REVEGETATION OF METAL MINE TAILINGS UNDER WETLAND CONDITIONS[1]

by

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Abstract. In greenhouse experiments two populations of *Glyceria fluitans*, one from a metal-contaminated and the other from a non-contaminated site were grown successfully on zinc mine tailings, under different flooding and fertiliser treatments. In an outdoor microcosm experiment *Glyceria fluitans*, *Phragmites australis* and *Typha latifolia* from non-contaminated sites were grown on alkaline zinc mine tailings with and without fertiliser treatments. Results indicate that these wetland plants can be established and grow well on zinc mine tailings and are suitable plants for the revegetation of metal mine tailings under flooded conditions.

Additional Key Words: Zinc, *Glyceria fluitans*, mine tailings, wetland plants.

Introduction

Rehabilitation of metal mine tailings is normally carried out under upland conditions. Revegetation can be difficult as mine tailings are generally low in nutrients, high in metal concentrations and may retain water poorly. There can also be pollution problems due to wind erosion. In recent years wetlands have been used for the treatment of metal-contaminated water (Brix & Schier 1989, Hammer 1989), indicating that wetland plants are able to tolerate high metal concentrations in soil and water. Revegetation of tailings under wetland conditions would alleviate many of the problems encountered with rehabilitation under upland conditions.

Glyceria fluitans was found growing in the tailings pond of an abandoned lead-zinc mine in County Wicklow, Ireland (Beining & Otte 1996). The possibility of using this plant for revegetation purposes is currently being investigated. A field survey, various greenhouse experiments and an outdoor microcosm experiment were carried out to determine how easily *Glyceria fluitans* can be established on tailings, how well it grows and the growth conditions required by this plant. The research so far concentrated on zinc. *Glyceria fluitans* is an amphibious plant, i.e. it can grow emerged as well as submerged, therefore the effects of flooding on survival and growth of these plants were investigated. The requirements for plant nutrients in the form of NPK fertiliser were investigated as this could form a major cost factor in the utilisation of these plants for rehabilitation purposes.

Materials and Methods

Field Survey

Glyceria fluitans was collected from a metal-contaminated site (Glendalough) and a non-contaminated site (Lough Dan), both in County Wicklow (see Beining & Otte, 1996, for detailed descriptions of the sites). Soil pH was measured after mixing 10g of dry homogenised soil with 25ml of water. Soil was analysed for nitrogen and phosphorus concentration after Kjelldahl digestion following the methods of Hendershot (1985) and Murphy and Reilly (1962). Soil and plant material from both sites was analysed for zinc concentrations by Flame Atomic Absorption Spectrophotometry following acid-digestion in Teflon bombs as described in Beining & Otte (1996).

Greenhouse Experiments

Both greenhouse experiments were carried out under temperature conditions ranging from 5-35°C and averaging at 20°C . The light regime followed daylight hours and no additional lighting was provided.

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Flooding Experiment. Two populations of *Glyceria fluitans* from Lough Dan (non-contaminated) and Glendalough (metal-contaminated) were grown under flooded and non-flooded conditions on mine tailings for a period of five weeks. The lengths of the leaves were measured weekly and dried biomass recorded for all plant material after harvesting. All plant material was dried for two days at 60°C.

Fertiliser Experiment. *Glyceria fluitans* from the tailings pond in Glendalough was grown on tailings, flooded and treated with Bio Gromore NPK fertiliser (7.0 N:3.0 P: 5.8 K) at a rate of 0, 0.5, 1.0, 2.5 and 5.0g per pot. Leaf growth was measured throughout the experiment and biomass recorded on harvesting the plants after five weeks.

Outdoor Microcosm Experiment

Glyceria fluitans, *Phragmites australis* and *Typha latifolia* from non-contaminated sites were established on alkaline lead-zinc tailings obtained from an active tailings pond in Tara mines, Co. Meath, Ireland. Plants were grown in large tubs with and without fertiliser treatment and flooded. pH and leaf growth were measured regularly and the tailings were analysed for zinc as described earlier. Results were recorded after eight weeks for all plants.

Statistical Analyses

Analysis of variance (ANOVA) was carried out to test for any significant differences using Minitab 8.1 for Macintosh. All data was $\log_{10}$ transformed to obtain homogeneity of variance.

Results

Field Survey

Zinc concentrations in soil at Glendalough and Tara mines were significantly higher than at Lough Dan (P<0.001) (table 1). The pH of soil at Tara mines was significantly higher than at Lough Dan and Glendalough (p<0.001). Nitrogen concentrations at Lough Dan and Glendalough were significantly higher than at Tara mines (p<0.001). There was no significant difference in soil phosphorus concentrations between sites. All values were tested by one-way ANOVA.

In plants there was a significant difference in zinc concentrations between sources (P<0.001) and between plant parts (P<0.01), (table 2), while the interaction between the factors was not significant. Concentrations of zinc in plants from Glendalough were significantly higher in all plant parts compared to plants from Lough Dan. They were highest in the roots of plants for both populations. Zinc concentrations were similar for dead leaves and flowering heads for the

Table 1 Means±standard deviations of zinc (μmolg^{-1}), nitrogen (nmolg^{-1}) and phosphorus (nmolg^{-1}) concentrations, and pH values of soil samples taken from Lough Dan, Glendalough and Tara mines.

	Lough Dan	Glendalough	Tara
Zn	0.55±0.11	270±66	187±55
N	8.1±4.0	14.0±2.8	2.3±2.7
P	5.4±2.8	14.9±3.8	10.8±17.2
pH	5.3±0.6	5.7±0.2	8.4±0.1

Lough Dan population, while in the Glendalough population they were four times greater in dead leaves than in flowering heads. Zinc concentrations were lowest in the shoots of *Glyceria fluitans* from Lough Dan and in the flowering heads for the Glendalough population.

Table 2. Means±standard deviations of zinc concentrations (μmolg^{-1}) in plant material taken from Lough Dan and Glendalough.

Source	Plant part	Zinc concentration
Lough Dan	live leaves	0.84±0.40
	dead leaves	0.75±0.35
	shoots	0.45±0.23
	roots	2.08±0.42
	flowering heads	0.76±0.56
Glendalough	live leaves	94±28
	dead leaves	289±240
	shoots	150±46
	roots	376±233
	flowering heads	75±8

Flooding Experiment

Plants in this experiment had to be harvested after five weeks as the profuse growth of epiphytic algae on leaves of plants in flooded treatments might have interfered with the growth of the plants and made measurements of leaf length difficult. There was no significant difference in the rate of growth of leaves between populations. However, the growth rate of leaves of *Glyceria fluitans* was significantly better under flooded than non-flooded conditions (P<0.01) when tested by ANOVA (figure 1).

Fertiliser Experiment

Plants in this experiment were again harvested after a period of five weeks due to the presence of epiphytic algae on leaves. Results from this experiment indicate the various fertiliser treatments had no effect on the rate of growth of leaves (figure 2) or on total biomass production (figure 3).

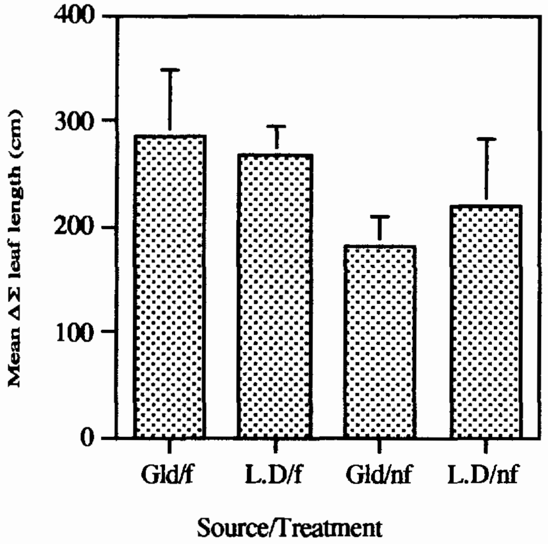

Figure 1. Mean difference in the sum of leaf length (cm) of *Glyceria fluitans* originating from Glendalough (Gld) and Lough Dan (L.D) grown under flooded (f) or non-flooded (nf) conditions for five weeks; bars indicate standard deviation (n=5).

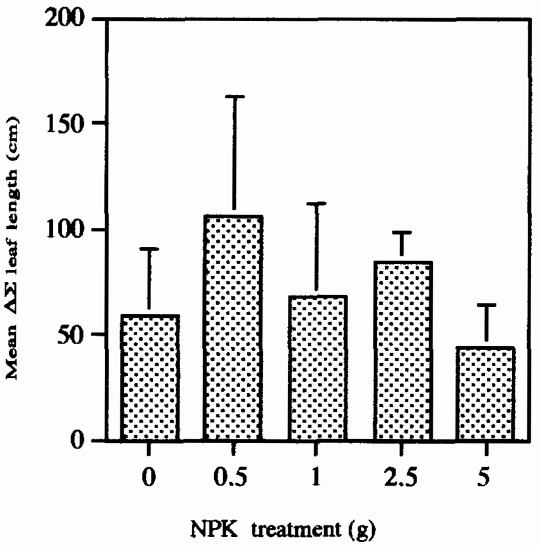

Figure 2. Mean difference in the sum of leaf length (cm) of *Glyceria fluitans* grown on tailings treated with NPK fertiliser (g per pot) under flooded conditions for five weeks; bars indicate standard deviation (n=4).

Outdoor Microcosm Experiment

Soil characteristics of the tailings from Tara mines are shown in table 1. Zinc and phosphorus concentrations in the soil from Tara mines are greater than those in Lough Dan soil but less than those in soil from Glendalough. Nitrogen concentration is less in soil from Tara mines than both other sites. The soil from Tara mines is alkaline whereas soil from Lough Dan and Glendalough is acidic indicating a broad pH range on which these plants can grow. Percentage leaf growth rate of *Glyceria fluitans* and *Phragmites australis* was very high and showed no significant difference due to fertiliser treatment after eight weeks. There was no leaf growth in *Typha latifolia* after an eight week period without NPK fertiliser treatment. (figure 4).

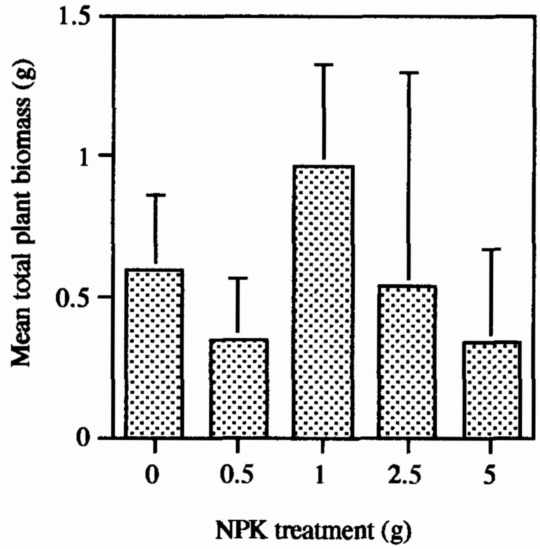

Figure 3. Mean total plant biomass (g) of *Glyceria fluitans* grown on tailings treated with NPK (g per pot) under flooded conditions for five weeks; bars indicate standard deviation (n=4).

Discussion

Metal tolerance of wetland plants and the possibility of using them for rehabilitation of mine tailings is a relatively new area of research so very little information is available for comparison purposes.

Elevated zinc concentrations in soil and plant material of the tailings pond where *Glyceria fluitans* was found growing indicated that this may be a suitable metal-tolerant plant for revegetation of mine tailings under wetland conditions. Soil zinc concentrations where *Glyceria fluitans* was found growing were up to four hundred times higher at Glendalough than those at Lough Dan (table 1).

The flooding experiment showed that both populations of *Glyceria fluitans* grew equally well on tailings regardless of origin. A field experiment was carried out to further investigate these results which involved transplanting *Glyceria fluitans* from Lough Dan to the tailings pond in Glendalough. After six weeks these plants continued to grow in these high zinc concentrations (unpublished data). Similar observations have been made for *Typha latifolia* which was able to colonise heavy metal contaminated soils in the absence of the evolution of tolerant races (McNaughton *et al.* 1974). Both populations of *Glyceria fuitans* did however grow significantly better under flooded than non-flooded conditions. This may be due to changes occurring in the soil under anoxic conditions associated with flooding, which in turn may affect metal mobility and availability to plants (Gambrell 1994). For example, the formation of insoluble sulphides under anoxic conditions could decrease the availability of zinc.

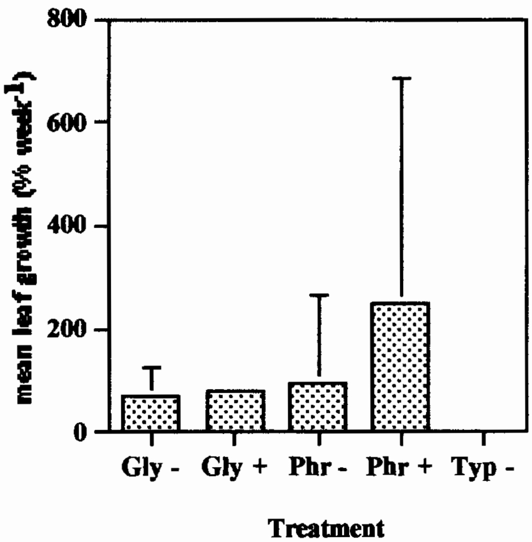

Figure 4. Mean percentage leaf growth per week of *Glyceria fluitans* (Gly), *Phragmites australis* (Phr) and *Typha latifolia* (Typ) grown on tailings with (+) and without (-) fertiliser treatment under flooded conditions for eight weeks; bars indicate standard deviation (n=3).

One of the major factors affecting maintenance costs of revegetated tailings is the high fertiliser requirements due to the low nutrient content of mine tailings. In this study treating *Glyceria fluitans* with NPK fertiliser had no obvious beneficial effect on plant growth or biomass production after a period of five weeks. The tailings pond in Glendalough where these plants originated from was very low in nitrogen and phosphorus content, which also indicates that these plants have very low nutrient requirements and is in agreement with the above results. The pond has been left unmanaged for at least fifty years suggesting *Glyceria fluitans* can survive longterm without any fertiliser treatment.

The outdoor microcosm experiment was set up to investigate the ability of *Glyceria fluitans, Phragmites australis* and *Typha latifolia,* of non-metal contaminated origin, to become established and grow on alkaline rather than acidic tailings, to establish their ability to disperse out and cover unvegetated areas and to further investigate the response of these wetland plants to NPK fertiliser treatment, under flooded conditions. *Glyceria fluitans* and *Phragmites australis* grew equally well on tailings with and without fertiliser treatment. These results for *Glyceria fluitans* are in agreement with earlier results from the greenhouse fertiliser experiment. *Phragmites australis* only produced new leaves in one out of three replications in those given NPK fertiliser so the response of this plant to fertiliser treatment is unclear. However, the fact that this plant was able to grow on these tailings favours its use for rehabilitation purposes. Previous research has shown *Phragmites australis* can grow successfully on slurry refuse indicating it has the potential for revegetation purposes (Nawrot *et al.*). No leaf growth was observed in *Typha latifolia* after eight weeks. It may be that this plant takes longer to become established on contaminated soil or that transplanting took place too late in the year. These plants were not given fertiliser treatment which could also explain why they didn't grow in the tailings. *Typha latifolia* has previously been successfully grown on metal contaminated soil (Naughton *et al* 1974). These are still preliminary results and further research will be carried out on all of these plants.

All experimental results to date clearly favour the use of *Glyceria fluitans* for revegetation of mine tailings under flooded conditions. They are easily established on acidic and alkaline tailings, have minimal fertiliser requirements and readily disperse out to cover previously unvegetated tailings, thus demanding little labour and cost input for maintenance during rehabilitation of metal mine tailings.

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