PRODUCTIVITY OF AGRONOMIC AND NATIVE PLANTS UNDER VARIOUS FERTILIZER AND SEED APPLICATION RATES ON A SIMULATED TRANSPORT CORRIDOR, FORT NORMAN, NORTHWEST TERRITORIES[1]

by

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Abstract. In spring 1987 a reclamation study was initiated on an east-west oriented right-of-way, cleared in a decadent, Subarctic black spruce forest near Fort Norman, N.W.T. The objective was to test the short-term effects of various rates of fertilizer and seed application on the productivity of agronomic (commercially-available) and native plants. The 25m-wide right-of-way was disturbed by 1800 passes of an all-terrain-cycle (ATC) over a 70m length. The site was seeded and fertilized using a seed mix and fertilizer similar to that employed in other northern reclamation projects. Phytomass of native graminoids, native herbaceous and agronomic seed-mix species, increased after the first and second growing seasons. The average increase in native species' phytomass from 1987 to 1988 was 573% in unseeded treatments. Within seeded treatments the average increase in native plant production was 346%. The average increase in agronomic seed-mix phytomass was 454% over the two growing seasons of the study, with the highest productivity occurring in those treatments in which 500 and 1000 kg ha^{-1} of fertilizer were applied.

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

Introduction

Exploration and development of northern hydrocarbon and other non-renewable resources has resulted in numerous human-induced terrain disturbances throughout the Arctic and Subarctic. These disturbances vary in degree but require mitigation and reclamation to reduce both the short-and long-term environmental impacts that result. A number of studies have been undertaken throughout the North to investigate means and methods of reducing the impacts associated with human-induced disturbances. Revegetation methods have been tested on disturbances in the taiga of Alaska (Elliott, *et al.* 1987) and Canada (Wein 1971; Hernandez 1973; Younkin 1972; 1973; 1976; Younkin and Martens 1985; Wishart 1988). However, the authors are unaware of studies in which the fertilizer application rate has been varied to determine the optimum amount for plant production.

Short-term goals of northern revegetation programmes include control of fluvial and thermokarst-induced erosion (Mackay 1970; Hernandez 1973; Kerfoot 1973; Zoltai and Pettapiece 1973; Haag and Bliss 1974) and the enhancement of soil stability (Younkin 1976). However, long-term reclamation of

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disturbances is desirable in order to establish low-maintenance plant cover, reduce the visual impact of the disturbance, establish wildlife habitat (e.g. shelter or browse) (Hernandez 1973; Dabbs, *et al.* 1974; Johnson and Van Cleve 1976; Younkin 1976), or produce plant communities which are similar to those which result from natural recovery (Densmore and Holmes 1987).

Agronomic species selected for northern reclamation projects should have an ability to maintain soil stability through growth and litter production (Watson *et al.* 1980). Furthermore, agronomic species should have a broad range of nutrient requirements, allowing growth at a wide range of soil nutrient levels (Watson *et al.* 1980). In addition, the agronomics that are sown should be long-lived and winter-hardy due to the short and cool growing season that is characteristic of the North (Interprovincial Pipe Lines 1983; Hardy Assoc. 1984; 1985).

The movement of vehicles and equipment throughout the North to isolated exploration and development sites causes one of the most wide-spread disturbances to the permafrost, soil and vegetation in the Arctic and Subarctic (Van Cleve 1977). The type of vehicle, time of year, and the terrain affected are the principal factors determining the level of disturbance created in Arctic and Subarctic regions (Bellamy *et al.* 1971; Hok 1971; Kerfoot 1972; Heginbottom 1973; Rickard and Slaughter 1973; Rickard and Brown 1974; Addison and Bell 1976; Van Cleve 1977; Dyke 1985; Lawson 1986). Within the Mackenzie River Valley, studies on the effects of vehicle traffic have been limited to winter roads (Strang 1973; Adam and Hernandez 1977).

The purpose of this study was to test the short-term effects of various rates of fertilizer and seed application on the productivity of agronomic and native plants on a simulated transport corridor. The main hypothesis that was tested was that increases in the fertilizer application rate would result in positive and corresponding growth rates in the standing crop of plants (including the seeded agronomic species and the invading, native plant species).

Study Site

The field research was conducted at the SEEDS (Studies of the Environmental Effects of Disturbances in the Subarctic) facility near Fort Norman, N.W.T. The study area, which is within the discontinuous permafrost zone (Brown 1978), has been classified as flat to sloping lacustrine and moraine plain (Reid 1974; Interprovincial Pipe Line (NW) Ltd. 1980). The permafrost-influenced soil of the study site has been classified as a Gleysolic Turbic Cryosol (Canadian Soil Survey Committee 1978; Kershaw and Evans 1987). The mean active layer depth for the study area was 48cm (Evans *et al.* 1988).

The pre-disturbance Subarctic forest was greater than 200 years-old. It was dominated by an overstory of *Picea mariana* (black spruce) and an understory of *Salix arbusculoides* (little tree willow), *Ledum groenlandicum* (Labrador tea), *Vaccinium vitis-idaea* (lingonberry), *V. uliginosum* (bog bilberry) and *Arctostaphylos rubra* (red fruit bearberry). Non-vascular ground cover was dominantly *Hylocomnium splendens* (stair-step moss), *Cladonia arbuscula (shrubby reindeer lichen)* and *Aulacomnium palustre* (marsh moss) (Kershaw 1988).

Methods

In 1986, an east-west portion - the South Link, of the SEEDS site was hand-cleared of all erect woody plants that were greater than 0.5m-tall (Figure 1). In 1987, upon removal of the tree stumps, this east-west oriented right-of-way was disturbed by 1800 passes of an all-terrain-cycle (ATC) (Honda 200m) over an 18h period. An improvised 'ripper' was dragged behind the ATC to increase the extent of surface disturbance by churning the organic mat and uprooting or clipping-off aerial portions of plants. However, due to the shallow thaw depth at this time, only the organic mat was lightly mulched and compacted.

Upon completing the surface disturbance, on 26 May 1987, twelve treatment plots were installed on each side of a simulated pipeline trench which bisected the right-of-way (Figure 1). The treatments included fertilizer and seed application rates similar to those used in other northern reclamation projects (Table 1). A complete fertilizer with a nitrogen-phosphorous-potassium blend (17-25-15) was hand broadcast at various rates (Table 1). The seed mix was identical to that used by Interprovincial Pipe Line (NW) Ltd. (1983) on their Norman Wells-Zama Lake pipeline. It was hand broadcast at a rate of 30 kg ha^{-1} and contained the following agronomic or commercially-available species: *Poa pratensis* (kentucky bluegrass) - 5%, *Festuca rubra* (BOREAL creeping red fescue) - 20%, *F. ovina* (sheep fescue) - 15%, *Agropyron trachycaulum* (REVENUE slender wheatgrass) - 28%, *Alopecurus arundinaceus* (GARRISON creeping

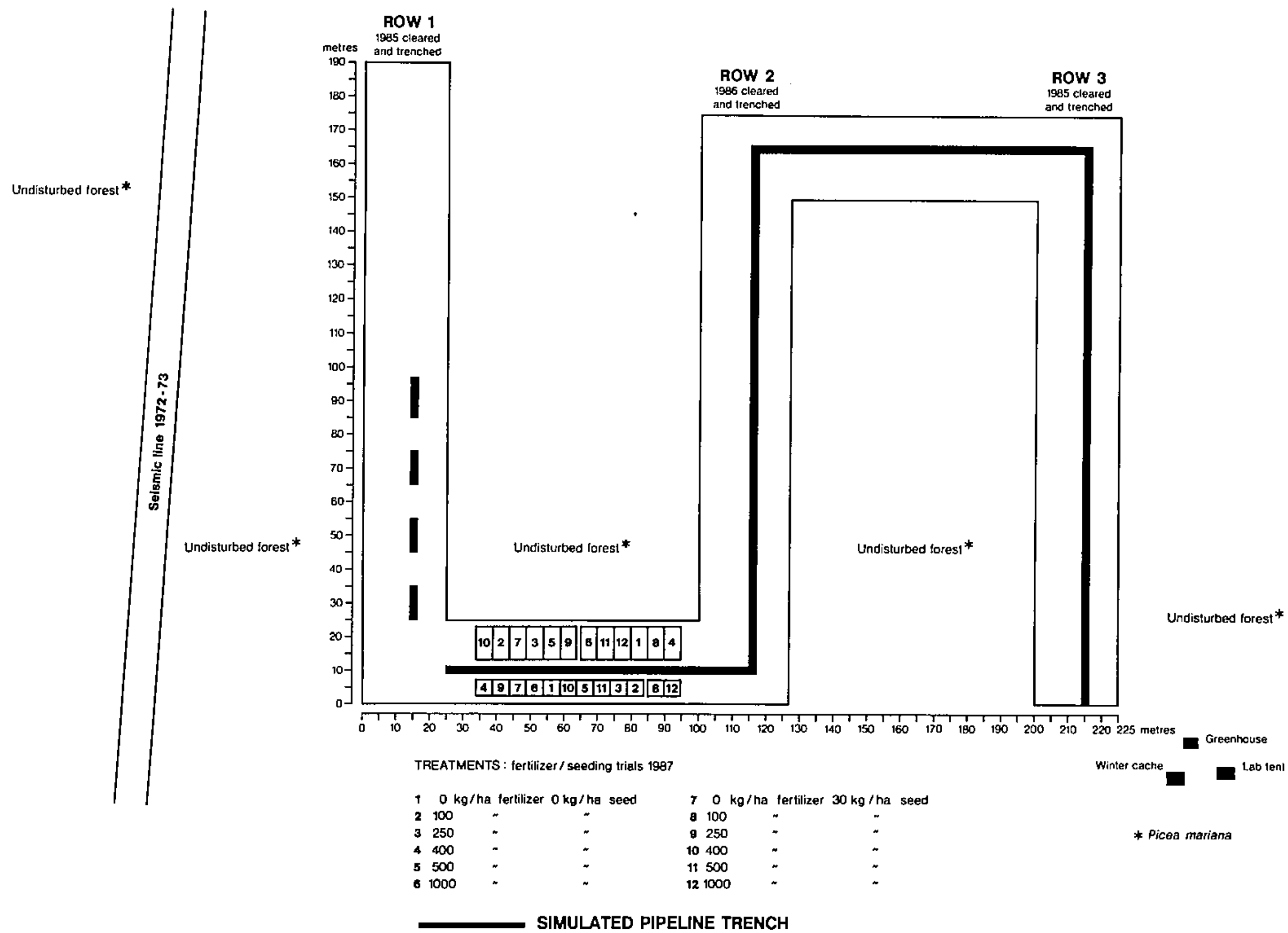

Figure 1: Location of fertilizer/seeding trials on the simulated transport corridor.

foxtail) - 15%, *Phalaris arundinacea* (VANTAGE reed canarygrass) - 12% and *Phleum pratense* (CLIMAX timothy) - 5%. These species are deemed to be suitable for northern reclamation because they are able to maintain soil stability, have low nutrient requirements, and are long-lived (Watson *et al.* 1980).

A 1m buffer zone within each of the twelve test treatment plots reduced any edge effect from the adjacent plots or untreated areas (Figure 2). In the test treatments south of the trench, the soil sampling, plant cover estimates, and phytomass (above-ground biomass) sampling, were conducted within a 3 x 3m quadrat centred in the treatment plot. However, north of the trench, the sampling plots were randomly placed at 1m intervals within the 10 x 5m treatment, while maintaining a 1m buffer zone. The treatment plots north of the simulated pipeline trench were larger than those on the south side due to the availability of space.

Table 1: Revegetation treatments at the SEEDS site and other northern reclamation projects.

Treatment number	Fertilizer application rate ($kg\ ha^{-1}$)	Seed application rate ($kg\ ha^{-1}$)
1	0	0
2	100	0
3	250 a,i	0
4	400 e,h	0
5	500 b,c,g,h	0
6	1000	0
7	0 f	30
8	100 d	30
9	250 d,j,k	30
10	400 d	30
11	500	30
12	1000	30

a) Wein 1971, b) Younkin 1972, c) Hernandez 1973, d) Dabbs *et al.* 1974, e) Younkin 1976, f) Johnson 1978, g) Chapin and Chapin 1980, h) Plazzo *et al.* 1980, i) Interprovincial Pipeline (NW) Ltd. 1983, j) Hardy Associates (1978) Ltd. 1984, k) Hardy Associates (1978) Ltd. 1985

The 1 x 1m cell in the centre of the sampling plot was divided into 16, 25 x 25cm cells of which 5 were selected for phytomass (above-ground biomass) sampling in each of 1987 and 1988. All plants rooted within the cells were clipped to ground level.

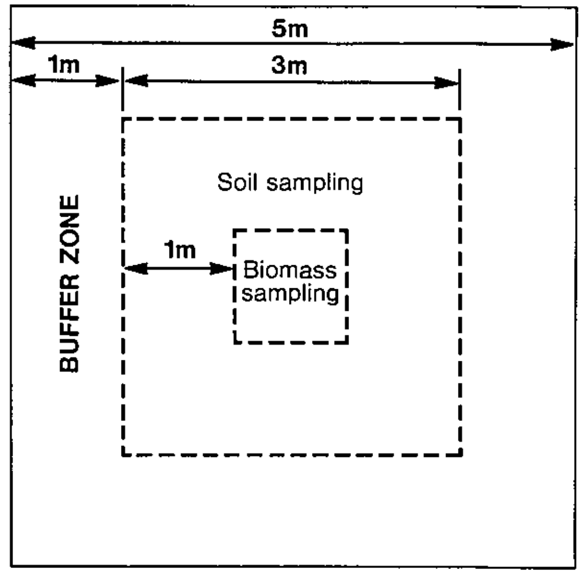

Figure 2: Typical test treatment layout on the South Link at the SEEDS research facility.

Results

Only results of the performance, as measured by the phytomass (biomass) or standing crop for the seeded test treatments (numbers 7 to 12 on Figure 1 and Table 1) are presented below. Total native (native), native graminoids (graminoids) and agronomic seed-mix (agronomics) biomass increased after the first and second growing seasons with higher initial applications of fertilizer. Phytomass of native plant species was greater than that of agronomic taxa in the first growing season within each of the seeded treatments except for those which received fertilizer at rates of 500 and 1000 kg ha^{-1}. Production of native and agronomic plants paralleled each other during both growing seasons. Species in the agronomic seed mix were less successful in the unfertilized treatment (Figure 3).

Native Species' Phytomass

Within unseeded treatments the average increase in biomass among native plants from 1987 to 1988 was 573%. In seeded areas the increase in native production was only 343%. This lower increase in native species' biomass suggests that agronomic species were able to outcompete native plants for available soil nutrients. The reason(s) for this apparent competitive advantage displayed by agronomic

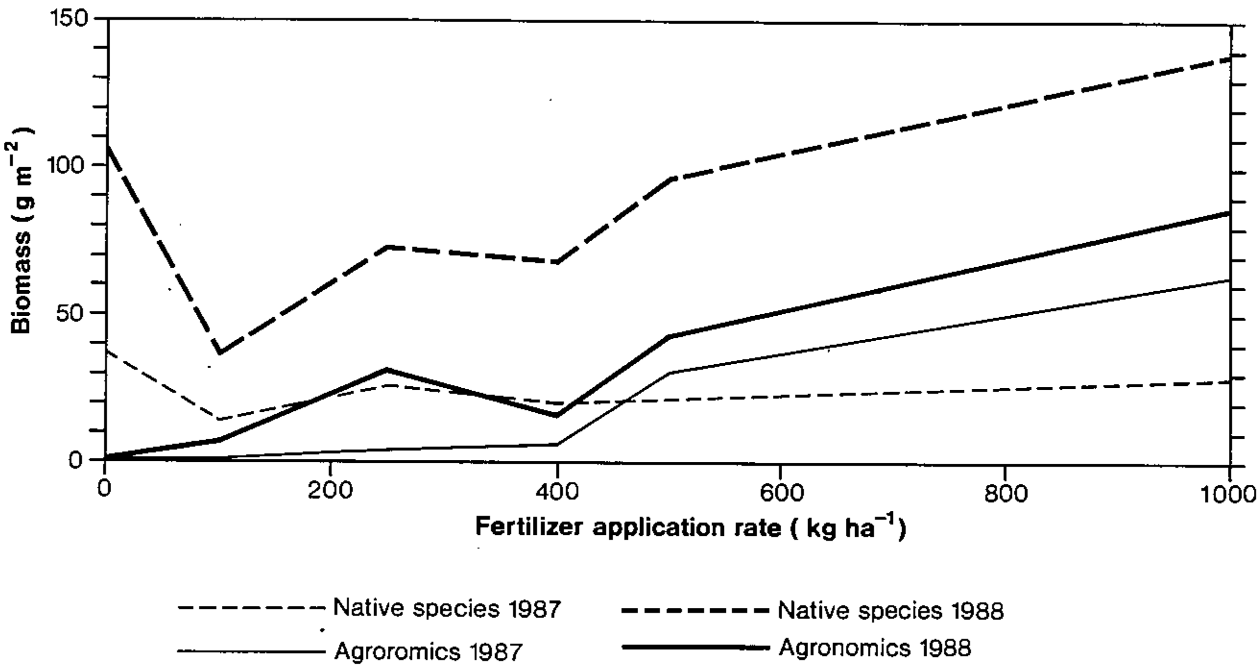

Figure 3: Agronomic versus total native biomass production on seeded plots.

species is beyond the scope of this study but is, no doubt, related to any one or a combination of ecological differences between the species' groups.

Table 2: Total native species' phytomass production (g m^{-2}) (standard deviation) and per cent increase from the first to the second growing season within unseeded treatments, SEEDS, NWT.

Treat-ment	1987		1988		Per cent increase
0	9.50	(0.85)	71.09	(5.50)	748
100	4.21	(0.30)	24.81	(1.91)	589
250	12.14	(0.63)	55.86	(3.10)	460
400	16.77	(1.29)	127.10	(10.84)	757
500	27.44	(5.14)	34.38	(3.89)	125
1000	19.97	(11.69)	151.79	(10.53)	760

The per cent increase in native species' phytomass from 1987 to 1988 varied among treatments, thereby implying that some factor, other than the addition of fertilizer, affected plant production (Tables 2 and 3). This was partially confirmed when, on one unseeded plot, dry substrate conditions resulted in low production despite a relatively high fertilizer application rate (500 kg ha^{-1}).

Agronomic Seed Mix Species' Phytomass

Although there was no agronomic seed applied in the unseeded treatments there were a few non-native species found within some of these treatments. These individuals must have originated as a result of transport of seed from adjacent plots following the initial seed application and/or natural seeding at the end of the first growing season. Wind was probably the most important agent of seed transport since few animals were found on the area during small mammal trapping, however, seed may also have been carried by runoff or, inadvertently, by researchers moving among the plots.

The average phytomass increase for agronomic seed mix species from 1987 to 1988 was 454%. In 1987, the agronomics were not successful in the lower fertilizer treatments.

They were, however, more productive at fertilizer application rates of 500 and 1000 kg ha^{-1} than the native plants (Table 2 and Figure 3). The increase in native plant production by the end of the second growing season was, however, lowest in the two treatments of highest fertilizer application. The initial increase in soil nutrients, as a result of fertilizer application, may have been responsible for the high productivity during the first growing season in the 500 and 1000 kg ha^{-1} treatments. However, by the second season reduced nutrient availability in the soil precluded similar increases in production.

Table 3: Phytomass production (g m^{-2}) (standard deviation) of all native species, native graminoids and agronomic (commercially available seed-mix) plants within seeded treatments, SEEDS, NWT.

Treatment	All native species	Native graminoids	Agronomic species
		1987	
0	37.92 (4.15)	2.22 (0.32)	0.14 (0.02)
100	14.80 (0.89)	0.80 (0.08)	0.90 (0.12)
250	26.37 (3.47)	0.78 (0.12)	4.94 (0.48)
400	20.43 (1.45)	1.92 (0.25)	5.18 (0.96)
500	21.74 (1.63)	1.42 (0.23)	31.70 (3.02)
1000	28.58 (2.03)	9.07 (1.01)	63.10 (8.94)
		1988	
0	106.22(11.44)	4.77 (0.81)	1.04 (0.28)
100	36.61 (2.65)	2.15 (0.19)	6.90 (0.72)
250	74.29 (5.20)	12.58 (2.53)	31.17 (3.45)
400	68.41 (5.93)	12.62 (3.63)	16.10 (3.38)
500	96.92 (6.89)	8.76 (1.42)	43.39 (4.27)
1000	139.33(13.47)	87.56(14.51)	86.43 (7.18)

Discussion

All components of the reestablishing vegetation were greater with higher fertilizer application rates (Table 2 and 3). However, only the native graminoids and agronomic species had significant increases in production as a result of fertilizer application (Table 4). This was true for both years although the relationship was less strong during the second growing season.

There was a correlation between the rate of fertilizer applied and both native graminoid and agronomic phytomass (Table 5). Both the graminoids and agronomics had a significant positive correlation with fertilizer application in each of 1987 and 1988. However, the total native biomass was not significantly correlated with fertilizer application in either of the two growing seasons (Table 5).

Table 4: Results of the analysis of variance in phytomass among species' groups (total native plants[1], native graminoids[2] and agronomics (commercially available seed-mix)[3]) in response to increases in fertilizer application rates. Revegetation test treatments, SEEDS, NWT.

Species groups	df	Sum of squares	Mean sum of squares	F-ratio
		1987		
Native[1]	5	12.4	2.5	0.88 #
Graminoids[2]	5	2.0	0.39	4.36 **
Agronomics[3]	5	123.7	24.70	3.80 **
		1988		
Native[1]	5	244.2	48.8	1.57 #
Graminoids[2]	5	208.6	41.7	2.48 *
Agronomics[3]	5	192.5	38.5	5.69 **

\# No significant difference
* $P<0.05$
** $P<0.01$

The fertilizer composition and amount applied appears to favour graminoids rather than forbs or woody plants. If a project proponent wished to enhance these components of the vegetation on a disturbance then the fertilizer would have to be altered.

Table 5: Correlations between fertilizer application and each of: total native material[1], native graminoids[2], and agronomic seed mix[3] on revegetation test treatments, SEEDS, NWT.

Species groups	Correlation coefficient	Significance level
	1987	
Native[1]	-0.10	0.9420
Graminoids[2]	0.448	0.0003
Agronomics[3]	0.483	0.0001
	1988	
Native[1]	0.236	0.0701
Graminoids[2]	0.386	0.0023
Agronomics[3]	0.562	0.0000

Conclusions

It must be stressed that the experiment we are reporting on is based upon: 1. the first two growing seasons following treatment, 2. a cleared right-of-way with an organic-dominated substrate, 3. a cleared right-of-way on which pre-disturbance root stock and buried propagules persist.

Site conditions, in addition to the placement of the seed (i.e. at the surface and not within the soil rooting zone) as a result of hand broadcasting, may account for some of the variations that existed among the treatments. However, based upon preliminary analyses of the phytomass of local native and introduced, commercially available agronomic plants the variation in fertilizer application rate resulted in increased biomass of both species' groups. However, without complete analysis of all variables, including soil nutrients, soil moisture content, etc., it is difficult to assess which fertilizer application rate is most suited for the short-term growth of plants on this and similarly disturbed sites in the Subarctic.

Indications are that competition occurs between introduced, agronomic, commercially-available species and native, locally growing plants in the early (first 2 growing seasons) stages of revegetation. This relationship was particularly evident when considering the non-graminoid component of the local plants (e.g. forbs and shrubs). Further analysis and the addition of data from more growing seasons will clarify this relationship.

Based on the first two growing seasons' production, it appears that competition for nutrient resources is not limiting for any species group. All revegetation components appear to have responded to fertilizer application during this early stage of reclamation.

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