Potential Revegetation of Processed Kimberlite at De Beers's Proposed Victor Diamond Project near Attawapiskat, Ontario

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Abstract

De Beers Canada has discovered diamondiferous kimberlite pipes in the James Bay lowlands near Attawapiskat, Ontario. This will be Ontario's first operational diamond project and Canada's first diamond project in the unique peatland ecosystem, the third largest wetland in the world. It is anticipated that a wetland ecosystem will be re-established at the mine-site following diamond extraction.

Greenhouse experiments indicated that cottongrass (Eriophorum vaginatum) could grow on the processed kimberlite that was mixed with peat and fertilized. To test these results under realistic conditions field plots were constructed at the Victor Diamond Project site in 2004. A test pad of coarse processed kimberlite, raised approximately 1.0 metre above the ground surface and water table, was constructed to simulate future waste piles requiring revegetation. On the pad a randomized block design of individual plots (surface area >1 x >1 m), each replicated three times, was constructed. Substrate mixtures of 100% peat, 75% peat with 25% fine processed kimberlite and 50% peat with 50% fine processed kimberlite were created at 3 depths (25, 50 and 75 cm), to evaluate cottongrass growth and water retaining capacity with different substrate depths. In the first season of growth cottongrass showed increase in the mean plant height and base diameter in all the substrate mixtures and depths. Root growth was also extensive.

In addition, other species trials were established with green alder (Alnus crispa), dwarf birch (Betula pumila), Labrador tea (Ledum groenlandicum), Leatherleaf (Chamaedaphne calyculata), Deer Grass (Scirpus caespitosus), Northern Reed Grass (Calamagrostis inexpansa), and Cloudberry (Rubus chamaemorus), as it believed that a species mixture will be necessary for micro-habitat variations and long term reclamation success. It is anticipated that further experiments will be initiated in order to establish a reliable protocol for initializing wetland re-formation following mining.

Introduction

De Beers Canada has discovered diamondiferous kimberlite pipes approximately 90 km west of Attawapiskat First Nations community on the James Bay coast within the Attawapiskat River Basin (De Beers, 2003). The site of Ontario's first diamond mine will be located in the world's third largest peatland in the Hudson Bay lowlands. The proposed mining project will consist of a 3-year construction period, 13-year operation period and 3-year reclamation period. During the operations of the mine it is estimated to produce 9.3 million tonnes of coarse processed kimberlite (CPK), 16.5 million tonnes of fine processed kimberlite (FPK), 12.2 million tonnes of overburden (silt, sand and clay) and 65 million tonnes of mine rock consisting of limestone, dolostone and non-diamondiferous kimberlite. Approximately 0.7 million m^3 of surface peat will be stripped and reserved for future reclamation activities (De Beers, 2003).

Geochemistry of the coarse and fine processed kimberlite was very similar with low sulphur concentrations, less than 0.2%, and pH ranges from 7.63 to 8.14. Metal leaching tests determined major elements of calcium, magnesium and iron, with minor concentrations of aluminum, potassium, phosphorus and titanium and trace concentrations of cobalt, chromium, copper, nickel and zinc. Acid base accounting lead to the conclusion this kimberlite is non-potentially acid generating, with FPK having a neutralization potential (NP) of 410 kg equivalents calcium carbonate per tonne of material, and the CPK NP was 310 kg eq $CaCO_3$/t (SRK Consulting, 2003). The mine rock samples consist mainly of limestone, some mudstone and dolostone. The geochemistries of these materials were also tested and determine to be non-potentially acid generating and non-metal leaching. They did contain high levels of magnesium and calcium with very high neutralization potentials greater than 900 kg eq $CaCO_3$ /t of material (SRK Consulting, 2003).

As in many revegetation projects, a successive ecological approach will be used with the Victor Diamond Project leading to healthy sustainable ecosystem. The underlying philosophy will be to recreate wetland and upland systems compatible with the existing ecological communities in this part of the Hudson Bay lowlands. This project will focus on the initial revegetation of the mine rock stockpiles by evaluating the use of FPK and peat mixtures as a substrate for revegetation on the CPK piles. The use of two existing stockpiled products created by the mining process will assist in the overall progressive reclamation and mine closure. The challenges are to create an environment to resemble the existing condition with the use of only native species and limiting the use of fertilizer and other maintenance activities to create a self-sustaining environment.

Victor Diamond Mine – Physical Environment and Vegetation

1. Physical Environment

The general physical environment is typical of northern Ontario with cold winters (mean January temperature of –20.4°C) and warm summers (mean July temperature of 16.2°C). Annual precipitation averages 690 mm (480 mm rainfall and 240 cm equivalent snowfall), with west-northwest dominant winter wind direction and southwest winds during the summer months. Typical wind speeds range between 20 and 40 km/hr with gusts measured up to 120 km/hr. Relative humidity recorded at the climate station ranged from 16.6% to 100%. Net solar radiation within the period of April 2000 and December 2002 the maximum hourly net radiation of 581 W/m^2 and a minimum hourly net radiation of –182 W/m^2 was recorded at the Victor Diamond Project climate station (De Beers, 2003).

The mean snow depth measured at the climate station was 0.6 m. Additional measurements at several local habitats in the winter of 2003, ranged from 0.45 m in open peatland areas and 0.70 m in the upland forested areas (De Beers, 2003).

The first several metres of ground are covered with peat and peat moss. A layer of silty-clay to silt-clay till ranging from 10 to 30 m deep, alternating layers of mudstone, limestone and dolostone, the kimberlite pipes extrude the rock formations in various areas. This area has prominent glacial features including eskers, outwash deposits and kames. There are several small limestone bedrock outcrop, known as bioherms, scattered throughout the region (De Beers, 2003).

This area is south of the continuous and discontinuous permafrost zones, although there has been minor evidence of sporadic permafrost amongst peat plateaus and palsa bogs (De Beers, 2003).

Surface water systems in this area consist mainly of saturated peatland (string bogs) that drain through creeks and rivers to the Nayshkootayaow and Attawapiskat Rivers and the Attawapiskat River drains into James Bay (De Beers, 2003).

2. Vegetation

The project area is defined as peatland dominated by *Sphagnum* mosses, black spruce (*Picea mariana*), tamarack (*Larix laricina*), cottongrass (*Eriphorum vaginatum*), green alder (*Alnus crispa*), dwarf birch (*Betula pumila*), Labrador tea (*Ledum groenlandicum*), Leatherleaf (*Chamaedaphne calyculata*), deer grass (*Scirpus caespitosus*), Northern Reed grass (*Calamagrostis inexpansa*), cloudberry (*Rubus chamaemorus*), three-leaved Solomon's Seal (*Maianthemum trifolium*), Canada Mayflower (*Maianthemum canadensis*), high bush cranberry (*Viburnum trilobum*), bog laurel (*Kalmia polifolia*), bog bilberry (*Vaccinium uliginosum*), bearberry (*Arctostaphylos uva-ursi*).

Fen species may dominate drainage areas with more nutrient flowthrough, while the area eskers and bioherms (mainly limestone) are dominated by Jack pine (*Pinus banksiana*), black spruce (*Picea mariana*), speckled alder (*Alnus incana*) and willows and dry site herbs...

Sphagnum does not readily recolonize bare peat after extensive mining and several factors such as; diaspore size and distribution, hydrology, and climate affect the success of *Sphagnum* regeneration. The use of nurse plants such as *Polytrichum strictum* and cottongrass (*Eriophorum* spp) are excellent companion species to improve *Sphagnum* recolonization (Rochefort, 2000). The nurse plants will create micro-environmental changes to reduce surface soil temperature fluctuations, increase soil moisture by reducing surface evaporation and stabilize the soil providing resistance to frost heaving (Rochefort, 2000) and (Marcoux *et al*, 2000).

Eriophorum vaginatum is a tussock forming sedge that is dominant in many plant communities with a large geographic range (Fetcher and Shaver, 1983). It is a flowering perennial that grows on average to 15 – 70 cm high (Legasy *et al*, 1995) and was the dominate species found on the highly disturbed winter airstrip located in the Project area (personal observations). *E. vaginatum* is commonly located in both undisturbed and disturbed sites and is a known invader of both natural and man-made disturbed sites (Fetcher and Shaver, 1983). *E. vaginatum* is also a commonly used plant species found in natural and anthropogenic revegetation projects in various locations around the world; in Finland (Tuittial *et al*, 2000), in England (Dickinson, 1973), in Alaska (Gartner, *et al*, 1983), as well as several projects undertaken by the Peatland Ecology Research Group (PERG) situated at Laval University, Quebec City, Canada (http://www.gret-perg.ulaval.ca/en_presentation.html.). The life histories and personal observation at the Project site lead us to assess this plant species as an early colonizing species for the initial revegetation efforts.

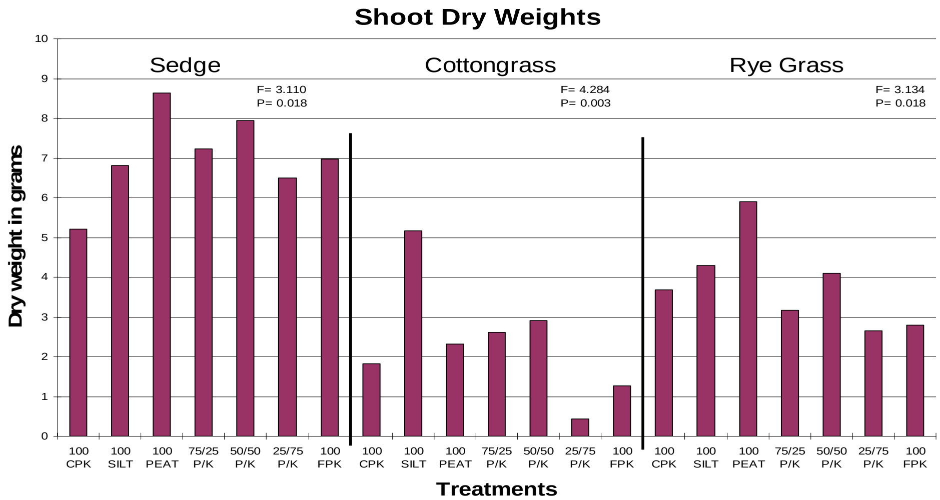
Glasshouse Trial

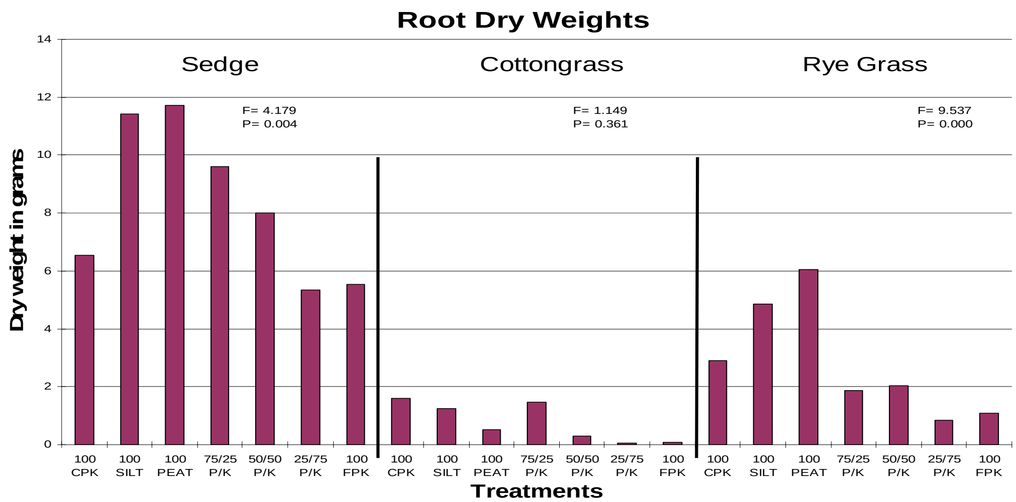
1. Methods

Glasshouse trials using substrate mixtures of 100% peat, 75% peat:25% FPK, 50% peat:50% FPK, 25% peat:75% FPK, 100% FPK and 100% silty-clay were conducted with 2 native plant species from the Project area, *Eriophorum vaginatum* and *Carex aquatilis*, and one species commonly used in Sudbury revegetation, *Lolium perenne*, to determine an appropriate substrate mix and species response to the substrates. Plants were grown in plastic cylinders with the appropriate mixture for 2 months. The plants were harvested and dry mass of the root and shoot component determined using a drying oven

2. Results and Discussion

Figure 1 shows the root, shoot and root: shoot ratio for the three species. Results determined that a minimum of 50% peat:50% FPK would be suitable for field trials. Although all species grew well, it was determined not to use the *C. aquatilis* due to its dependence on saturated soils where *E. vaginatum* has a larger moisture tolerance range (Wein and MacLean, 1973) and it was observed that the plants in the glasshouse responded better in less saturated soils than those in more saturated soils. Wein and MacLean (1973) also found *E. vaginatum* to be a good choice for revegetation on wet mineral soils where few other species in the Arctic would successfully invade.





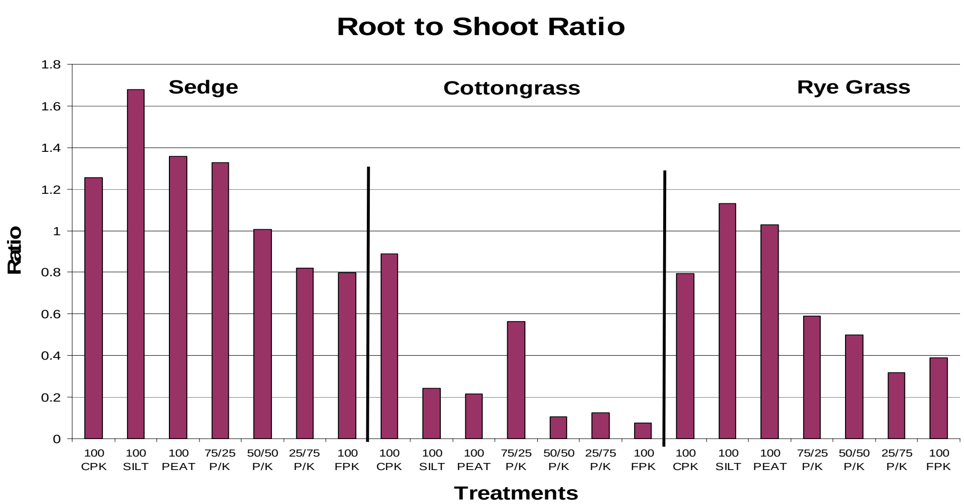


Figure 1. Shoot, root and root: shoot ratios for Cotton Grass, Water Sedge and Rye grass gown in the glasshouse

Field Trails at Victor Mine Site.

Two plots were established in June 2004. The major plot, known as ‘Fort Victor’, was established to test the viability of cottongrass on kimberlite under field conditions, while survival and success of other potential revegetation species are being compared in the second plot known as ‘Little Victor’.

1. Fort Victor Eriophorum Trial

The plot area of approximately 5 m by 20 m consisting of a 1 metre deep pad of CPK over peat to accommodate three rows of nine 1.5 metre by 1.5 metre individual plots.

Peat was manually sieved peat to remove any unwanted objects such as sticks, rocks and large pieces of compressed peat moss. Piles of peat and FPK were constructed and measured on the basis of trailer volumes that were used to move the material. Each trailer had a volume of 0.5 m^3. A half trailer load of FPK, approximately 0.25 m^3, was moved at one time due to the mass of the material, while peat was moved in approximately 5/6’s of a full load or 0.42 m^3. The 50:50 ratio of peat to FPK consisted of 14.5 loads of peat and 24 loads of FPK, the 75:25 ratio of peat to FPK consisted of 22 loads of peat and 12 loads of FPK and the 100% peat consisted of 30 loads of peat to be moved into piles. As the two substrates were being moved and dumped onto tarps for each individual mixture they were constantly mixed with shovels until homogeneous. Each of the three substrate piles consisted of approximately 12.2 m^3 of material.

Figure 2 shows the randomized block design used to determine the location of the nine individual plots within each replicate row. Snow stakes were used to mark the outer corners of each plot, marked for levels of CPK base, where required. A CPK base was used to build up plots with substrate depths of 50 and 25 cm to ensure all plots were at equal heights to reduce wind effects. Each substrate mixture was placed in the plot to the level marked on the snow stakes to maintain accurate depths. A path of approximately 0.5 m was left between the rows, and the paths were filled with approximately 10 cm of CPK to allow access to the plots. Further the spaces between the individual plots in each row were filled in with peat to prevent erosion and reduce wind effects.

To reduce erosion on the sides of the individual plots, CPK was placed along the east and west facing sides; while extra substrate mixtures were placed between the individual plots in the north-south direction. To reduced overall erosion and increase stability of the test plot base a series of logs that were placed horizontally on the sides of the base. Fence poles put into the ground at 1 m intervals around the perimeter. The logs were then placed over the poles and laid down against the perimeter of the test plot. Wire fencing was then placed around the test plot and stapled to the bottom logs to prevent the logs from slipping under and small mammals from entering.

Cottongrass tussocks of similar size were collected from the nearby winter airstrip and transplanted into the plots. Each plot contains 16 plants arranged in a four by four matrix.

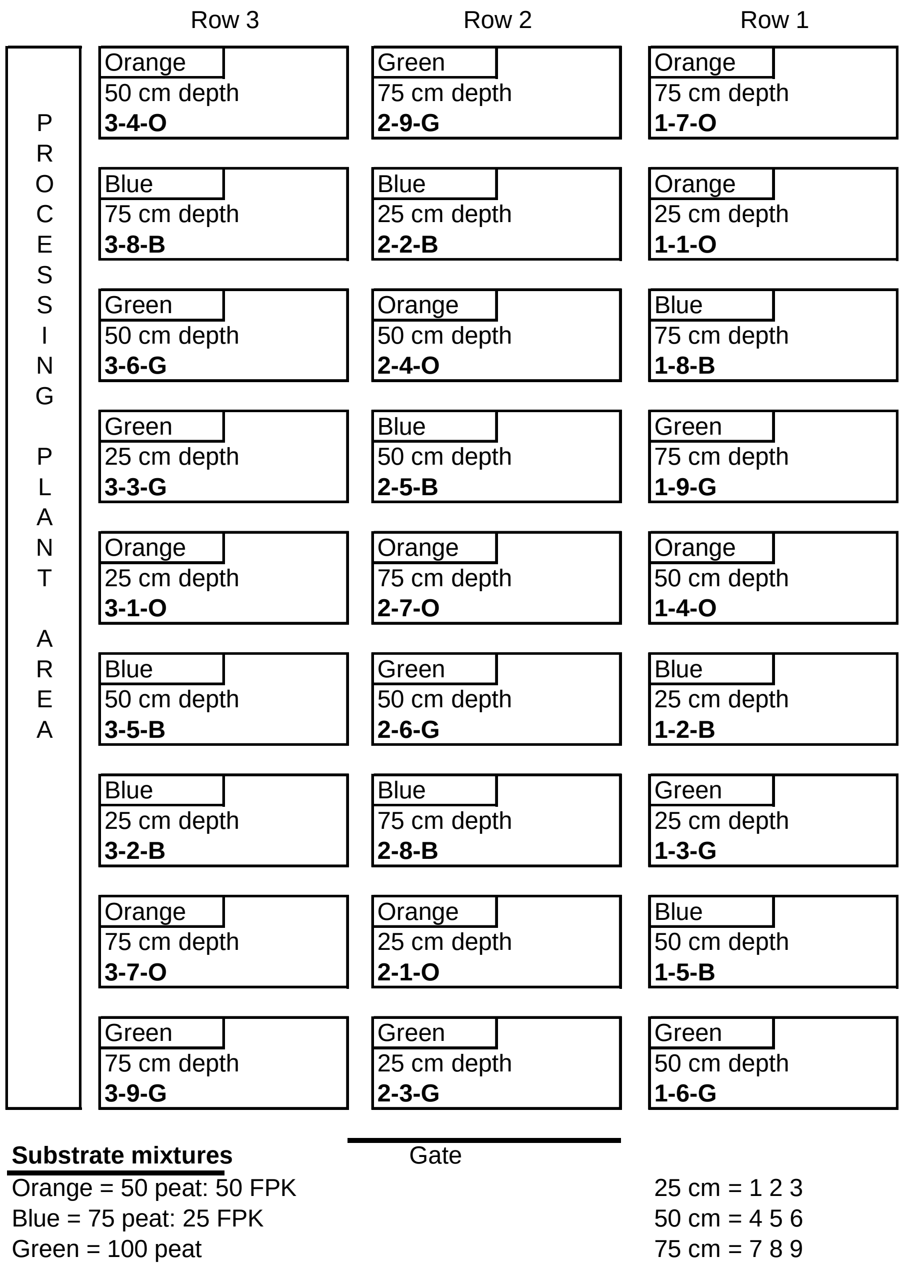


Figure 2. Victor main field plot, known as Fort Victor, layout showing the randomized block design consisting of 3 replicate rows, each consisting of 3 substrate mixtures at 3 different depths for a total of 9 plots per row.

2. Little Victor Plot

Figure 3 shows the layout of the one metre by one metre plots were constructed on the peat substrate adjacent to the larger test pad containing each of the following species; green alder (*Alnus crispa*), dwarf birch (*Betula pumila*), Labrador tea (*Ledum groenlandicum*), Leatherleaf (*Chamaedaphne calyculata*), deer grass (*Scirpus caespitosus*), Northern Reed grass (*Calamagrostis inexpansa*), cloudberry (*Rubus chamaemorus*). Each species was transplanted into 1 metre by 1 metre plots of 100 percent peat and 75% peat: 25% FPK substrate mixtures with a depth of approximately 10 cm. Cottongrass seeds were collected from the winter airstrip at the Victor Project site in June, July and August of 2003, green alder seeds were collected in August 2003 from the Victor Project area and in September 2003 from Yellowknife, NWT. All seeds were cold stratified over the winter of 2003-2004 prior to field plot construction in June 2004.

Seeds from each collection were placed in individual 0.5 metre by 0.5 metre plots constructed from each of the above mentioned substrate mixes at a depth of 10 cm.

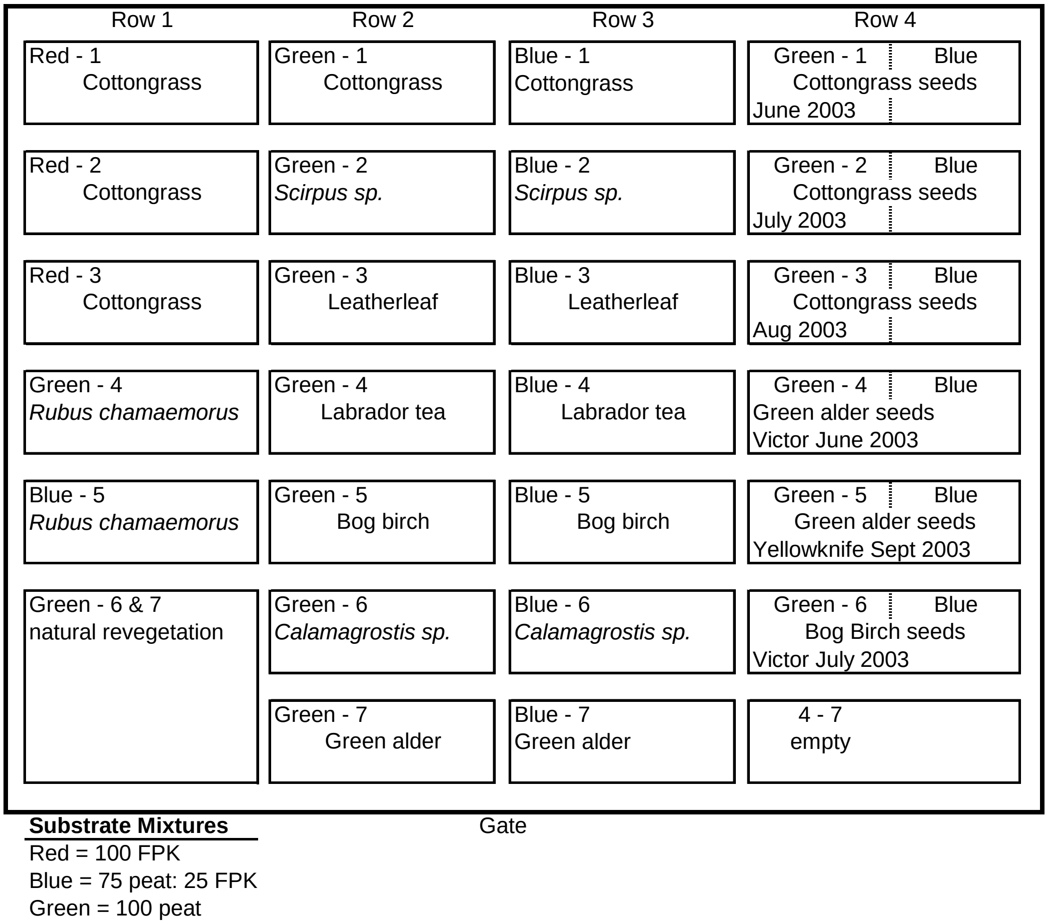


Figure 3. Secondary species trials, known as Little Victor, layout showing the block designs each consisting of 2 substrate mixtures.

The uneven ground surface is sloped towards the west on a moisture gradient, species were arranged on the moisture gradient such that vegetation species more favourable to moister environments were planted in the western plots and the species more favourable to drier environments were planted in the eastern plots closer to the gate. A fence was then built around it and a log surrounded the bottom of the fence to inhibit small mammal entry. Each plant species used for transplant was collected from the Project site area.

All plots were fertilized with 15-30-15 at a rate of 20 grams per plot or 200 kg per hectare. A soluble fertilizer was mixed in 4 litres of water prior to application to provide an initial nutrient supply to assist with plant stabilization for the first growing season.

3. Measurements

Individual plants in each plot were measured for base diameter, height of the tallest green tiller and general plant health in June 2004, after transplanting and again in September 2004 after the first growing season. Health was on a scale of 1 to 4, based on the percentage of green plant material in the overall plant. Therefore, plants with 75 – 100% green material were ranked 4, between 50 and 75% green ranked 3, between 25 and 50% green ranked 2 and less than 25% green were ranked 1. Plant base diameters were measured in the same orientation of east – west to ensure consistency in measure with growth.

The treatment effects were compared using SPSS in a 5-way factorial ANOVA for mixed design to test both between subject and within subject effects, followed with One-way analysis of variance with Scheffe's ($P<0.05$) for *post hoc* analysis to determine differences between treatments. Student's *t*-test was also performed for each substrate mixture and depth, and row to determine statistical significance in plant measurements over the first growing season.

4.Results

4.1 Eriophorum Trial

A 5-way factorial analysis of variance on normalized data at the 0.01 significance level resulted in a 3-way interaction ($F_{25,406}=5.36$ $P<0.001$, $eta^2= 0.026$) between substrate mixtures by depth by time of measurement was performed. Further detailed analyses of data are described in the following paragraphs.

4.1.1 Substrate Mixtures

The measurements of plant base diameter by substrate mixtures in September were statistically significant ($F_{8,431}=4.26$ $P<0.05$) and the Scheffe's test showed the differences were between the 50% peat:50% FPK and the 75% peat:25% FPK mixtures. There was also statistical significance ($F_{8,431}=4.40$ $P<0.05$) in plant heights by substrate mixtures in September. Scheffe's test showed the differences were between the 50% peat:50% FPK and the 100% peat substrate mixtures. While health of plants between the 75% peat:25% FPK mixtures and 50% peat:50% FPK mixtures were also statistically significant ($F_{8,431}=3.86$ $P<0.05$).

4.1.2 Substrate Depths

The health ratings in September between the substrate depths of 25 cm and 50 cm with 75 cm were statistically significant ($F_{8,431}=7.97$ $P<0.0001$).

4.13 Treatment blocks

Plant base diameters in September between rows 1 and 3 with 2 were statistically significant ($F_{8,431}=3.90$ $P<0.05$). And the plant heights in June between rows 1 and 3 were statistically significant ($F_{8,431}=6.25$ $P<0.01$). While the health ratings in June between rows 1 and 2 with row 3 where statistically significant ($F_{8,431}=4.34$ $P<0.05$).

Table 1.0 shows the results of within subject measures for each substrate mixture for the measured variables between June and September 2004. Student *t*-tests were performed on the selected variables to confirm statistically significant differences. All measured variables were statistically significant between June and September except the height of plants in the 75% peat:25% FPK and 50% peat:50% FPK mixtures.

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Table 1.0 Within Subject Measures using Student 't' tests

	t-test		DF	t-value	P
	June 21/04	Sept 21/04			
All	Diameter	Diameter	429	-38.02	<0.001
	Height	Height	431	-3.4	<0.001
	Health	Health	431	26.77	<0.001
100% Peat	Diameter	Diameter	143	-23.34	<0.001
	Height	Height	143	-3.39	<0.001
	Health	Health	143	18.6	<0.001
75% Peat:25% FPK	Diameter	Diameter	142	-19.27	<0.001
	Height	Height	143	-1.3	n.s.
	Health	Health	143	14.65	<0.001
50% Peat:50% FPK	Diameter	Diameter	142	-24.2	<0.001
	Height	Height	143	-1.11	n.s.
	Health	Health	143	13.81	<0.001

Figure 4 shows the mean plant base diameters for each substrate mixture for each plot depth. There was no statistically significant difference in plant base diameters in June while there was a statistically significant increase in base diameter for all substrate mixtures and depths between June and September 2004. There was also statistically significant differences ($F_{8,431}$=4.26 $P<0.05$) in September's plant base diameters between the 50% peat:50% FPK substrate and 75% peat:25% FPK substrate mixtures as well the base diameters of plants in replicate rows 1 and 3 where statistically significant ($F_{8,431}$=3.90 $P<0.05$) from row 2.

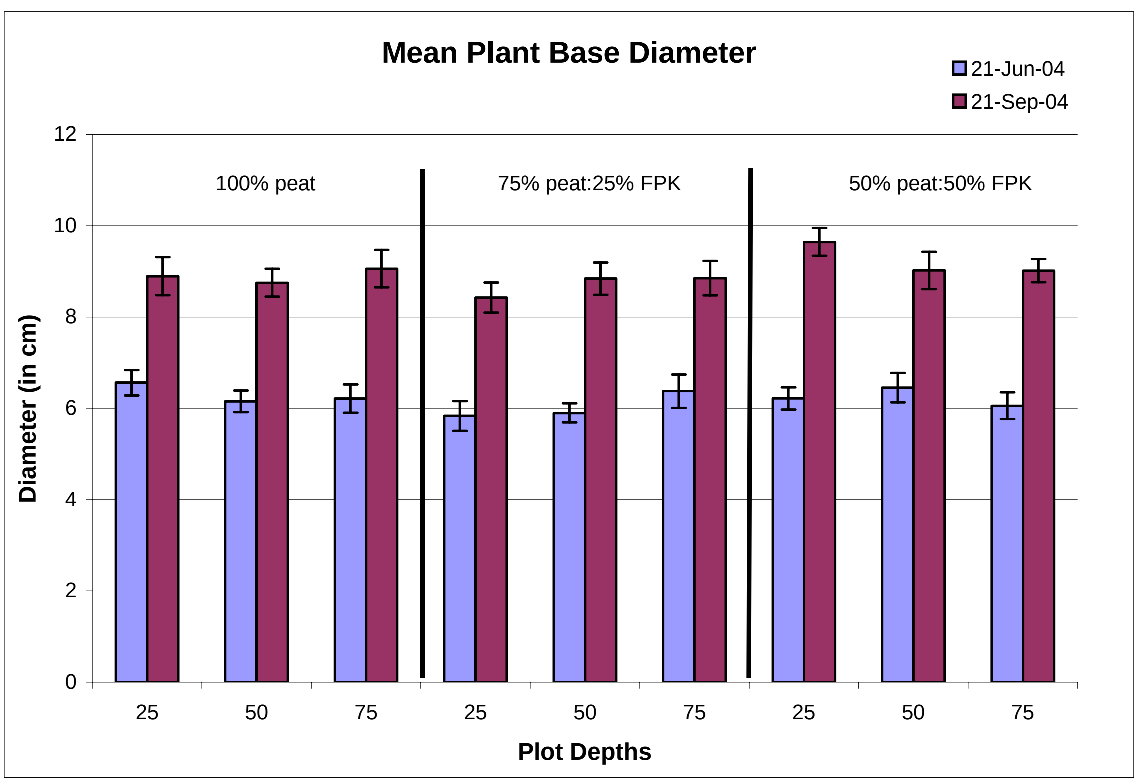

Figure 4. Mean plant base diameters for each substrate mix and depth measured June 21, 2004 after transplanting and remeasured September 21, 2004 after one growing season.

Figure 5 shows plant heights measured in June were statistically significant ($F_{8,431}$=6.25 P<0.05), and Scheffe's test showed the difference was between rows 1 and 3. While plant heights measured in September between the 50% peat: 50% FPK and 75% peat:25% FPK

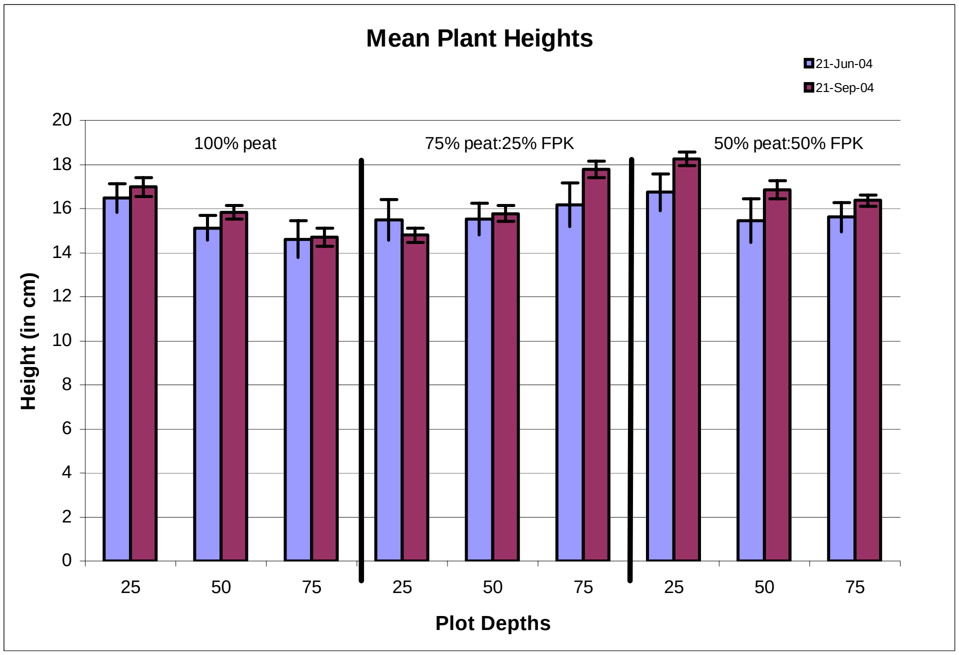

Figure 5. **Mean plant heights for each substrate mix and depth measured on the tallest green stem. First measured June 21, 2004 after transplanting and remeasured September 21, 2004 after one growing season.**

substrate mixtures were statistically significantly different ($F_{8,431}$=4.40 P<0.05). The reduced plant height in the 75% peat: 25% FPK substrate mixture at the 25 cm depth is likely due to the senescing of the larger stems and not an overall reduction in plant height

Figure 6 shows the mean health ranking for each substrate mixture and depth. Plant

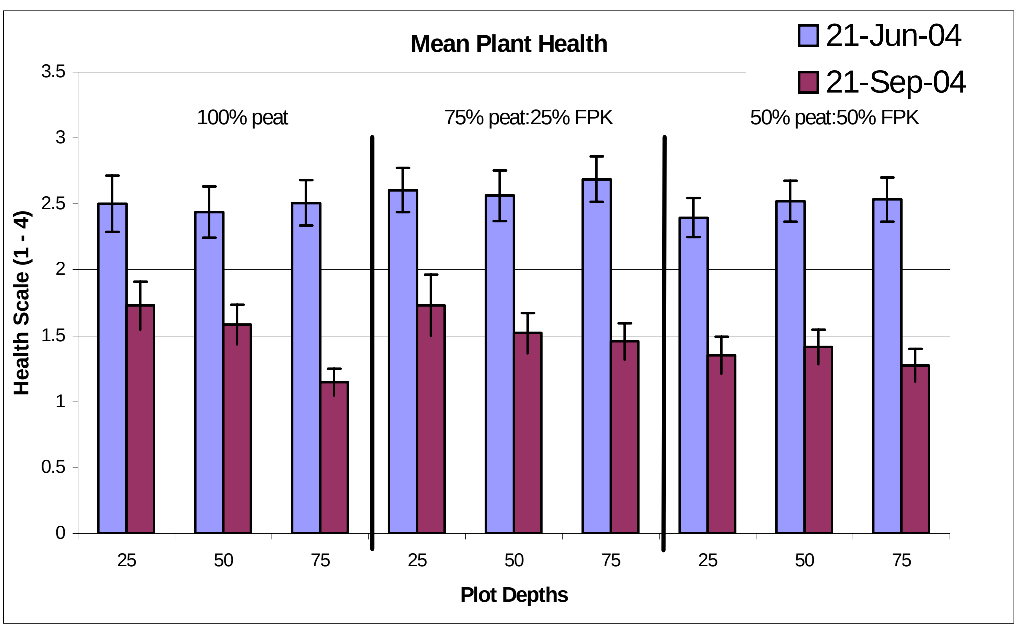

Figure 6. **Mean plant health in each substrate mix and depth based on percent green vegetation on the overall plant. Four equals 75 – 100% green, three equals 50 – 75% green, 2 equals 25 – 50% green and 1 equals <25% green.**

health in June by replicate row was statistically significant ($F_{8,431}$=4.34 P<0.05), and Scheffe's test showed the differences were between rows 1 and 3. While plant health in September was statistically significant differences by substrate mixture ($F_{8,431}$=3.86 P<0.05) and depth ($F_{8,431}$=7.976 P<0.001). Scheffe's test showed the differences were between the 50% peat:50% FPK and 75% peat:25% FPK; and the 25 and 50 cm depths with the 75 cm substrate depth, respectively. The overall reduction in plant health is likely due to senescing and not a decrease in plant health. Future measurements in the spring/summer of 2005 will confirm or reject this hypothesis of plant health.

4.2 Soil Chemistry

Samples of each substrate and mixture of substrates used in the glasshouse experiments and field experiments were sent to a lab for nutrient and mineral analyses, these results are shown in Table 2. The mixture of 50% peat:50% FPK has similar mineral and nutrient concentrations as the 100% FPK, with the expectations of aluminum, % saturated phosphorus, sodium, magnesium and percent organic matter. While the 75% peat:25% FPK more similar to the 100% peat except for the organic matter percentage, magnesium, sodium and aluminum contents.

Table 2 Substrate mineral and nutrient contents.

* Mineral		100% CPK	100% FPK	50% Peat:50% FPK	75% Peat:25% FPK	100% Peat
Organic Matter (%)		1	0.7	7	13	36.6
Phosphorus		12	6	7	5	5
Potassium		34	43	34	30	27
Magnesium		830	1270	555	580	380
Calcium		3830	7200	7200	4700	4080
Sodium		51	764	50	43	14
pH		8.3	8.7	7.9	7.8	7.5
CEC (meq/100 g)		26.4	50	40.9	28.6	23.7
Iron		70	60	64	61	69
Copper		1.6	1.6	1.4	1.2	0.8
% Sat Phosphorus		14	67	23	10	7
Aluminum		155	15	48	89	136
Percent Base Saturations	K	0.3	0.2	0.2	0.3	0.3
	Mg	26.2	21.2	11.3	16.9	13.4
	Ca	72.6	72	88	82.2	86.1
	Na	0.8	6.6	0.5	0.7	0.3

* units in mg/L unless otherwise stated

General Discussion and Conclusions

Tiller density per area of tussock declines with increasing diameter and larger tussocks may become invaded by mosses and shrubs, which further reduce tiller density. The centre of the tussock is more productive than the edges (Shaver *et al*, 1986).

There was statistically significant increase in plant diameter over the growing season; while there was an overall increase in plant height in all the plots the differences were not statistically significant. It was also concluded that tiller number and not tussock size (base diameter) is more affected by nutrient availability (Shaver *et al*, 1986).

Measurements of plant heights were based on the tallest green tiller and health rating was based on a percentage of green plant material. Since the second measurements were taken mid-September when the plants already began senescence and therefore the results may not reflect plant health due to treatments but due to seasonal changes. Winter survival will determine the effect of treatment on plant health, although Shaver *et al* (1986) found that old tillers of *E. vaginatum* may serve as a source of carbohydrate and support early spring growth such that they survive the winter only to die in the spring. Plant health and growth over the first growing season lead to the conclusion the substrate mixtures and plant species selections may likely be viable choices for initial ecological succession in the revegetation at the Victor Diamond Project, though winter survival and long term monitoring will provide more definitive results.

Future Studies

Plants will be measured again after spring growth and prior to autumn senescence in 2005 for short term assessment then continued for several years for long term assessment. Other experiments are currently in progress to test the drought tolerance of cottongrass, evaporation and evapotranspiration effects on substrates under wind conditions and soil water characteristic curves. Expanded assessment of other species and species mixes need to be evaluated to develop plant diversity and sustainability can be achieved in revegetation strategies for the Victor mine site.

References

Chapin III, F.S., Van Cleve, K., and Chapin, M.C. 1979. Soil Temperature and Nutrient Cycling in the Tussock Growth Form of *Eriophorum vaginatum*. *Journal of Ecology*, **67**, 169-189.

De Beers, May 2003. Victor Diamond Project Preliminary Draft Environmental Assessment.

Dickinson, W., 1973. The Development of the Raised Bog Complex near Rusland in the Furness District of North Lancashire. *Journal of Ecology*, **61**, No. 3, 871-886.

Fetcher, N. and Shaver, G.R., 1983. Life Histories of Tillers of *Eriophorum vaginatum* in Relation to Tundra Disturbance. *Journal of Ecology*, **71**, 131-147.

Legasy, K., LeBelle, S., and Chambers, B. 1995. Forest Plants of Northeastern Ontario. Lone Pine Publishing. Edmonton.

Marcoux, K., Lavoie, C., Price, J.S., 2000. Les Invasions de Linaigrette (*Eriophorum vaginatum* L.): Aide Ou Frein à la Restauratíon des Tourbièrs? Faculté d'Aménagement d'Architecture et des Arts Visuals, Université Laval.

Rochefort, L. 2000. *Sphagnum* – A Keystone Genus in Habitat Restoration. *The Bryologist*, **103**(3), 503-508.

Shaver, G.R., Chapin III, F.S., and Gartner, B.L. 1986. Factors Limiting Seasonal Growth and Peak Biomass Accumulation in *Eriophorum vaginatum* in Alaskan Tussock Tundra. *Journal of Ecology*, **74**, 257-278.

SRK Consulting, October 2003. Summary of Geochemical Characterization and Water Quality Estimates – Victor Diamond Project, Ontario. SRK Report # 2CD002.07.999, prepared for De Beers Canada.

Tuittila, E-S., Rita, H., Vasander, H., and Laine, J. 2000. Vegetation patterns around *Eriophorum vaginatum* L. tussocks in a cut-away peatland in southern Finland. *Canadian Journal of Botany*, **78**, 47-58.

Wein, R.W, and MacLean, D.A., 1973. Cotton grass (*Eriophorum vaginatum*) germination requirements and colonizing potential in the Arctic. *Canadian Journal of Botany*, **51**, 2509-2513.