<i>Castilleja raupii</i> Pennell	Orobanchaceae
redosier dogwood	<i>Cornus sericea</i> L.	Cornaceae
roundleaf harebell	<i>Campanula rotundifolia</i> L.	Campanulaceae
russet buffaloberry	<i>Shepherdia canadensis</i> (L.) Nutt.	Elaeagnaceae
Saskatoon serviceberry	<i>Amelanchier alnifolia</i> (Nutt.) Nutt. ex M. Roem.	Rosaceae
shrubby cinquefoil	<i>Dasiphora fruticosa</i> (L.) Rydb.	Rosaceae
shrubby fivefingers	<i>Sibbaldiopsis tridentata</i> (Aiton) Rydb.	Rosaceae
smooth blue aster	<i>Symphyotrichum laeve</i> (L.) Á. Löve & D. Löve	Asteraceae
spreading dog bane	<i>Apocynum androsaemifolium</i> L.	Apocynaceae
squashberry	<i>Viburnum edule</i> (Michx.) Raf.	Adoxaceae
velvet-leaf blueberry	<i>Vaccinium myrtilloides</i> Michx.	Ericaceae
western dock	<i>Rumex aquaticus</i> L.	Polygonaceae
wild sarsaparilla	<i>Aralia nudicaulis</i> L.	Araliaceae
wild strawberry	<i>Fragaria virginiana</i> Duchesne	Rosaceae
wood lily	<i>Lilium philadelphicum</i> L.	Liliaceae

A composite of 3 experimental sites.

analysis as it informs where a particular species is more likely to establish from direct sowing.

Experiment Establishment

To account for potential environmental variation in seed quality, 2 harvests were conducted for each species (in consecutive years where possible) from each of 2 harvest locations. Each year, seeds were pooled. All harvest locations were within 50 km of the experimental sites. Seeds were cleaned (extracted) using standard methods: either by macerating fruit and decanting pulp and skins or by screening and winnowing (Smreciu and others 2013). Cleaned seeds were counted or weighed and separated prior to seeding. Whole fleshy fruits were counted, separated, and stored frozen until sown. Propagules harvested in summer were sown 1 y later in the fall and again the following spring.

Eight replicate 1-m² subplots were sown for each treatment—half in each of 2 y. This procedure resulted in 32 subplots per site for species with fleshy fruit (2 seasons × 2 propagules × 8 replicates) and 16 subplots per site for species with dry seeds (2 seasons × 8 replicates).

Seeding rates varied from 80 seeds/plot for false toadflax to 1000 seeds/plot for minute seeds such as those of roundleaf harebell. Rates can be found in Table 3. For fleshy-fruited

species, the average number of seeds per fruit was used to determine a seeding rate that was equal to the fruit sowing rate. For example, wild sarsaparilla berries contain, on average, 5 seeds; in each plot, 50 fruits or 250 seeds were sown. Most false lily-of-the-valley berries contain only 1 seed, but occasionally 2 or 3 are found; in each of these plots, 100 fruits or 130 seeds were sown. Because of the microscopic size of pink lady's slipper seeds, 1 capsule was broken and the seeds within scattered over the entire plot.

At time of sowing, a garden rake was used to break the soil surface. Seeds (or fruit) were scattered by hand over the entire plot. The back of the rake, or hands, were used to incorporate seeds (or fruit) into the soil, and the plot was tamped to ensure seed-soil contact. Plots were monitored during the first summer (late July or early August) after sowing and in following summers for up to 4 y (depending on species). Each plot was closely examined for seedlings to determine an emergence percentage. In the second season it was difficult or impossible to differentiate new seedlings of some species from previous ones. By the third summer after emergence, however, most of the emergence/survival percentage was survival. Species were not statistically analyzed against one another. Nonetheless, final emergence results may be generally compared to identify species for which broadcasting seeds is an effective way to establish plants on reclaimed substrates in the oil sands.

Data Analysis

A three-way ANOVA was used to analyze species with fleshy fruit and a two-way ANOVA for those with dry fruit. Sowing season and experimental site (and propagule type for fleshy-fruited species) were each tested for significance with interactions. For season and propagule type, if $P < 0.05$ the treatment was deemed significant. When experimental site was found to be significant, a post hoc test (Tukey HSD) was used to determine which sites were significantly different from one another.

When significant interactions were observed between controlled independent variables (season or propagule) and uncontrolled independent variables (experimental site), each site was examined individually. This experiment was designed not to analyze the effect of site on emergence, but rather, emergence in more ideal or less ideal conditions was observed and acknowledged.

RESULTS AND DISCUSSION

Note that although we did not specifically evaluate site as an independent variable, experimental site was a significant factor for many of the species. Generally, seedlings emerged in greater proportions at AFH than at ML. This trend was likely attributable to higher average soil temperatures (see Table 2) resulting from the coarse-grained soils and the south-facing slopes at

TABLE 2

Experimental site descriptions.

Experimental site Latitude (N) Longitude (W)	Capping depth	Planting prescription	Stems/ha	Soil texture and pH	Aspect/slope	Average soil temperature
Mildred Lake ML 57.017694 111.729889	110 cm (top 14 cm peat only)	trembling aspen ^z white spruce ^y green alder	1360 670 250	Clay to clay loam 7.2–7.8	North face, slight slope	13.5 °C
Aurora Fort Hills AFH 57.330389 111.532889	90 cm	trembling aspen white spruce prickly rose Saskatoon serviceberry	882 1218 230 321	Loamy sand to sandy loam 7.4–7.6	South face, significant slope	16.3 °C
Suncor Steepbank SS 56.899111 111.402019	28 cm Fertilized: 23.5N: 25P ₂ O ₅ : 8K ₂ O 200 kg/ha	trembling aspen white spruce paper birch squashberry pin cherry chokecherry green alder Saskatoon serviceberry Plowed before sown	3062 Over all species	Sandy loam to sandy clay loam Average pH 7.29	Nearly flat	15.2 °C

^z trembling aspen = *Populus tremuloides* Michx. (Salicaceae).

^y white spruce = *Picea glauca* (Moench) Voss (Pinaceae).

AFH. The high level of competition resulting from abundant weedy, agronomic species at ML had a negative impact on seedling emergence. Emergence rate at SS was most often found to be somewhere between the other 2.

Each species is presented individually as they were examined separately; however, Table 4 summarizes the statistical interactions and significance.

Bearberry is most often found on well-drained sandy sites and it emerged well at AFH, which has such soils. Emergence at ML and SS, with finer grained material, was so low that any difference among treatments was not statistically significant. This finding resulted in an interaction among sites, propagule types, and sowing seasons (Table 5). When examining emergence recorded only from AFH (Figure 1), both propagule and sowing season significantly affected emergence. Fall-sown, cleaned seeds emerged in significantly greater percentages than did spring-sown whole fruit ($P < 0.05$); however, both spring-sown seeds and fall-sown fruit were not significantly different from any other treatment ($P > 0.05$). Fall sowing and using

cleaned seeds each improve emergence. Therefore, we recommend sowing cleaned seeds in the fall.

Significant interaction occurred between sowing season and site on the emergence of Canada bunchberry. The majority of seedlings observed at AFH were sown in the spring as cleaned seeds, whereas the emergent seedlings at SS were from both seeds and fruit sown in the fall. At all sites emergence was low ($< 0.2\%$; Figure 2). For this reason, neither experimental site nor sowing season nor propagule type significantly affected emergence of Canada bunchberry ($P > 0.05$; Table 6). Canada bunchberry is an understory species that may not perform well on open, disturbed sites. Moreover, further monitoring of these plots may have resulted in greater emergence and more conclusive results.

Chokecherry emergence was statistically affected by experimental site, sowing season, and propagule type, and there was an interaction among the 3 factors. At all 3 sites, spring-sown cleaned seeds emerged in greater proportions than the alternatives; however, at ML the difference between sowing seasons

TABLE 3

Sowing rates for seeds and fruit.

Plant species	Seeds/fruit	Seeds/m ² (average)	Fruit/m ²
American vetch		100	
bare-stem bishop's cap		500	
bearberry	6	300	50
blue honeysuckle	8	160	20
Canada bunchberry	1	100	100
Canada goldenrod		1000	
Canadian needle grass		90	
chokecherry	1	100	100
common snowberry	2	100	50
common red raspberry	37	925	25
cut-leaf anemone		100	
eastern pasqueflower		100	
false lily-of-the-valley		130	100
false melic		100	
false toadflax	1	80	80
fringed brome		100	
gray alder		300	
green alder		300	
Labrador tea		1000	
lingonberry	11	550	50
Mt Albert goldenrod		1000	
northern star flower		300	
paper birch		300	
pin cherry	1	100	100
pink lady's slipper orchid		1 capsule	
prickly rose	53	575	25
Raup's Indian paintbrush		200	
redosier dogwood	1	100	100
roundleaf harebell		1000	
russet buffaloberry	1	100	100
Saskatoon serviceberry	9	450	50
shrubby cinquefoil		500	
shrubby fivefingers		300	
smooth blue aster		500	
spreading dog bane		1000	
squashberry	1	100	100
velvet-leaf blueberry	35	1750	50
western dock		100	
wild sarsparilla	5	250	50
wild strawberry	30	750	25
wood lily		100	

was not significant. Overall emergence was significantly lower at ML ($P < 0.05$) than at either SS or AFH, which were similar ($P > 0.05$; Table 7). An interaction between sowing season and propagule type was the result of significantly greater emergence from spring-sown clean seeds than any other treatment (Figure 3), and this treatment is our recommendation when sowing chokecherry.

Little to no emergence of common snowberry occurred in the first year after sowing. After 2 winter seasons, however, snowberry seedlings were observed at all 3 experimental sites. Snowberry species are known to be difficult to germinate; they can have impermeable seedcoats, which benefit from scarification, as well as embryo dormancy, which can be overcome by a combination of warm and cold stratification (Young and Young 1992). Both site and propagule type significantly affected emergence ($P < 0.05$), and these 2 interacted statistically. At all 3 sites, emergence from clean seeds was greater than from whole fruit. Season did not significantly affect emergence at any site as seeds planted in both fall and spring were subjected to a warm and cold period prior to germination in the second season. Emergence of snowberry at AFH was significantly greater than at SS ($P < 0.05$), which was significantly greater than at ML ($P < 0.05$; Table 8), but the trend at all 3 sites was the same (Figure 4). We recommend sowing cleaned seeds in either spring or fall.

Seedlings of common red raspberry emerged at all 3 experimental sites with significantly greater emergence at AFH ($P < 0.05$) than at SS, which had significantly greater emergence than at ML ($P < 0.05$). This finding resulted in a statistical interaction between site, propagule type, and sowing season (Table 9). Emergence from fall-sown cleaned seeds at AFH (4–6%; Figure 5) was so much greater than other treatment combinations, which were not significantly different from one another, and is therefore suggested as a best practice.

Only 3 y of data were available for prickly rose. Seedling emergence varied statistically among experimental sites with significantly lower emergence at AFH ($P < 0.05$) than at SS or ML, which were statistically similar ($P > 0.05$; Table 10). There was an interaction between propagule type and experimental site, likely a result of the reduced emergence on AFH. Extracted seeds emerged well, particularly following at least 1 winter season (Figure 6), significantly more than from entire hips ($P < 0.05$). Sowing season was not significant and did not result in any statistical interactions ($P > 0.05$). Some of the emergent seedlings on SS were bearing fruit, indicating that in just a few years, prickly rose can be established and reproductive from seeds. Sowing cleaned seeds in spring or fall is recommended.

Redosier dogwood emergence varied among experimental sites (Figure 7) and among treatments, resulting in a statistical interaction. Because experimental site is an independent and uncontrollable variable, we analyzed the treatments at each site separately. Significantly higher proportions of seedlings

TABLE 4

Summary of results.

Plant species	Site interaction	Site significance	Season interaction	Season significance	Propagule interaction	Propagule significance
bearberry	Yes	AFH>ML=SS	Yes	Fall>Spring	Yes	Seeds>Fruit
Canada bunchberry	Yes	No	Yes	No	No	No
chokecherry	Yes	AFH=SS>ML	Yes	Spring>Fall	Yes	Seeds>Fruit
common snowberry	No	AFH>SS>ML	No	No	Yes	Seeds>Fruit
common red raspberry	Yes	AFH>SS>ML	Yes	Fall>Spring	Yes	Seeds>Fruit
prickly rose	Yes	AFH>SS=ML	No	No	Yes	Seeds>Fruit
redosier dogwood	Yes	AFH=SS>ML	Yes	Spring>Fall	Yes	Seeds>Fruit
russet buffaloberry	Yes	AFH=SS>ML	Yes	Fall>Spring	Yes	Fruit>Seeds
Saskatoon serviceberry	Yes	AFH>SS=ML	Yes	No	Yes	Seeds>Fruit
squashberry	Yes	AFH>SS=ML	No	No	Yes	Fruit>Seeds
wild strawberry	Yes	AFH>SS>ML	Yes	Fall>Spring	Yes	Seeds>Fruit
pin cherry	Yes	AFH>SS=ML	Yes	No	Yes	Seeds>Fruit
American vetch	No	AFH=SS<ML	No	No	No	No
Canada needle grass	No	AFH>SS>ML	No	No	—	—
cut-leaf anemone	No	AFH>SS=ML	No	No	—	—
eastern pasqueflower	Yes	AFH>SS=ML	Yes	Spring>Fall	—	—
fringed brome	No	No	Yes	Inconclusive ^z	—	—
smooth blue aster	No	AFLML	No	Fall>Spring	—	—
Canada goldenrod	No	AFH>SS=ML	No	No	—	—
Mt Albert goldenrod	Yes	AFH>SS=ML	Yes	Spring>Fall	—	—
Raup's Indian paintbrush	No	AFH>SS=ML	No	No	—	—
shrubby cinquefoil	No	AFH<ML<SS	No	Fall<Spring	—	—

^z Change of season mid-experiment, see fringed brome.

Bearberries growing on sand.

established from seeds than from fruit ($P < 0.05$) at all sites, but season was only significant at AFH (Table 11). Where season was significant, spring-sown seeds emerged best and would be our recommended practice.

Russet buffaloberry emergence was significantly lower at ML ($P < 0.05$) than at SS or AFH, which were statistically similar to one another ($P > 0.05$; Table 12). A statistical interaction presented different responses to the tested variables at each site, and therefore each site was analyzed separately (Figure 8). At AFH, both sowing season and propagule type had a significant effect on seedling emergence, such that the best emergence percentages were obtained from fall-sown fruit ($P < 0.05$). This may be attributable to very early drying of the exposed soils, or the fall-sown fruit may take advantage of the late winter moisture that would have disappeared prior to spring sowing. At SS, the best emergence percentages resulted from sowing fruits ($P < 0.05$) regardless of the season. At ML, neither sowing season nor propagule type significantly affected emergence ($P > 0.05$).

TABLE 5

Bearberry ANOVA.

	Df	Sum square ($\times 10^{-4}$)	Mean square ($\times 10^{-4}$)	F Value	Pr(>F)	Significance
Season	1	0.48	0.48	6.09	0.014	Fall>Spring
Propagule	1	2.35	2.35	29.58	< 0.001	Seed>Fruit
Site	2	11.69	5.84	73.68	< 0.001	AFH>ML=SS
Season: Propagule	1	0.02	0.02	0.28	0.597	
Season: Site	2	0.72	3.61	4.56	0.011	
Propagule: Site	2	3.06	1.50	18.95	< 0.001	
Seas: Prop: Site	2	0.02	0.01	0.10	0.901	
Residuals	393	31.17	0.08

Figure 1. Bearberry emergence at AFH. Bars with the same letter are not significantly different ($P > 0.05$).

Figure 2. Canada bunchberry emergence. Season and propagule type are not significant. Emergence at AFH tends to spring-sown seeds (blue bars) whereas emergence at SS was primarily from fall-sown fruit and seeds (red and green bars).

TABLE 6

Canada bunchberry ANOVA.

	Df	Sum square ($\times 10^{-4}$)	Mean square	F value	Pr(>F)	Significance
Season	1	< 0.01	0.04	0.03	0.876	Not significant
Propagule	1	0.23	2.32	1.30	0.255	Not significant
Site	2	1.04	5.19	2.91	0.056	Not significant
Season: Propagule	1	0.34	3.41	1.91	0.168	
Season: Site	2	1.35	6.75	3.79	0.024	
Propagule: Site	2	0.82	4.10	2.30	0.102	
Seas: Prop: Site	2	0.38	1.90	1.07	0.346	
Residuals	321	57.25	1.78			

TABLE 7

Chokecherry ANOVA.

	Df	Sum square	Mean square ($\times 10^{-2}$)	F Value	Pr(>F)	Significance
Season	1	0.164	16.44	67.78	< 0.001	Spring>Fall
Propagule	1	0.068	3.39	13.99	< 0.001	Seed<Fruit
Site	2	0.041	4.06	16.74	< 0.001	AFH>SS>ML
Season: Propagule	1	0.014	0.70	2.87	0.058	
Season: Site	2	0.035	3.47	14.32	< 0.001	
Propagule: Site	2	0.006	0.28	1.15	0.317	
Seas: Prop: Site	2	0.089	4.46	18.39	< 0.001	
Residuals	396	0.961	0.24

Figure 3. Average chokecherry emergence at AFH, SS, and ML. Bars with the same letter are not significantly different ($P > 0.05$).

Figure 4. Average common snowberry emergence at AFH, SS, and ML. Bars with the same letter are not significantly different ($P > 0.05$).

TABLE 8

Common snowberry ANOVA.

	Df	Sum square ($\times 10^{-4}$)	Mean square ($\times 10^{-4}$)	F Value	Pr(>F)	Significance
Season	1	1.80	1.79	0.20	0.653	Not significant
Propagule	1	33.01	33.01	37.44	< 0.001	Seed>Fruit
Site	2	36.03	18.01	20.43	< 0.001	AFH>SS>ML
Season: Propagule	1	15.20	1.52	1.72	0.190	
Season: Site	2	12.50	0.62	0.71	0.494	
Propagule: Site	2	18.13	9.06	10.28	< 0.001	
Seas: Prop: Site	2	2.02	1.01	1.15	0.318	
Residuals	396	349.15	0.88			

TABLE 9

Red raspberry ANOVA.

	Df	Sum square ($\times 10^{-3}$)	Mean square ($\times 10^{-3}$)	F Value	Pr(>F)	Significance
Season	1	2.59	2.59	10.15	0.002	Fall>Spring
Propagule	1	1.01	1.01	3.96	0.047	Seed>Fruit
Site	2	30.19	15.09	59.13	< 0.001	AFH>SS>ML
Season: Propagule	1	2.40	2.40	9.39	0.002	
Season: Site	2	4.82	2.41	9.44	< 0.001	
Propagule: Site	2	2.07	1.03	4.05	0.018	
Seas: Prop: Site	2	5.10	2.55	9.99	< 0.001	
Residuals	396	101.08	0.26

Figure 5. Common red raspberry emergence/survival at AFH. Bars with the same letter are not significantly different ($P > 0.05$).

Prickly rose in bloom.

TABLE 10

Prickly rose ANOVA.

	Df	Sum square ($\times 10^{-3}$)	Mean square ($\times 10^{-3}$)	F Value	Pr(>F)	Significance
Season	1	0.40	0.40	0.83	0.362	Not significant
Propagule	1	41.60	41.60	86.90	< 0.001	Seed>Fruit
Site	2	3.75	1.87	3.91	0.021	AFH>SS=ML
Season: Propagule	1	0.07	0.07	0.15	0.190	
Season: Site	2	0.30	0.15	0.31	0.494	
Propagule: Site	2	8.04	4.02	8.39	4.43	
Seas: Prop: Site	2	0.69	0.34	0.72		
Residuals	361	172.90	0.48

Figure 6. Average prickly rose emergence at AFH, SS, and ML. Bars with the same letter are not significantly different ($P > 0.05$).

Figure 7. Redosier dogwood emergence at AFH, SS, and ML. Each group of 4 bars is a subsequent growing season, from initial through fourth. At each experimental site, bars with the same letter are not statistically different ($P > 0.05$).

TABLE 11

Redosier dogwood ANOVA.

	Df	Sum square	Mean square	F Value	Pr(>F)	Significance
Season	1	0.061	0.061	10.86	0.001	Spring<Fall
Propagule	1	0.214	0.214	38.25	< 0.001	Seed>Fruit
Site	2	0.057	0.029	5.13	0.006	AFH=SS>ML
Season: Propagule	1	0.057	0.057	10.18	0.002	
Season: Site	2	0.031	0.015	2.73	0.664	
Propagule: Site	2	0.082	0.041	7.29	0.008	
Seas: Prop: Site	2	0.017	0.008	1.52	0.221	
Residuals	396	2.214	0.006			

The increased competition at ML was most likely responsible for the reduced emergence and survival. SS, being relatively flat with a moderate cover, may have provided the most ideal moisture and cover conditions of the 3 experimental sites, and when this was the case, emergence from fruit was not affected by sowing season.

Sowing season did not significantly affect emergence/survival percentages ($P < 0.05$) of Saskatoon serviceberry. Clean seeds resulted in greater emergence/survival at all 3 experimental sites; however, statistical interactions were found between propagule type and both sowing season and experimental site. A significantly greater proportion of seeds emerged at AFH ($P < 0.05$) than at either ML or SS, which were not significantly different from one another ($P > 0.05$; Table 13). Initial emergence from fall-sown seeds is a reflection of this species' requirement for a stratification period (Young and Young 1992).

In the second year (following a winter in the ground), enough spring-sown seeds emerged to render sowing season not statistically significant ($P > 0.05$; Figure 9). Fall or spring sowing of cleaned seeds is recommended.

Squashberry has a complex dormancy that requires a combination of warm and cold stratification between 3 and 5 mo for each treatment (Luna 2008). Not surprisingly, seedlings

were not observed in the first year after sowing. In the second growing season, seedlings were found at 2 of the 3 sites. Significantly more seedlings emerged at AFH ($P < 0.05$), and emergence at ML remained low enough to be statistically similar to SS where no seedlings emerged ($P > 0.05$; Table 14). The result was an interaction between experimental site and propagule. To simplify analysis, AFH emergence was analyzed separately (Figure 10). There was a similar trend at ML, but with much lower percentages. Season of sowing did not significantly affect emergence ($P > 0.05$); however, whole fruits emerged in significantly greater proportions than from clean seeds ($P < 0.05$), a characteristic that was anecdotally reported for the closely related European cranberrybush (*Viburnum opulus* L. [Adoxaceae]) (Smreciu and Barron 1997). We recommend that whole fruit be sown directly in either spring or fall.

Experimental site, sowing season, and propagule type all significantly affected the emergence of wild strawberry. Additionally, propagule type interacted statistically with both sowing season and site, so each experimental site was analyzed separately. In part because of lower percentages, neither season nor propagule had a significant effect on emergence at ML ($P > 0.05$; Table 15). At SS, as exemplified in Figure 11, fall-sown seeds emerged in the highest percentages, significantly better than fall-sown fruit ($P < 0.05$). At AFH, the difference in emergence between fall-sown seeds and fall-sown fruit was not significant ($P > 0.05$). Emergence was significantly higher at AFH when compared to ML ($P < 0.05$), but SS was not significantly different from either ($P > 0.05$). Regardless, at all sites wild strawberry established and produced runners. Our seeding rate of approximately 3 kg/ha was more than sufficient to establish a 40% cover. A more practical seeding rate would be

Figure 8. Russet buffaloberry emergence at AFH, SS, and ML. Each group of 4 bars is a subsequent growing season, from initial through fourth. At each experimental site, bars with the same letter are not statistically different ($P > 0.05$).

TABLE 12

Russet buffaloberry ANOVA.

	Df	Sum square ($\times 10^{-3}$)	Mean square ($\times 10^{-3}$)	F Value	Pr(>F)	Significance
Season	1	3.99	3.99	6.17	0.013	Fall>Spring ^z
Propagule	1	11.65	11.65	18.02	< 0.001	Fruit>Seed ^z
Site	2	8.96	4.48	6.94	0.001	AFH=SS>ML
Season: Propagule	1	0.37	0.37	0.57	0.449	
Season: Site	2	1.66	0.83	1.29	0.278	
Propagule: Site	2	7.43	3.71	5.75	0.003	
Seas: Prop: Site	2	2.79	1.40	2.16	0.117	
Residuals	396	255.92	0.65			

^z Significance varies among sites.

TABLE 13

Saskatoon serviceberry ANOVA.

	Df	Sum square ($\times 10^{-3}$)	Mean square ($\times 10^{-3}$)	F Value	Pr(>F)	Significance
Season	1	1.03	1.03	2.11	0.147	Not significant
Propagule	1	38.80	38.60	79.55	< 0.001	Seed>Fruit
Site	2	3.06	1.53	3.14	0.044	AFH>SS=ML
Season: Propagule	1	2.78	2.78	5.69	0.018	
Season: Site	2	0.04	0.02	0.04	0.965	
Propagule: Site	2	4.27	2.13	4.37	0.013	
Seas: Prop: Site	2	0.65	0.33	0.67	0.514	
Residuals	396	193.16	0.49

Figure 9. Average Saskatoon serviceberry emergence at AFH, SS, and ML. Bars with the same letter are not significantly different ($P > 0.05$).

0.5 kg/ha. To maximize establishment success, seeds or fruit should be sown in the fall.

No emergent pin cherry was found at ML, and emergence was so low at SS as to be significantly similar ($P > 0.05$; Table 16), which resulted in an interaction between site and both sowing season and propagule. To eliminate some interaction, we examined emergence at AFH (Figure 12) separately. Of the 3 sites, AFH has conditions most similar to those of natural pin cherry stands (that is, coarse-textured, well-drained soils). In this instance, emergence from seeds was significantly higher than from whole drupes ($P < 0.05$), and season of sowing did not affect emergence ($P > 0.05$). We recommend sowing cleaned seeds in the spring and to target sites with coarse-textured substrate.

American vetch emerged at all 3 experimental sites. Emergence percentages were significantly higher ($P < 0.05$) at ML (average 4.00%) than at either SS (0.57%) or AFH (0.11%),

TABLE 14

Squashberry ANOVA.

	Df	Sum square ($\times 10^{-3}$)	Mean square ($\times 10^{-3}$)	F Value	Pr(>F)	Significance
Season	1	< 0.01	0.02	0.01	0.909	Not significant
Propagule	1	5.93	5.93	32.65	< 0.001	Fruit>Seed
Site	2	8.04	4.02	22.15	< 0.001	AFH>SS=ML
Season: Propagule	1	0.01	0.01	0.07	0.787	
Season: Site	2	0.01	0.01	0.04	0.966	
Propagule: Site	2	7.58	3.79	20.89	< 0.001	
Seas: Prop: Site	2	0.04	0.02	0.10	0.907	
Residuals	396	71.88	0.18

Figure 10. Squashberry emergence at AFH. Bars with the same letter are not significantly different ($P > 0.05$).

Diminutive ripe fruit of a wild strawberry.

TABLE 15

Wild strawberry ANOVA.

	Df	Sum square ($\times 10^{-3}$)	Mean square ($\times 10^{-3}$)	F Value	Pr(>F)	Significance
Season	1	16.07	16.07	10.55	0.001	Fall>Spring
Propagule	1	25.45	25.45	16.69	< 0.001	Seed>Fruit
Site	2	11.93	5.97	3.91	0.021	AFH $\geq$ SS $\geq$ ML
Season: Propagule	1	21.70	21.70	14.24	< 0.001	
Season: Site	2	3.70	1.85	1.21	0.300	
Propagule: Site	2	15.65	7.83	5.13	0.006	
Seas: Prop: Site	2	3.85	1.93	1.26	0.280	
Residuals	324	493.83	1.52

Figure 11. Wild strawberry emergence at AFH, SS, and ML. Each group of 4 bars is a subsequent growing season, from initial through fourth. At each experimental site, bars with the same letter are not statistically different ($P > 0.05$).

TABLE 16

Pin cherry ANOVA.

	Df	Sum square ($\times 10^{-3}$)	Mean square ($\times 10^{-3}$)	F Value	Pr(>F)	Significance
Season	1	0.37	0.37	3.26	0.072	Not significant
Propagule	1	1.99	1.99	17.46	< 0.001	Seed>Fruit
Site	2	12.17	6.09	53.52	< 0.001	AFH>SS=ML
Season: Propagule	1	1.71	1.71	15.01	< 0.001	
Season: Site	2	0.53	0.26	2.32	0.100	
Propagule: Site	2	3.20	1.60	14.06	< 0.001	
Seas: Prop: Site	2	2.12	1.06	9.31	< 0.001	
Residuals	396	45.03	0.11			

which were not significantly different from one another ($P > 0.05$). Site did not interact with sowing season ($P > 0.05$), and sowing season did not significantly affect emergence ($P > 0.05$; Table 17). By the fourth growing season the number of plants had declined, suggesting that plants were not reproducing. This ubiquitous species could be important for reclamation of highly disturbed areas because of its nitrogen-fixing capability. Its failure to emerge in large numbers could be attributable to its hard seedcoat, so perhaps it should be treated prior to sowing. This species can be produced agronomically (Pahl and Smreciu 1999). Further study with scarified seeds could yield a more precise recommendation.

Canada needle grass emerged in greatest proportions at AFH (3.32% on average). This site was the most similar of the 3 experimental sites to the sandy, south-facing slopes from which seeds were harvested. Emergence at ML (0.41%) was

Figure 12. Pin cherry emergence at AFH. Bars with the same letter are not significantly different ($P > 0.05$).

TABLE 17

American vetch ANOVA.

	Df	Sum square ($\times 10^{-3}$)	Mean square ($\times 10^{-3}$)	F Value	Pr(>F)	Significance
Season	1	0.03	0.03	0.01	0.921	Not significant
Site	2	58.20	29.10	9.06	< 0.001	AFH=SS<ML
Season: Site	2	1.07	0.54	0.17	0.846	
Residuals	198	635.85	3.21			

TABLE 18

Canada needle grass ANOVA.

	Df	Sum square ($\times 10^{-3}$)	Mean square ($\times 10^{-3}$)	F Value	Pr(>F)	Significance
Season	1	0.15	0.15	0.17	0.681	Not significant
Site	2	29.31	14.65	16.31	< 0.001	AFH $\geq$ SS $\geq$ ML
Season: Site	2	2.52	1.26	1.40	0.249	
Residuals	162	145.56	0.90			

TABLE 19

Cutleaf anemone ANOVA.

	Df	Sum square ($\times 10^{-3}$)	Mean square ($\times 10^{-3}$)	F Value	Pr(>F)	Significance
Season	1	0.01	0.01	0.01	0.938	Not significant
Site	2	23.31	11.66	12.35	< 0.001	AFH>SS=ML
Season: Site	2	2.67	1.34	1.42	0.245	
Residuals	198	186.81	0.94			

significantly less ($P < 0.05$) than at AFH, and emergence at SS (3.09%) was not significantly different from either ($P > 0.05$; Table 18). Experimental site did not statistically interact with sowing season, and season of sowing did not significantly affect emergence ($P > 0.05$). Although emergence in the first season was low, it increased in the following years. This trend reflects the results of our germination testing (Smreciu and Gould 2009), in which seeds of this species were found to benefit from a year of ambient storage, or after-ripening. Within 3 y of sowing, Canada needle grass was reproductive, spreading by seeds, and we recommend sowing this species on similar sites.

Cutleaf anemone emerged in significantly higher proportions at AFH (2.60% on average) than at either SS (0.71%) or ML (0.13%, $P < 0.05$), but did not interact statistically with sowing season (Table 19). Seeds sown in the spring were equally likely to emerge as those sown in the fall ($P > 0.05$). This finding was expected as natural seed dispersal occurs

early, and seeds do not require cold stratification (Smreciu and Gould 2009). We recommend sowing this species on similar sites (coarse, exposed soils).

Eastern pasqueflower seedlings emerged at all 3 experimental sites but in significantly higher percentages at AFH ($P < 0.05$) than at either ML or SS, which were not significantly different from one another ($P > 0.05$; Table 20). A statistical interaction was found between site and sowing season, resulting in significantly greater emergence from seeds sown in the spring ($P < 0.05$) at AFH, and no sowing season significance at the other 2 sites. To demonstrate the difference between fall and spring sowings, Figure 13 presents data from AFH alone. Although seeds from both sowing seasons emerged in roughly equal proportions for the first year, spring-sown seeds continued to emerge in the second and third growing seasons whereas emergence/survival of seedlings from fall-sown seeds began to decline. Late spring or early summer is the natural

Eastern pasqueflower seedlings.

Figure 13. Eastern pasqueflower emergence at AFH. Bars with the same letter are not significantly different ($P > 0.05$).

TABLE 20

Eastern pasqueflower ANOVA.

	Df	Sum square ($\times 10^{-3}$)	Mean square ($\times 10^{-3}$)	F Value	Pr(>F)	Significance
Season	1	0.56	0.56	3.99	0.047	Spring>Fall
Site	2	6.07	3.03	21.66	< 0.001	AFH>SS=ML
Season: Site	2	1.32	0.66	4.72	0.010	
Residuals	198	27.72	0.14			

TABLE 21

Fringed brome ANOVA.

	Df	Sum square ($\times 10^{-3}$)	Mean square ($\times 10^{-3}$)	F Value	Pr(>F)	Significance
Season	1	34.97	34.97	9.52	0.002	Variable
Site	2	4.57	2.28	0.62	0.540	Not significant
Season: Site	2	0.42	0.21	0.06	0.940	
Residuals	185	679.47	3.67			

dispersal time for this species, often prior to the end of June. We recommend spring sowing.

Fringed brome emerged well and grew quickly. We found no significant difference in emergence among the 3 experimental sites ($P > 0.05$; Table 21) and no interaction between variables. Fringed brome can successfully establish by the end of a third growing season and can begin spreading by means of both tillers and seeds. Oddly, although fall-sown seeds emerged in significantly larger proportions ($P < 0.05$) in the third growing season, by the fourth growing season we observed the reverse

(Figure 14). Fringed brome seeds lose viability relatively quickly (Schultz and others 2001; Smreciu and Gould 2009), therefore, individuals monitored in the fourth season were most likely offspring of seeds produced in previous years. We have no explanation for the increased proliferation of seedlings in spring-sown plots over those sown in the fall. Despite these strange observations, fringed brome is an excellent species for broadcast sowing. Its rapid development is ideal for erosion control. It is also possible to multiply seeds using agronomic practices (Pahl and Smreciu 1999). A sowing rate of 1.9 kg/ha

Figure 14. Average fringed brome emergence/survival at AFH, SS, and ML. Bars with the same letter are not significantly different ($P > 0.05$).

Figure 15. Average smooth blue aster emergence/survival at AFH, SS, and ML. Bars with the same letter are not significantly different ($P > 0.05$).

TABLE 22

Smooth blue aster ANOVA.

	Df	Sum square ($\times 10^{-3}$)	Mean square ($\times 10^{-3}$)	F Value	Pr(>F)
Season	1	13.68	13.68	4.52	0.035
Site	2	36.02	18.01	5.94	0.003
Season: Site	2	5.41	2.70	0.89	0.412
Residuals	162	490.67	3.03		

is sufficient for 10% cover, and this seeding rate can be adjusted based on the intended final cover.

Smooth blue aster emerged in significantly higher percentages at SS ($P < 0.05$) than at either AFH or ML, which were not statistically different from one another ($P > 0.05$; Table 22). No interaction was found between experimental site and sowing season. Fall-sown seeds emerged in significantly greater percentages ($P < 0.05$; Figure 15) at all 3 experimental sites. Germination testing indicated that this species does not require cold stratification (Smreciu and others 2013); however, in this trial, fall sowings were significantly more successful than spring sowings. Although no flowering was observed, seedlings continued to emerge for up to 3 y after sowing. Because of a lack of observed flowering stems, it is unclear if our seeding rate of 10 kg/ha is sufficient to start spread.

Emergence of Canada goldenrod was significantly ($P < 0.05$) higher at AFH (0.27% on average) than at either ML (0.01%) or SS (0.20%), which were not significantly different from one another ($P > 0.05$; Table 23). Experimental site did not interact with sowing season ($P > 0.05$), and both spring- and fall-sown seeds emerged equally well ($P > 0.05$), as would be expected

since no stratification is required (Smreciu and others 2013). Only 3 y of data are available for this species as lack of seed availability delayed sowing the replicate year. Based on seed weight, our seeding rate was approximately 11 kg/ha, but we recommend a higher seeding rate, > 20 kg/ha, to ensure enough flowering stems for establishment.

Mt Albert goldenrod emerged in greatest percentages at AFH ($P < 0.05$; Table 24), a reflection of its preference for coarse-textured soils and open sites. A statistical interaction was observed between season and site. Spring-sown seeds emerged in greater percentages than did seeds sown in the fall ($P < 0.05$), but this difference was only statistically significant at AFH (Figure 16). Emergence percentages at ML and SS were not significantly different from one another ($P > 0.05$). We recommend this species be sown in the spring. Like Canada goldenrod, Mt Albert goldenrod should be sown at a higher rate, > 20 kg/ha.

Raup's Indian paintbrush emergence was very low (0.06% maximum); however, blooming individuals, observed as soon as 1 y after sowing, began dispersing seeds. Seedlings emerged in significantly greater percentages ($P < 0.05$) at AFH than at SS or ML, which were statistically similar (Table 25). Although cold stratification is recommended for germination (Smreciu and others 2013), sowing season did not significantly affect emergence ($P > 0.05$). No interaction was observed between sowing season and experimental site. Our sowing rate of < 1 kg/ha was sufficient to establish on 1 site; however, > 5 kg/ha would improve the chances of establishing enough individuals to start spreading.

Both sowing season and experimental site significantly affected emergence of shrubby cinquefoil; however, no statistical interaction occurred between these variables ($P > 0.05$; Table 26). Fall-sown seeds emerged in significantly greater percentages at all sites ($P < 0.05$; Figure 17), as could be predicted from the requirement this species has for cold stratification (Smreciu

TABLE 23

Canada goldenrod ANOVA.

	Df	Sum square ($\times 10^{-3}$)	Mean square ($\times 10^{-4}$)	F Value	Pr(>F)	Significance
Season	1	0.02	0.23	1.80	0.181	Not significant
Site	2	0.22	1.12	8.61	< 0.001	AFH>SS=ML
Season: Site	2	0.02	0.09	0.70	0.496	
Residuals	186	2.42	0.13			

TABLE 24

Mt Albert goldenrod ANOVA.

	Df	Sum square ($\times 10^{-3}$)	Mean square ($\times 10^{-3}$)	F Value	Pr(>F)	Significance
Season	1	7.92	7.93	15.60	< 0.001	Spring>Fall
Site	2	32.21	16.11	31.70	< 0.001	AFH>SS=ML
Season: Site	2	4.72	2.36	4.64	0.011	
Residuals	198	100.59	0.51			

TABLE 25

Raup's Indian paintbrush ANOVA.

	Df	Sum square ($\times 10^{-3}$)	Mean square ($\times 10^{-3}$)	F Value	Pr(>F)	Significance
Season	1	0.003	0.003	0.06	0.812	Not significant
Site	2	0.722	0.361	6.25	0.002	AFH>SS=ML
Season: Site	2	0.050	0.025	0.43	0.648	
Residuals	198	11.450	0.058

Figure 16. Mt Albert goldenrod emergence at AFH. Bars with the same letter are not significantly different ($P > 0.05$).

and others 2013). Emergence was lower at AFH than at SS with emergence at ML statistically similar to both. In the first season, emergent seedlings were very small (< 1 cm in height), which likely contributed to their failure to survive over winter. There was little to no decline in survival after the first season, once seedlings had grown beyond the vulnerable 3 to 8 leaf stage. As early as the second year after sowing, flowering began, making reproduction and spread in the near future possible and indicating that our seeding rate of 10 kg/ha may be sufficient when sown in the fall on appropriate sites.

Some species failed to emerge in our study, and a few emerged in such small percentages that statistical analysis was not feasible (less than 5 individuals among all sites and treatments). The latter included false lily-of-the valley, false melic, paper birch, roundleaf harebell, and shrubby five-fingers. Previous work with these species indicates that generally seeds are

Shrubby cinquefoil emerging on Aurora.

viable and germinate well when given appropriate treatments (Smreciu and others 2013). Species that failed to emerge at any site include many typically found in late seral communities, such as bare-stem bishop's cap and wild sarsaparilla, which occur under closed canopy mixed wood, and false toadflax, velvet-leaf blueberry, and lingonberry, which grow naturally under pine. Labrador tea is generally found in bogs, and gray alder in riparian areas, neither of which conditions were represented at our experimental sites. Pink lady's slipper is rare in Alberta and is likely to be disturbed by mining operations because it is found in bituminous areas. This orchid, like many others, has complicated germination requirements (Anderson 1989) and a growth cycle that likely involves a requirement for specific mycorrhizal symbionts (Smreciu and Currah 1989). Northern star flower and blue honeysuckle are found along the margins of forests and, in the case of blue honeysuckle, wet areas. Green alder is found in a variety of habitats, both as an understory species and in open areas. Although it is a prolific

TABLE 26

Shrubby cinquefoil ANOVA.

	Df	Sum square ($\times 10^{-3}$)	Mean square ($\times 10^{-3}$)	F Value	Pr(>F)	Significance
Season	1	15.57	15.57	21.42	< 0.001	Spring>Fall
Site	2	6.01	3.01	4.13	0.017	AFH<ML<SS
Season: Site	2	1.86	0.93	1.28	0.280	
Residuals	197	143.22	0.73

Figure 17. Average shrubby cinquefoil emergence at AFH, SS, and ML. Bars with the same letter are not significantly different ($P > 0.05$).

seed producer and plants are easily produced in a nursery and (or) greenhouse, it does not appear to be well suited for broadcast seeding.

A few early seral herbaceous species did not emerge in this experiment. Wood lily, spreading dogbane, and western dock are all found naturally in open areas, often at the edges of forests and along roadsides. Previous work with wood lily has shown it to germinate and emerge at disturbed sites in the same region as this experiment (Smreciu and Gould 2009). Lawrence and Leighton (1999) reported that although this species usually germinates under light conditions, some seeds seem to require complete darkness—a condition that would not have been met in this experiment. It is possible the seeding rate in this study was too low, not reflecting the thousands of seeds produced by a few stems.

Seeding rates in this experiment are much higher than greenhouse cavity fill rates (usually about 2–4 seeds/cavity), but direct seeding can eliminate costs associated with greenhouse production, transportation, and subsequent planting. This is particularly the case with species such as wild strawberry and fringed brome, which both establish and provide cover on an exposed site in just 1 to 3 y. Many more species (purple paintbrush, both goldenrods, smooth blue aster, prickly rose, shrubby cinquefoil, and Canada needlegrass) were seen to be

reproductive within 4 y, and ideal cover may be only a matter of time and seeding rate. Perhaps most important, many of the herbaceous species can be multiplied quickly using agronomic methods. All produce ample seeds such that wild harvest, year after year, would not be necessary. This would put less strain on undisturbed or lightly disturbed areas as well as provide a steady supply of seeds.

Paper birch, gray alder, and green alder are prolific seed producers, and seeds germinate and emerge well in greenhouse situations. Perhaps direct sowing of these species may be more successful when snow is on the ground, which would more closely emulate conditions of natural seed drop and emergence.

Of particular interest is that seeding the entire fruit of low-bush cranberry was more successful than sowing extracted and cleaned seeds. This circumstance has been reported previously (Smreciu and Barron 1997) for the related high-bush cranberry, and further study of this species is warranted. Low-bush cranberry is difficult to grow in a nursery setting (Barry Wood, personal communication; Paulus Vrijmoed, personal communication) where the ratio of seeds sown/seedlings emerging is very high.

SUMMARY

Many shrubs are not prolific seed producers (particularly those with fleshy fruit) when compared with herbaceous plants. As such, seeds can often be limiting. Direct sowing of this valuable resource should be considered carefully and perhaps sown using a seeder or seed drill that can place seeds at appropriate depths for maximum utilization of moisture. Broadcast sowing is better suited to herbaceous and graminoid species that produce plenty of seeds and are adapted to wind dispersal.

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