USING POPULATIONS OF SCIRPUS ATROCINCTUS, A SEDGE, FOR STABILIZING TAILINGS BEACHES AND TILL BERMS

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ABSTRACT

An important component of decommissioning mining operations is physical stabilization through revegetation of barren tailing areas and man-made peat berms. conventional revegetation, using agricultural seed mixtures, fertilizer and lime, are effective as long as the terrain allows access of machinery. Tailings beaches and peat berms are difficult to reclaim and stabilize permanently. The reclamation process is generally very costly, sometimes requiring repeated applications.

Indigenous plant species populating either the peat bog or the tailings areas have demonstrated their ability to colonize these substrates. This paper reports on utilizing local populations of Scirpus atrocinctus, a species of sedge, for the stabilization tests of peat berms and tailings beaches. This species was found growing on polymetallic, acidic tailings at Buchans, Newfoundland. See was collected from the vicinity of mine-disturbed lands and used for the stabilization tests.

Seed collection time, storage requirements, and the specific conditions required for seed germination and seedling establishment of Scirpus atrocinctus were examined in laboratory and field experiments. High light intensities and temperatures with adequate moisture were determined to be the critical factors for breaking seed dormancy. Supplementation of seedlings with an adequate nitrogen supply in moist conditions promoted good plant growth. A simple, cost-effective technique has been developed to rapidly vegetate and stabilize peat berms. Further experiments are required to obtain better results for tailings beaches.

Introduction

Decommissioning of mining operations typically requires physical stabilization of barren tailings areas, the plant site, and any areas disturbed during operations. Conventional revegetation measures apply agricultural seed mixtures, combined with fertilizer and lime, using machinery.

The use of conventional reclamation measures is, to a large part, restricted to areas accessible to machinery. Acid-generating tailings beaches and dams/berms are examples of this problem. Methods which facilitate establishment and growth of indigenous species in areas inaccessible by machinery are useful tools in rehabilitation.
Stabilization of acidic tailings beaches and peat berms was required at Buchans, Newfoundland. The Buchans mill and ore bodies are located within a 1.5 km radius of the town of Buchans, in west-central Newfoundland, Canada (Long. 56° 52', Lat. 48° 48'). The mines and mill operated between 1928 and 1984, producing copper, lead, and zinc concentrates, containing some gold and silver. A barite concentrate was produced for a short time.

A species of sedge, *Scirpus atrocinctus*, is the most abundant, and one of a very few species, which has colonized some areas of the tailings. This species is dominant in the wet sedge meadows and marshes, a common habitat in the west-central Newfoundland. *Scirpus atrocinctus*, commonly known as Wool grass, is a perennial sedge species with stout rootstocks, found in moist to swampy areas from Newfoundland to Ontario, as well in Saskatchewan and the southern United States (Britton and Brown, 1970).

This paper reports on the conditions for germination and establishment of seeds of Wool grass. Field trials are carried out, both on tailings and on peat berms, with the objective of devising a technique to establish sedge populations as self-maintaining vegetation covers.

MATERIALS AND METHODS

Laboratory Experiments

Seed Collection: Seed heads were cut from senescing plants in a wet sedge meadow near Buchans, Newfoundland on October 12, 1990 and air-dried at ambient temperatures in an unheated building for two weeks. Seed head samples were split into three sub-samples for storage in sealed plastic bags at room temperature (21°C), in a refrigerator (8°C) and in a freezer (-20°C). Samples were stored at the three temperatures for at least 70 days before laboratory experiments were performed.

The dried seeds were shaken from the inflorescences and the seed concentrate was gathered into pipettes using a vacuum pump. The seed concentrates were re-stored at room temperature, or in the fridge or freezer.

Seed Germination: Seeds stored at the three temperatures were scarified for different time periods. Scarification consisted of wetting seeds with 60 % sulphuric acid then thoroughly rinsing the seeds with distilled water. The seeds, suspended in distilled water with residual acid (pH 1.2 - 1.5), were then pipetted into plastic petri plates containing a layer of 0.8 % agar. The plates were capped, sealed with electrical tape, then placed 50 cm below four 1.22 m long "cool white" fluorescent lights (12 hr:12 hr, light : dark) and temperature controlled at $21 \pm 3°$ C.

The seeds were examined weekly for germination under a stereo microscope. Final counts of the total number, and the number of germinated seeds, were made after 16 days.

A second experiment was a repeat of the first, except only those seeds stored in the freezer were used, and a control (no scarification) was included. Again, the seeds were examined weekly for germination under a stereo microscope. Final counts of the number of germinated seeds were made after 16 days.

A third experiment repeated the two previous experiments, using the same methodology. However, one additional treatment was applied after 16 days incubation. All petri plates were moved outdoors for 24 hours, during which all plates were exposed to bright sunlight for 6 hours. The number of germinated seeds were counted on day 16 prior to sunlight exposure, and again on day 25, 8 days after exposure to sunlight.

Field Experiments

Experiments were set up examining germination of *S. atrocinctus* on peat-till berms and acid-generating tailings in field conditions in Buchans, Newfoundland. During these field trials, seed samples stored at refrigerator temperatures were used. Seeds were not scarified prior to planting, as the tailings were acid.

Till Berm Field Trial: The banks of 1 m high peat-till berms (1:1.7 slope) erected during construction of six circular ponds in 1989 remained generally devoid of vegetation three years later. The pH of this till, slurried with distilled water, is 5 to 6. A field germination trial was set up on the bank of one berm facing west, on May 30 1992.

Natural phosphate rock and Nutricote (18-18-18), a slow-release fertilizer, were applied at rates of 0.4 $kg.m^{-2}$ and 0.34 $kg.m^{-2}$ respectively to 1 m wide by 2 m long plots, each spanning from the base to the crest of the berms. Some plots received no fertilization. Control plots were parallel strips of till which did not receive chemical amendments. In total, six sets of the three treatments (control, phosphate rock, Nutricote) were set up.

Seed heads collected on October 12, 1991 were slurried with water, and approximately 40 g equivalent of dry seed was spread over each replicate of half of the treatments.

Clear plastic sheeting was placed over two of the three pairs of seeded/unseeded plots. The plastic sheeting was removed July 17, 1992, and the percent cover by plants over the top, middle and bottom of the berm spanned by each replicate was assessed on September 27, 1992.

Tailings Field Trial: The tailings, inactive since 1982, are generally devoid of a vegetation cover, except for peripheral encroaching vegetation and isolated clumps of *S. atrocinctus*. The pH of these tailings, slurried with distilled water, ranges from pH 2.7 to 5.7. Nutrients, peat and/or sawdust was applied to the tailings surface prior to seeding with *S. atrocinctus*.

On May 31, 1992, a section of the tailings surface was roughened before application of nutrients and peat or sawdust using a stiff-tined hand rake. The trial area was divided into three equal areas, and treatments were replicated within these three areas. Approximately 50 $L.m^{-2}$ of peat or sawdust were applied to the surface of 0.8 m by 3 m strips, while a third set of strips did not receive organic material.

Nutrients were the same as used for the berm experiments at application rates of 0.07 $kg.m^{-2}$ nutricote, phosphate rock (0.14 $kg.m^{-2}$) and limestone (0.07 $kg.m^{-2}$). Pairs of plots were set up perpendicular to, and over the strips with and without organic amendment.

One plot of each pair was seeded with *S. atrocinctus*, while the second plot was left unseeded. After slurrying seed heads with water, the equivalent of 25 $g.m^{-2}$ of dry seed were applied to each plot.

The percent cover by *S. atrocinctus*, moss, and a species of grass naturally colonizing the field trial was assessed on September 29, 1992.

RESULTS

Laboratory Experiments: In the first laboratory experiment, the highest percent germination was 14.6 % after 16 days incubation, in the treatment using seeds stored at -20°C and scarified for 2 minutes prior to planting (Table 1). Germination ranged from 0% to 4% in the remainder of treatments.

Scarification	Room (21C)	Fridge (8C)	**Freezer (-20C)**	28-Feb-92
0.5 min	2.1% 2 252	2.9% 1 34	1.9% 2 172	Germination No of Replicates No. of Seeds
2.0 min	4.0% 2 323	2.0% 2 187	**14.6%** 2 468	**Germination** No of Replicates No. of Seeds
5.0 min	1.1% 2 485	0.0% 2 361	0.4% 2 401	Germination No of Replicates No. of Seeds

Table 1: *Germination of Scirpus atrocinctus seeds in Laboratory Experiment 1, according to storage temperature and scarification time. Seeds collected October 12, 1991. Sulphuric acid (60%) used for scarification. Experiment performed February 12 through February 28, 1992.*

These results suggested that those seeds stored at -20°C experiment were most viable. In the second experiment, seeds stored in the freezer were used and the scarification treatment was repeated. In this experiment, the highest percent germination, 36.8 %, was recorded for the 0.5 minute scarification treatment (Table 2), in contrast with the results of the first experiment, where the highest percent germination was observed in the two minute scarification treatment. Less than 10 % of seeds germinated in the remainder of treatments. Overall, a clear relationship between time of scarification and percent germination is not apparent.

Scarification	**Freezer (-20 C)**	14-Apr-92
Control	1.5% 2 331	Germination No. of Replicates No. of Seeds
0.5 min	**36.8%** 3 361	**Germination** No. of Replicates No. of Seeds
1.0 min	9.7% 3 594	Germination No. of Replicates No. of Seeds
2.0 min	6.6% 3 814	Germination No. of Replicates No. of Seeds
5.0 min	4.8% 3 516	Germination No. of Replicates No. of Seeds

Table 2: *Germination of Scirpus atrocinctus seeds in Laboratory Experiment 2, according to storage temperature and scarification time. Seeds collected October 12, 1991. Sulphuric acid (60%) used for scarification. Experiment performed March 29 through April 14, 1992.*

The third germination experiment repeated the treatments tested in the first two experiments. After 16 days following set-up, germination in all treatments was less than 5 % (results not shown). This is in contrast with the previous two experiments, where percent germination was as high as 36.8 %.

Given these poor germination results after 16 days, a final measure was taken before abandonment of the third experiment. All plates with seeds on agar were moved outdoors on May 21, 1992, into bright sunlight and high temperatures inside the petri plates. The next morning, all petri plates were returned to the laboratory growth set-up. From examination of the plates two days later, it was apparent that, although those seedlings which had developed prior to exposure to sunlight were dead, a large percentage of the remaining seeds had germinated.

Eight days after exposure to sunlight, germination had reached as high as 89.5% in un-scarified seeds originally stored in the refrigerator (Table 3), while 87.2% (1 minute scarification) and 80.9 % (2 minute scarification) germination were observed in other treatments using the refrigerator-stored seeds.

Scarification	Room (21 C)	Fridge (8 C)	Freezer (-20 C)	29-May-92
Control	0.0% 1 145	**89.5%** 1 153	0.0% 1 99	**Germination** No. of Replicates No. of Seeds
1.0 min	71.8% 4 216	87.2% 4 187	85.3% 5 218	**Germination** No. of Replicates No. of Seeds
2.0 min	0.0% 4 146	80.9% 4 178	0.0% 4 240	**Germination** No. of Replicates No. of Seeds
5.0 min	37.1% 4 197	0.0% 5 210	10.1% 4 218	**Germination** No. of Replicates No. of Seeds

Table 3: *Germination of Scirpus atrocinctus seeds in Laboratory Experiment 3, according to storage temperature and scarification time. Seeds collected October 12, 1991. Sulphuric acid (60%) used for scarification. Experiment performed May 4 through May 29, 1992. Seeds incubated in laboratory May 4 through May 20 (germination < 5 % in all treatments). Seeds exposed to direct sunlight May 21, then returned to laboratory.*

Field Plots: Poor germination/seedling establishment was observed when *S. atrocinctus* seeds were planted directly onto the till without nutrients (Control, 1.7% to 5% cover; Table 4). Better coverage by seedlings was observed in those treatments where the till berm was amended with natural phosphate rock (8% to 30% coverage). However, the best coverage was observed in those treatments where nitrogen was supplied as well (58% to 72% coverage) through addition of Nutricote. Plants were as tall as 0.3 m.

	Seeding	**Natural Phosphate Rock S.atrocinctus cover ***	**Nutricote Slow-Release Fertilizer S. atrocinctus cover ***	**Control (No Amendment) S. atrocinctus cover ***
Top of Berm	S.atrocinctus	23.3%	66.7%	3.7%
	None	0.4%	0.1%	0.0%
Middle	S.atrocinctus	30.0%	58.3%	5.0%
	None	1.7%	1.3%	0.0%
Bottom of Berm	S.atrocinctus	8.3%	71.7%	1.7%
	None	1.7%	18.3%	0.0%
* Number of Replicates = 3				

Table 4: *Percentage cover by Scirpus atrocinctus in seeded and unseeded plots on till berm amended with natural phosphate rock or Nutricote slow release fertilizer, September 28, 1992, 121 days following seeding.*

The control plots (no seeding, no amendments) remained bare as expected. Addition of phosphate rock and Nutricote promoted the development of *S. atrocinctus* seedlings. In unseeded treatments with phosphate rock, coverage by seedlings ranged from 0.4% to 1.7%. In the unseeded plots with Nutricote, coverage by seedlings ranged from 0.1% to 18.3%.

Overall, in the tailings plot, poor development of *S. atrocinctus*, moss and any other species was observed in all treatments. There was no *S. atrocinctus*, moss, or other species growing on plots which received natural phosphate rock alone or limestone alone, with or without sawdust or peat.

However, in treatments receiving Nutricote, or Nutricote plus limestone, small patches of moss protonema developed, covering 0.1% to 5% of the plots. As well, seedlings of an unidentified grass had established, especially in those plots where sawdust or peat was added. *S. atrocinctus* plants were not observed in any of the treatments where Nutricote alone was added to bare tailings, or to tailings where peat or sawdust were added (Table 5). When both phosphate rock and nutricote was applied, *S. atrocinctus* was present.

The addition of both Nutricote and natural phosphate rock, combined with sawdust or peat amendments, appears to have provided conditions, at some spots within these treatments, where *S. atrocinctus* seeds could germinate and seedlings could develop (Table 5). These plots also supported greater moss development and the same species of grass which had invaded the other plots. However, coverage by *S. atrocinctus* seedlings was relatively low (2.5 %) within these plots, compared to the results of till berm field trial.

ORGANIC AMENDMENT		CHEMICAL AMENDMENT ***								
		Nutricote Slow-Release Fertilizer			Limestone + Nutricote			Phosphate Rock + Nutricote		
		% Cover			% Cover			% Cover		
	Seeding	S.a*	Moss	Grass **	S.a.	Moss	Grass **	S.a.	Moss	Grass **
Control	S.a.*	0	1.0	0	0	0.1	1	0	3	1
	None	0	3.7	0	0	5.0	0	0	10	0
Peat	S.a.*	0	0.1	1	0	0.5	1	2.5	1	1
	None	0	0.5	0	0	0.1	0	0	10	0
Sawdust	S.a.*	0	0.1	1	0	0.1	1	2.5	0.5	1
	None	0	0.5	0	0	0	1	0	1	1

* Scirpus atrocinctus
** Single grass species
*** Control, Natural Phosphate Rock, Limestone treatment results all zero; results not shown.

Table 5: *Percentage cover by S. atrocinctus, moss and a grass species in seeded and unseeded plots on acidic tailings with chemical and/or organic amendments, September 29, 1992, 122 days following seeding.*

Discussion and Conclusions

The results of the third laboratory experiment, where a high percentage of seeds germinated only two days following exposure to bright sunlight, clearly indicate that high or variable light and/or temperature is (are) necessary for triggering germination of *Scirpus atrocinctus* seeds.

In light of these results, variation within and between the first, second and third laboratory experiments may have been due to subtle differences (unrecorded) in levels or fluctuations of temperature and/or light during the incubation periods under fluorescent lighting. Given the high percent germination in the control treatment in the third lab experiment, scarification using concentrated sulphuric acid appears unnecessary for seed germination. Storage temperature of the seeds is also not important. Similar results for species closely related to *S. atrocinctus* have been observed by other workers. Pons and Schroder (1986) observed that the germination of seeds of *Scirpus juncoides* required temperature fluctuations, and that oxygen concentrations greater that 10% suppress germination.

Overall, the results of the laboratory experiments indicate that a high percentage (90%) of *S. atrocinctus* seeds collected in the fall can be viable, and will germinate if the correct conditions for germination are provided. High or fluctuating light and/or temperature can, in fact, be expected at the surface of bare till berms or tailings. Second, up to 37 % of seeds remained viable following exposure to concentrated sulphuric acid for 5 minutes, and following incubation on agar wetted with low pH rinse water. Therefore, it is feasible that *S. atrocinctus* seeds would germinate and seedlings develop in acidic conditions such as on acidic tailings beaches.

The results of the field trials reflect the relative effectiveness of the various treatments in supporting seedling establishment. Given the rapid development of *S. atrocinctus* cover on the till berms with the addition of seeds and slow release fertilizer, it appears that a simple technique for revegetating disturbed soils using an endemic species has been developed. This technique should serve as an effective tool for permanently stabilizing disturbed areas against erosion, particularly in areas inaccessible by heavy machinery.

The field trials on the tailings indicate that supplying seeds alone is inadequate to initiate colonization. Organic amendments, available nitrogen and, possibly, surface tailings neutralization, must be supplied for *S. atrocinctus* seedling survival. While limestone addition did not provide appropriate conditions for seedling survival, natural phosphate rock addition did. Phosphate rock probably served as a slow release neutralizing agent, while the reactions between limestone and acidic tailings likely occur only in the short term.

While a good vegetation cover was not achieved in any of the treatments applied to the tailings surface, the results of the Nutricote-phosphate rock-organic amendment treatments are encouraging. Promotion of moss cover development, through supplying available nitrogen and phosphate as phosphate rock may find applications in certain conditions.

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