FIRST YEAR RESULTS OF REVEGETATION TRIALS USING SELECTED NATIVE PLANT SPECIES ON A SIMULATED PIPELINE TRENCH, FORT NORMAN, N.W.T., CANADA[1]

by
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Abstract. The following revegetation treatments using locally-collected native species and commercially-available native cultivars were seeded with and without fertilizer onto a simulated pipeline trench: local treatments - *Arctagrostis latifolia, Carex membranacea, Arctostaphylos rubra, Betula glandulosa, Empetrum nigrum, Ledum groenlandicum,* and *Vaccinium uliginosum*; commercial treatments - Alyeska polargrass, *Artemesia Tilesii* and *Calamagrostis canadensis*, and Decora seed mix (*Agropyron violaceum, Festuca ovina, Poa alpina, P. glauca*). *Epilobium angustifolium* rhizomes were also planted. *B. glandulosa* and *L. groenlandicum* seeds germinated well but remained as seedlings during the first growing season. *C. membranacea* and the other shrub species did not germinate. Based on above-ground production, fertilized Alyeska polargrass performed better than all other treatments and was the only treatment to respond to fertilizer. The other cultivated and locally-collected herbaceous species all established well and had similar but low above-ground production.

Additional Key Words: biomass, commercial seed, fertilizer, reclamation, revegetation, Subarctic.

Introduction

Depending on site characteristics and programme objectives, the use of native plant species in northern revegetation programmes is now often recommended (Mitchell 1982; McKendrick *et al.* 1984; Elliot *et al.* 1987; Johnson 1987), but seldom implemented, despite the fact that several plant species native to the North have been identified as suitable candidates for revegetation (Chapin and Chapin 1980; Miller *et al.* 1983; Cargill and Chapin 1987; Kershaw and Kershaw 1987; Mitchell 1987; Vaartnou 1988). Reasons cited for this usually include the lack of commercially available seed and slow rates of establishment. Attention is now focusing on producing a readily-available stock of native seeds for commercial purposes and several cultivars of northern species are now available (Mitchell 1982; Miller *et al.* 1983; Wright 1989). However, most cultivation programmes are still in an early stage and a need for additional field testing of cultivars remains. As well, few field tests have been conducted to assess performance of candidate species. In order for native species to gain acceptance with practitioners they must be tested under controlled field conditions.

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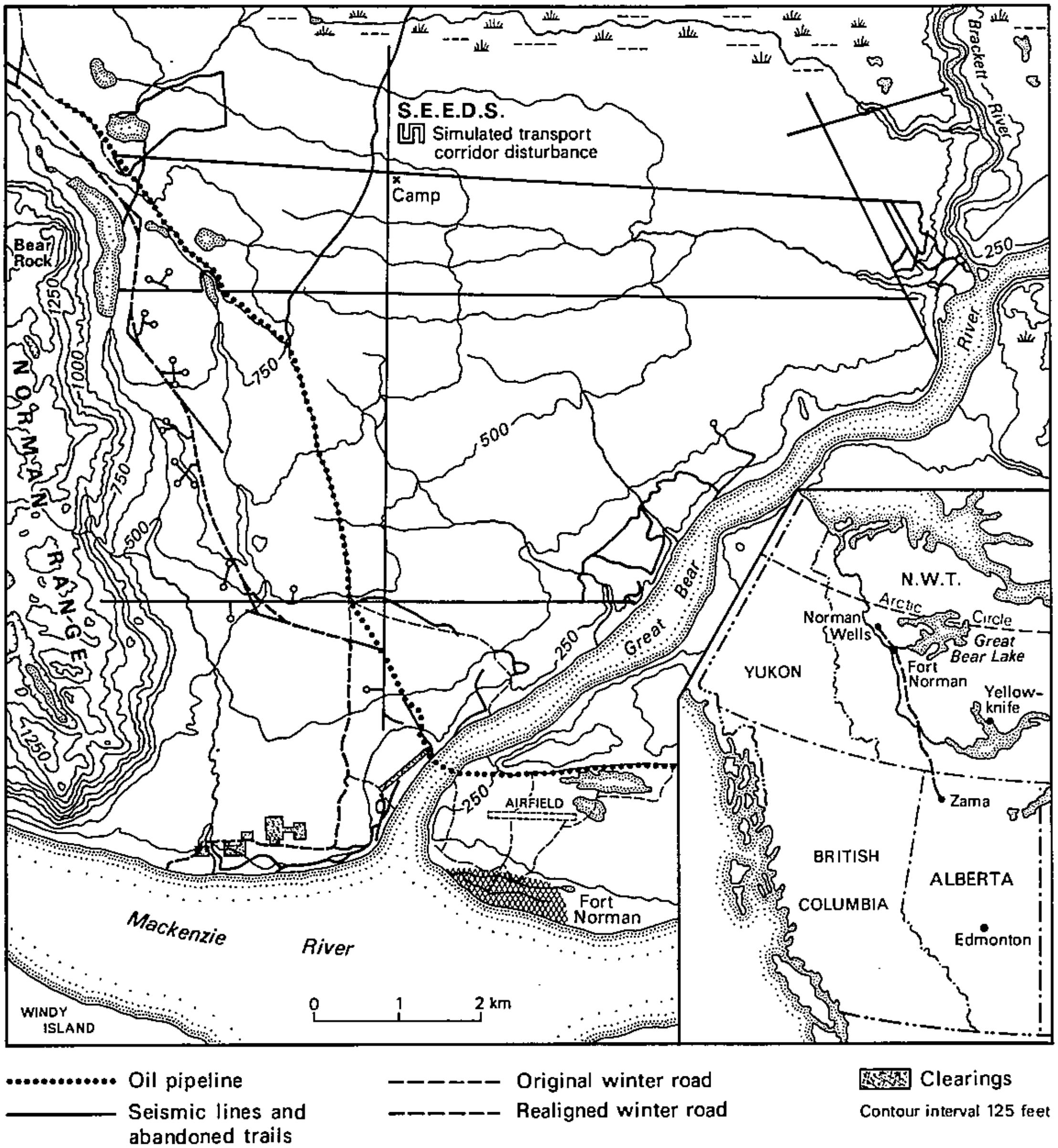

Figure 1: Location of the simulated transport corridor, SEEDS, Fort Norman, NWT.

In permafrost-affected terrain the amount of dry matter produced is important as it can contribute to the insulation of the soil surfacelayers (Viereck 1973 and 1982) and thus reduce soil heat flux during the thaw season (Rouse 1982). It is particularly important to quickly accumulate organic matter because of its influence on soil heat flux but also because of its significance for soil characteristics such as fertility, erosive potential and moisture content. Development-related surface disturbances in Subarctic terrain often result in either the compaction or removal of surface organic layers (Kershaw 1983). It is therefore important to replace these surface layers as quickly as possible following their modification. Plants exhibiting high rates of biomass concentration are therefore most desirable.

In addition, vegetation on disturbances will be utilized by resident wildlife species for cover and food. In order to minimize impacts on wildlife, reclamation programmes must consider the time required to establish cover and the amount and quality of forage produced (Densmore *et al.* 1987).

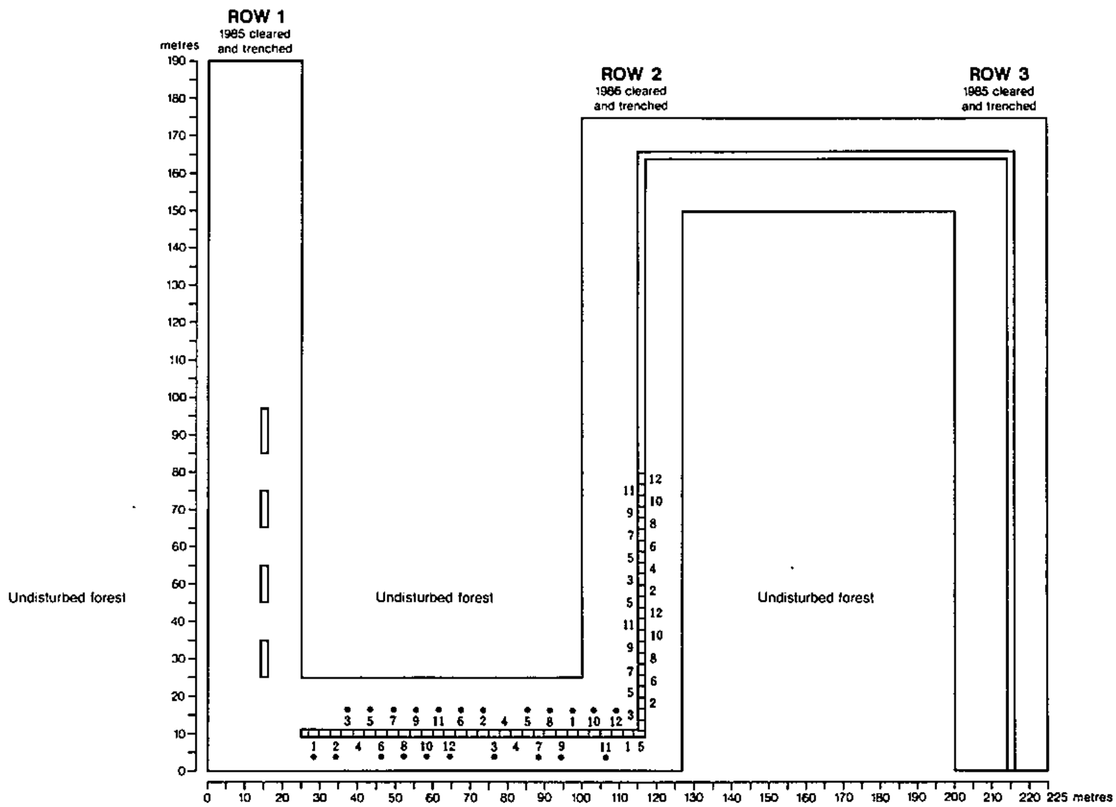

Figure 2: Revegetation test treatments on ROW 2 and South Link, SEEDS, Fort Norman, NWT. (1) *Artostaphylos rubra* seed, (2) *Arctagrostis latifolia* [Alyeska polargrass] seed, (3) *Epilobium angustifolium* rhizomes, (4) Untreated [control], (5) *Empetrum nigrum* seed, (6) *Artemisia Tilesii* and *Calamagrostis canadensis* seed, (7) *Carex membranacea* seed, (8) *Betula glandulosa* seed, (9) Decora grass seed mix, (10) *Vaccinium uliginosum* seed, (11) *Arctagrostis latifolia* [local] seed, (12) *Ledum groenlandicum* seed.

This study was initiated to assess the potential of selected locally-collected native shrub and herb species and selected commercially-available species for use in Subarctic revegetation programmes. The approach taken was to sow seed on a simulated pipeline trench, located in the Subarctic boreal forest, to evaluate establishment potential and performance differences due to species and cultivation programmes. The effects of fertilization were also evaluated. In this paper we will report on the productivity (phytomass or above-ground biomass) component of the study. The cover, shrub plantings and native species invasion components will be the subject of future papers.

Study Area

At the SEEDS (Studies of the Environmental Effects of Disturbances in the Subarctic) research site, 10km north of Fort Norman, a 25-m-wide right-of-way (ROW) was cleared in a 200-year-old, Subarctic, *Picea mariana*-dominated forest (Figure 1). The area was underlain by permafrost and Gleysolic Turbic Cryosol soils (Kershaw and Evans 1987). A 2-m-wide simulated pipeline trench was installed within ROW 2 (Figure 2) during July and August 1986 and remained untreated for the remainder of that season. Natural revegetation was negligible by the end of 1986. Pre-disturbance soil conditions were found to be highly variable on the site. Five soil horizons were present: a fibric Of, a slightly decomposed Om, a discontinuous Bm, a gleyed-cryoturbated Cgy, and a perennially frozen Cz. The mean pH of each horizon increased with depth, ranging from 6.5 in the Of horizon to 7.2 in the Bmz horizon (Evans *et al.* 1988).

The trench was hand-excavated to an average depth of 50 cm and was immediately backfilled with the material that was originally excavated, resulting in complete alteration of the original soil profile, and random blending of the organic and mineral soils. Although post-excavation soil samples were not taken, the pre-excavation variability seen on the site was likely increased after excavation due to this mixing. The trench surface, though dominated by exposed mineral soil, was heterogeneous with respect to moisture, organic content, and microtopography.

Methods

Species Selection and Experimental Design

Seven herbaceous and shrub species that are commonly found in Subarctic forests, and that had successfully established on disturbances near the study area, were selected for testing: herbaceous - *Arctagrostis latifolia* (R.Br.) Griseb., *Carex membranacea* Hook.; shrubs - *Arctostaphylos rubra* (Rehn. & Wils.) Fern., *Betula glandulosa* Michx., *Empetrum nigrum* L., *Ledum groenlandicum* Oeder and *Vaccinium uliginosum* L. s.lat. (nomenclature follows Porsild and Cody 1980). During the summer of 1986, seeds of each species were hand collected from randomly-selected plants growing on local seismic lines. The seeds were stored in the field, in paper bags and were air dried. In September, they were moved to the lab, placed in plastic bags and stored at -23°C, until May 1987, at which time the seeds were removed from cold storage, cleaned and weighed in preparation for seeding. Additional species, that are native to the North and are currently being cultivated by experimental seed farms, were selected for field testing based on seed availability and discussions with the research centres where they were obtained (Table 1). All seeds were taken to the study site, where they were stored for 3 weeks, at ambient temperatures, while the revegetation plots were prepared.

In May 1987, while the ground remained frozen, *E. angustifolium* rhizomes were collected from local seismic lines and a burned area 5 km from the study site. The rhizomes were put in cold storage (buried under the snow) where they remained dormant until planting.

Using the above species, a total of 23 revegetation treatments were designed for field testing (Table 2). With the exception of the control, each of the species was tested both with and without fertilizer. Most were tested in separate treatments to allow for accurate identification of seedlings and to control for the effects of competition, however, the easily distinguished cultivated species were sown as mixes. Seeding rates were determined by the germination rates achieved in previously conducted growth chamber germination experiments, seed weights and recommended seeding rates (Hernandez 1973; Johnson 1981; Kubanis 1982). In some cases (e.g. *A. latifolia* local) allowances were made for chaff that was mixed in with some of the locally collected seeds. Seed coats of *A. rubra*, *E. nigrum* and *V. uliginosum* seeds were mechanically scarified using sandpaper; seeds from the other species were not treated in any way.

Table 1: Cultivated varieties obtained from seed farms.

SPECIES	ORIGIN OF SEED STOCK
Arctagrostis latifolia[1] var. Alyeska Polargrass	Alaska
Artemesia Tilesii Ledeb.[1]	Alaska
Calamagrostis canadensis[1] (Michx.) Beauv. var. Sourdough Bluejoint	Alaska
Decora Grass Seed Mix:[2]	
Agropyron violaceum (Hornem.) Lange -82%,	Northern Alberta
Festuca ovina L.-10%	Northern Alberta
Poa alpina L.-5%,	Alaska
Poa glauca M. Vahl -3%,	Alaska

[1] Provided by The Alaska Plant Material Centre, Palmer, Alaska
[2] Provided by Decora Landscaping Ltd., Whitehorse, Yukon

Forty-eight revegetation plots (2 x 3 m each) were established on the trench in ROW 2 (Figure 2). Between 21 May and 30 May 1987, immediately following snowmelt on the trench, each of the 23 revegetation treatments was applied to plots in duplicate. The control plot was replicated 3 times. Treatments were assigned to plots at random, however, to control for possible transportation of fertilizer to unfertilized plots, by runoff, all of the treatments that included fertilizer were grouped together on the east-west section of the trench (Figure 2). Seeds were hand broadcast onto the plots. The *E. angustifolium* rhizomes were cut to lengths of 25-60 cm, and all lateral roots and shoots were trimmed. Rhizomes were buried at a depth of approximately 5 cm, in rows at 10 cm intervals, beginning 5 cm in from the trench edge. Planting density varied from 25 to 35 per plot. One to 10 days prior to application of the treatments N-P_2O_5-K_2O (17:25:15) fertilizer was hand broadcast onto the designated plots, at a rate of 25 g m^{-2} (250 kg ha^{-1}). The fertilizer and application rate were the same as that used on Interprovincial Pipe Line's Norman Wells project (Wishart 1988).

Table 2: Revegetation treatments applied to trench surface.

TREATMENT	SOURCE	SEEDING RATE (g m^{-2})
Arctagrostis latifolia seed (reed polar grass)	local	3.50
Arctagrostis latifolia seed (Alyeska Polargrass)	seed farm Alaska	2.50
Carex membranacea seed (fragile sedge)	local	1.50
Artemisia Tilesii seed (mountain wormwood)-56% and *Calamagrostis canadensis* seed (sourdough bluejoint)-44%	seed farm Alaska	2.75
Decora grass seed mix: *Agropyron violaceum* (violet wheatgrass)-82%, *Poa alpina* (alpine bluegrass)-5%, *Poa glauca* (glaucous bluegrass) -3%, *Festuca ovina* (sheep fescue)-10%	seed farm Yukon	3.00
Epilobium angustifolium rhizomes (fireweed)	local	4-6 rhizomes
Arctostaphylos rubra seed (red fruit bearberry)	local	8.00
Betula glandulosa seed (glandular birch)	local	8.00
Empetrum nigrum seed (crowberry)	local	4.00
Ledum groenlandicum seed (Labrador tea)	local	0.50
Vaccinium uliginosum seed (bilberry)	local	6.50
Untreated Control		no seed

Assessment of Performance

A buffer zone of 10 cm was established around the periphery of each of the revegetation plots to control for the removal of soil and seed that had occurred along the edges of the trench through fluvial erosion. This zone was exempt from all sampling.

Phytomass was estimated for each of the treatments where the trial species achieved a plant cover >1%. Six treatments did not meet this criterion - *C. membranacea, A. rubra, B. glandulosa, E. nigrum, L. groenlandicum* and *V. uliginosum*. Five 25 x 25 cm quadrats, were randomly located within each 1.8 x 2.8 m revegetation plot using a random numbers table, for a total of 10 samples from each treatment. All above-ground portions of vascular plants rooted within the quadrats were collected. The phytomass was then sorted into 2 categories: trial species and other species. Samples were stored in paper bags in the field and air dried. In September, samples were oven dried, at 39°C, for 24 h in the laboratory before being weighed to the nearest 0.01 g.

For those revegetation plots in which the trial species was present at <1% cover, species density and frequency, rather than phytomass, were estimated, using 5 randomly located 25 x 25 cm quadrats in each 1.8 x 2.8 m revegetation plot, for a total of 10 samples from each treatment.

Data Analysis

All data were tested for normality using the Kolomogorov-Smirnov test for goodness of fit (Zar 1974; Statistical Graphics Corp. 1985). Appropriate transformations to normality were used when necessary. Analysis of variance was used to test for differences among species and treatments for all data which were normally distributed or transformed. Homogeneity of variance was tested using Cochrane's C test and Bartlett's test (Sokal and Rohlf 1981; Statistical Graphics Corp 1985). Differences in means were tested using Tukey's Multiple Range Test (Sokal and Rohlf 1981; Statistical Graphics Corp. 1985).

Results

Phytomass

With the exception of the fertilized Alyeska polargrass, which produced greater phytomass (68.38 g m^{-2}, $P<0.05$) than any other trial species, there was no difference among treatments in above-ground production by trial species (Table 3). Fertilizer applied to the Alyeska polargrass treatment resulted in a mean increase in phytomass of 663%, relative to the unfertilized treatment. This was the only treatment in which fertilizer affected above-ground production by the trial species, although a trend toward increased production was present for every species except *A. Tilesii* and *C. canadensis.* For six treatments, the amounts produced were not quantifiable due to the extremely low success. Variation (standard deviation) in phytomass was high for each trial species, indicating that production within the treatments was uneven. Some of this variation appeared to be a function of fluvial erosion. Although the effects of runoff were apparent along the entire trench, erosion was most prevalent in the north-south section where 28% of the total plot surface area was identified as disturbed in August, compared to only 15% of the surface area in the east-west section of the trench.

Table 3: Mean phytomass (g m^{-2})(SD) of trial species in each treatment at the end of the first growing season.

TREATMENT	n	TOTAL (SD)		TRIAL SPECIES (SD)
Arctagrostis latifolia Alyeska Polargrass				
F[1]	10	72.23 **a** (44.88)		68.38 **a** (45.85)
UF[2]	10	17.68 **bc** (7.67)		10.32 **b** (6.15)
Arctagrostis latifolia Local				
F	10	16.73 **bc** (9.01)		14.72 **b** (8.96)
UF	10	8.83 **bc** (4.55)		1.00 **b** (1.31)
Artemisia Tilesii and *Calamagrostis canadensis*				
F	10	12.63 **bc** (8.52)	AT[3]:	8.00 **b** (6.40)
			Cc[4]:	3.41 **b** (3.65)
UF	10	15.81 **bc** (8.95)	AT:	6.82 **b** (6.39)
			Cc:	4.86 **b** (5.60)
Decora Mix				
F	10	24.07 **b** (15.86)		22.02 **b** (14.25)
UF	10	8.07 **bc** (7.54)		4.98 **b** (6.84)
Epilobium angustifolium				
F	10	15.18 **bc** (20.81)		12.59 **b** (20.54)
UF	10	10.52 **bc** (14.69)		0.74 **b** (1.60)
Untreated Control				
UF	14	1.81 **c** (2.39)		--

[1]F-Fertilized [2]UF-Unfertilized
[3]AT-*Artemisia Tilesii*, [4]Cc-*Calamagrostis canadensis* Note: Means in the same column, with the same letters are not significantly different (P>0.05)).

Density and Frequency

Density and frequency were assessed for the 2 trial species, *B. glandulosa* and *L. groenlandicum*, that had some seedling establishment but achieved a mean per cent cover of <1%. First year emergence was high in all treatments involving these species. Mean seedling densities were 243 m^{-2} for *B. glandulosa* and 375 m^{-2} for *L. groenlandicum*; the difference between the 2 species was not significant (Table 4). Fertilizer did not affect seedling density of either species. The high standard deviations indicate that seedling distribution of both species was clumped, particularly for *L. groenlandicum.* Even with such high densities a frequency of <100% was recorded for *L. groenlandicum* in the fertilized treatment (Table 4).

Discussion

Treatment Performance

First year phytomass was low for all treatments except the fertilized Alyeska polargrass. This may in part be due to the effects of fluvial erosion. Cover was significantly lower on areas of the trench that were eroded. Including these areas in phytomass sampling likely lowered the mean phytomass values. The Alyeska polargrass that received fertilizer was the only treatment where disturbed substrate was not present.

The performance of the fertilized Alyeska Polargrass was superior to any of the other trial species. Concurrent testing of the locally collected *A. latifolia* and the variety Alyeska polargrass indicated that selection and cultivation programmes have enhanced the

Table 4: Mean seedling density (m^{-2}) and frequency (FQY), of species that achieved seeded cover values <1%, but >0%.

TREATMENT		n	DENSITY	FQY (%)
Betula glandulosa				
	F[1]	12	316 (271.0) **a**	100
	UF[2]	12	252 (218.5) **a**	100
Combined		24	284 (243.0) **a**	
Ledum groenlandicum				
	F	12	207 (326.7) **a**	83
	UF	12	459 (390.5) **a**	100
Combined		24	333 (374.9) **a**	

[1]F-Fertilized, [2]UF-Unfertilized, Note: Means with the same letter are not significantly different (P=0.05).

ability of this species to rapidly accumulate phytomass on exposed mineral soil. Even when unfertilized, Alyeska polargrass performed as well as the fertilized local *A. latifolia*.

Each of the other cultivated species also performed as well as, or better than the local *A. latifolia*. Each of these species germinated and established well, however, they were slow to develop and produce significant phytomass, relative to Alyeska polargrass.

The relatively poor performance by the Decora Seed Mix appeared to be primarily due to the slow growth rate of two component species, *A. violaceum* and *F. ovina*. However, based on the apparently successful seedling establishment by all 4 species, second year production is expected to be significantly higher for each of the species comprising this mix and the combination of the 2 rapid and 2 relatively slowly-establishing species that comprise the Decora Seed Mix should result in high long-term production.

The transplanted and fertilized *E. angustifolium* rhizomes were successful in producing phytomass while the unfertilized rhizomes were not. Three explanations emerge: the rhizomes did not survive the transplant, they were eroded from the plot or, during the first year following disturbance the limited available nutrients in the unfertilized plots were allocated primarily towards below-ground production, rather than production of new tillers. If the third explanation is correct then cover in the unfertilized plots may increase during subsequent years.

B. glandulosa and *L. groenlandicum* successfully established during the first growing season, however, seedling development of both species produced little phytomass. The high rates of germination conform to those observed by Karlin and Bliss (1983) which was reasonable since the substrates were ideal for germination (fine-grained, moist soils), no shading was present and the seed was collected locally and sown shortly after collection (Karlin and Bliss 1983).

The inability of the other shrub species - *A. rubra*, *E. nigrum*, and *V. uliginosum*, to establish from seed on the test plots appeared to be the result of poor germination success. It is not known if the seeds were inviable or dormant. The shrub seeds were planted without stratification in the hope that after being stored at ambient temperature on site for approximately three weeks they would germinate under the natural conditions encountered in the field. In Alaska, each of these species has been observed to naturally colonize exposed mineral soil from seed (Densmore 1979), and each successfully germinated after either 1 or 2 seasons when planted untreated in the field (Densmore 1979). If the poor germination seen in this experiment was due to seed dormancy rather than inviable seeds, it is possible that these species will germinate after the second growing season. Although mature *C. membranacea* individuals were found on several of the revegetation plots, the *Carex* seeds sewn in this experiment did not germinate.

Erosion Control Potential

Species suitable for short-term fluvial erosion control must be able to establish rapidly and root profusely during the first growing season. The degree of rooting necessary to control erosion is, of course, dependent on site characteristics, however, in the absence of severe runoff erosion, on flat to gently-sloping areas, Younkin and Martens (1987) conclude that approximately 40% live seeded cover would likely provide adequate erosion control for most situations. Based on performance during the first growing season, Alyeska polargrass is the only one of the trial species (and varieties) considered to have potential for this purpose, and even this variety is only suitable when fertilized. First year phytomass of 68.38 g m^{-2} produced by the fertilized Alyeska polargrass should contribute significantly to soil stabilization, although in areas with high erosion potential, such as pipeline trenches or ice-rich slopes, engineering measures will likely be required (Wishart 1988).

The significant above-ground production by Alyeska polargrass will contribute to a higher total cover in the second year by producing ground cover in the form of litter.

Alyeska polargrass is known to be suitable for use in reclamation programmes in Alaska (Millar *et al.* 1983). First year performance of Alyeska polargrass in this study suggests that this variety is also suitable for use on permafrost-affected soils in Subarctic boreal forest habitats.

Effects of Fertilizer

The effects of fertilizer on native plant species has recently been reviewed (Walker *et al.* 1987). In our study, fertilizer application resulted in increased mean phytomass in all of the trial species but, with the exception of Alyeska polargrass, the values were not significantly different from unfertilized treatments. Therefore, on the basis of phytomass, fertilizer cannot be considered essential to the success of the other trial species, and is not recommended for use in the first year. During the second growing season, some positive effects of the fertilizer may become apparent, which would then alter this recommendation. Fertilizer had no effect on seedling establishment or growth of *B. glandulosa* or *L. groenlandicum*. Once seedlings have produced an extensive root system, fertilizer may positively affect production, however, the fertilizer may be unavailable to plants by the second growing season due to its removal by running water or other agents.

In some cases, the results of fluvial erosion confounded the effects of fertilizer application. The role of running water in eroding soil, seed and fertilizer was likely underestimated. Although the survey method provided an accurate measure of the fluvially-disturbed substrate present in August, it would have been difficult to identify areas similarly affected early in the season (immediately following snowmelt) since these areas quickly restabilized after the peak in runoff occurred. Plots that had been so affected would have lost some or all of the seeds, rhizomes or fertilizer available for revegetation. It may be that the low production achieved on the unfertilized plots was due in part to this phenomena. However, the high seedling density seen on some of the unfertilized treatments (e.g. *B. glandulosa* and *L. groenlandicum*) suggests that, on at least some of the plots, erosion of seed was not a problem.

Conclusions

Based on productivity and seedling densities we conclude that *A. latifolia* (local and Alyeska polargrass), the Decora Seed Mix (*A. violaceum, F. ovina, P. alpina, P. glauca*), *C. canadensis, A. Tilesii, B. glandulosa* and *L. groenlandicum* are suitable for use in revegetation programmes of exposed mineral soils in Subarctic areas with low erosion potential. Alyeska polargrass is also suitable for erosion control purposes on areas with moderate erosion potential. However, using the same criteria, we concluded that *C. membranacea, A. rubra, V. uliginosum* and *E. nigrum* are not suitable for revegetation programmes. Planting *E. angustifolium* rhizomes appears to have potential for accelerating the establishment of vegetation, if used with fertilizer.

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