EKATI DIAMOND MINE™ PROCESSED KIMBERLITE RECLAMATION

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ABSTRACT

The option to establish a vegetation cover over a rock cover to stabilize processed kimberlite tailings after diamond extraction has prompted revegetation research at the Ekati Diamond Mine™ in the Canadian sub-arctic barrenlands. Laboratory testing has shown coarse texture, no organic component and lack of available macronutrients to be the principal limitations to plant colonization. This study aims to ameliorate these plant growth limitations to establish a permanent self-sustaining vegetation cover on the Ekati kimberlite tailings containment area, stabilizing the surface materials and promoting natural colonization by the surrounding tundra vegetation. With the addition of structural improving and nutrient providing amendments, plant growth on these kimberlite tailings has shown promise. Successful amendment combinations have included peat moss or papermill waste in combination with biosolids from the mine site and/or fertilizer.

INTRODUCTION

Ekati Diamond Mine™ is Canada's first and only diamond mine currently in production. The mine is located 300 km northeast of Yellowknife and 200 km south of the Arctic Circle in the Northwest Territories. This heath tundra ecosystem is parented by Precambrian granite swept clean by glaciations of the last ice age. Boulder fields, sand eskers and countless lakes eclipse the landscape. This reclamation study is concerned with the mine's processed kimberlite tailings, which are more specifically the crushed kimberlitic ore wastes left after diamond extraction. These waste materials are transported by pipe from the processing facility and discharged in a slurry form into the natural basin of Long Lake Containment Facility (LLCF), Cell B. Tailings deposit began at the north end of Cell B in October 1998 and has progressively moved south creating a drainage slope from north to south. In spring 2000 the tailings at the most northerly end of LLCF had significantly dewatered and became suitable for reclamation. These dewatered tailings have a sand fraction of 87%, and with no measurable organic component this substrate, once dried, becomes highly susceptible to wind and water erosion. This study will focus on reclaiming the processed kimberlite tailings dewatered in Cell B of the LLCF through substrate amendment and establishment of a self-sustaining vegetation cover, stabilizing this potentially erodable substrate.

The Ekati Diamond Mine™ processed kimberlite tailings have several limitations in relation to plant growth including course texture, no organic component (poor water and nutrient holding capacities), low macronutrients and an unbalanced calcium magnesium fraction. Amelioration of these poor growing conditions through the testing of several different amendment materials is the main focus of these reclamation efforts. Peat, lake sediment, mine biosolids, papermill waste, Agri-boost (commercial soil conditioner), fertilizer and three calcium sources (gypsum, rock phosphate, calcium carbonate) are being evaluated at different rates, alone and in combination, in relation to improving these kimberlite tailings as a plant growth medium.

This amendment evaluation study was carried out in two phases: (i) a laboratory study evaluating the chemical and physical properties of potential amendments followed by a greenhouse study testing these amendment combinations in relation to plant growth, and (ii) field trials of the more promising amendment combinations in field plots established on Cell B at the LLCF. The focus of this paper will be the results of the first phase of this research, the lab and greenhouse portions.

MATERIALS AND METHODS

The greenhouse study was conducted between October 2000 and October 2001 and considered 164 amendment combinations and amendment application rates. Due to space constraints and the large number of variables to be tested, the greenhouse study was subdivided into three, four-month sessions. The first week of each 16-week session was used for the preparation of amendment combinations prior to seeding. The greenhouse pots were filled with the appropriate mixtures, seeded and allowed 14 weeks to germinate and grow. Harvest and final quantification of results occurred in the final week of each session.

Once the greenhouse pots were filled they were moved from the lab to the greenhouse and saturated with 400 ml of deionised water. The pots sat overnight under greenhouse conditions then saturated again with another 400 ml of deionised water per pot prior to seeding. The pots were then broadcast seeded and fertilizer applied by broadcasting it with seed into appropriate amendment combinations. The seed and fertilizer were weighed individually for each pot and hand broadcast over its surface.

Once seeding was complete pots were kept at field capacity as determined by the filter paper method (Alef and Nannipieri 1995) for the duration of the 14-week growing period. To maintain each pot at field capacity 250 ml of deionised water was added every 24 hours.

The greenhouse temperature and hours of light were regulated to simulate natural conditions at the mine's latitude. Light was kept constant for all pots at 18 hours light a day, simulating the long hours of daylight during the mines summer months. The temperature was kept fairly cool between 15 and 21 °C, simulating the cool mean monthly conditions for the growing season (July, August, September), The temperature control was variable depending on daily and seasonal fluctuations in solar radiation as these greenhouse sessions ran over the course of a year.

Amendment success in the three greenhouse sessions has been based on several aspects of plant growth and substrate parameters. Ground cover, root and shoot biomass production, plant height (mean and maximum), plant development (flowering, tillering) and plant health (scale 1 = green to 4 = dead) were measured at the end of each of the three 14-week greenhouse growth sessions. Soil samples were collected from each greenhouse pot at harvest and analysed for the following: available nutrients (nitrogen (N), phosphorus (P), potassium (K), sulphur (S)), pH, total cations (calcium (Ca), magnesium (Mg), sodium (Na), K), cation exchange capacity (CEC), extractable cations (Ca, Mg, Na, K), total carbon and total inorganic carbon.

RESULTS AND DISSCUSSION

The production of a substrate stabilizing, self sustaining vegetation cover on the processed kimberlite tailings at the Ekati Diamone Mine™ will require the amendment of both the physical and nutrient limitations of this material. The most favourable plant response to the amended kimberlite tailings occurred when both the physical and nutrient limitations were simultaneously combated. This was supported by the positive plant response observed when peat moss and sewage sludge were included in an amendment combination. Peat moss and sewage sludge worked to improve both physical structure of these tailings and the availability of macronutrients. The amendment of low macronutrient availability in these kimberlite tailings is not only important for positive initial plant response but also for sustained growth as a nutrient cycle is established. Without good substrate structure nutrients are lost to leaching or made unavailable to vegetation (Smith 1992).

The additions of calcium in the form gypsum, rock phosphate and calcium carbonate to ameliorate the unbalanced calcium magnesium fraction did not result in improved plant response or a balanced Ca:Mg ratio. However, other researchers suggest the benefit of surface applied gypsum may not show in the short term (Schuman et al. 1994). In a study on revegetation of mine spoil, perennial grass ground cover and biomass production were not improved by the addition of surface applied gypsum until the third growth season. Time is required to dissolve the gypsum and cause any significant effect on plant growth (Schuman et al. 1994). The 14-week growth period afforded the amended tailings in this study was likely not sufficient to show the calcium addition effects and further research would be needed to explore the effect of these additions.

The remote location of the Ekati Diamone Mine™ and processed kimberlite tailings in the LLCF raise the question of reclamation cost and overall amendment feasibility. Without permanent road access the cost of transporting materials to the mine by air is substantial. This study has considered this issue in initial amendment selection, however, application method and rate, availability and purchase cost of each amendment must be included in the overall feasibility of large scale tailing reclamation. In consideration of overall feasibility, mine biosolids would be the best option, as it is produced at the mine and therefore requires minimal transport costs and no purchase cost. It has also proven the most effective single amendment as a nutrient source and with proper safety procedures such as outlined by Dunigan and Dick (1980), could ultimately solve both sewage disposal and tailings nutrient availability issues.

Commercial peat moss preformed well in ameliorating the processed kimberlite's structural limitations and would likely prove valuable as a long-term nutrient source if a nutrient cycle were successfully established. However, the cost associated with the purchase and transport of commercial peat will be high and based on rate of application performance should be tested at lower more feasible rates perhaps in combination with small amounts of lake sediment or paper mill sludge. Papermill sludge has shown excellent potential in this study and has proven beneficial in field trial on acid-generating tailings in other research (Belsito and Winterhalder 1999). Composted papermill sludge is recommended for further testing as a structural improving and long term nutrient providing amendment for the processed kimberlite. The application of a calcium source is also recommended despite the poor short-term performance in this study. Other researchers suggests gypsum has long-term values and further research on its effects in the Ekati processed kimberlite tailings is recommended. Application rates of amendments in this study, with the exception of sewage sludge, were likely too high and lesser quantities of peat moss, papermill waste and lake sediment are recommended for testing with mine biosolids to determine optimum application rates and more feasibly large scale reclamation solutions.

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