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Lead and Zinc Tolerance of *Agrostis capillaris* L. and *Festuca rubra* L. Across a Mine-Pasture Boundary at Minera, North Wales

By

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With 2 Figures

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Summary

KARATAGLIS S. S., MCNEILLY T. & BRADSHAW A. D. 1986. Lead and zinc tolerance of *Agrostix capillaris* L. and *Festuca rubra* L. across a mine-pasture boundary at Minera, North Wales. – Phyton (Austria) 26 (1): 65–72, 2 figures. – English with German summary.

Lead, zinc, and copper tolerance was measured in six samples of 30 plants of *Agrostis capillaris* L. and *Festuca rubra* L. across a mine/pasture boundary at the abandoned lead/zinc mine at Minera, North Wales. Tolerance was also measured for a control sample of each species from an uncontaminated site.

Mean lead and zince tolerance for both species did not differ significantly between the two mine sites and the site 1 m into the pasture. Significantly lower lead and zinc tolerances than these were recorded for the samples 10 m, 15 m, and 150 m from the mine boundary. These three samples however had tolerance levels significantly greater than those of the control samples. No sample of either species was copper tolerant. The absence of a sharp fall in tolerance to lead and zinc is explained in terms of the influence of gene flow, and of the movement of toxic waste into adjacent pasture soils.

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Zusammenfassung

KARATAGLIS S. S., McNEILLY T. & BRADSHAW A. D. 1986. Blei- und Zinktoleranz von *Agrostis capillaris* L. und *Festuca rubra* L. an der Grenze zwischen Bergwerksgelände und Weideland in Nord-Wales. – Phyton (Austria) 26 (1): 65–72, 2 Abbildungen. – Englisch mit deutscher Zusammenfassung.

An sechs Proben von 30 Pflanzen von Agrostis capillaris L. und Festuca rubra L. wurde die Blei-, Zink- und Kupfertoleranz an der Grenze einer stillgelegten Blei-Zink-Mine gegen Weideland untersucht und mit der Toleranz der gleichen Species von nicht contaminierten Böden verglichen. Die Blei- und Zinktoleranzen der beiden Species zeigten an den Probestellen 1 und 10 m von der Grenze gegen die Mine und 1 m gegen das Weideland keine signifikanten Unterschiede. Pflanzen im Weideland 10–150 m von der Grenze der Grundstücke entfernt wiesen hingegen eine signifikant niedrigere Toleranz gegen beide Schwermetalle auf, sie war jedoch deutlich höher als die Toleranzwerte von uncontaminierten Böden. Keine einzige der untersuchten Proben erwies sich gegen Kupfer tolerant. Das Fehlen eines scharfen Abfalles der Blei- und Zinktoleranz wird auf die Wirkung eines Genflusses sowie auf Eintrag toxischer Abfälle in die benachbarte Weidefläche erklärt.

Editor transl.

Introduction

A number of studies of plant populations from adjacent heavy metal contaminated and uncontaminated soils have revealed sharp boundaries between heavy metal tolerant and normal populations, which reflect the sharp boundaries separating the contrasting soil types (JAIN & BRADSHAW 1966, McNEILLY 1968, ANTONOVICS & BRADSHAW 1970). It is not uncommon, however, to find that more recently produced mine waste, composed of finely ground materials (2 mm diameter or less) has been readily eroded by wind to be re-deposited on adjacent non mine soils (JOHNSON, McNEILLY & PUTWAIN 1977, McNEILLY, WILLIAMS & CHRISTIAN 1984). Such erosion characteristically produces an exponential decline in metal levels with distance from the mine.

On normal soils metal tolerant individuals have been shown to be at a disadvantage in competition with non-tolerant individuals (COOK, LEFEBVRE & McNEILLY 1972, HICKEY & McNEILLY 1975). The gradient of contamination of soils produced as a consequence of the pattern of re-deposition of wind eroded mine spoil onto adjacent pastures could provide interesting information about the interaction between soil contamination and the outcome of competition between normal and metal tolerant plants on such soils. Such a situation occurs at the boundary of part of the extensive abandoned lead/zinc mine at Minera, Clwyd, North Wales. This paper examines the distribution of lead and zinc tolerance in *Agrostis capillaris* L. (*A. tenuis* SIBTH.) and *Festuca rubra* L. along a 150 m transect across the mine pasture boundary.

Materials and Methods

Ten single plant samples of *A. capillaris* and *F. rubra* were taken at random from 6 sites each 1 m^2 along each of three parallel transects passing from the mine to the pasture. Sites 1 and 2 were 10 m and 1 m respectively inwards from the edge of the mine waste tip, which was separated from the adjacent pasture by an open fence and narrow stream. Sites 3 to 6 were 1 m, 10 m, 15 m and 150 m into the pasture away from the mine waste edge. A control population was sampled from an area 5 × 5 m on soil known to be uncontaminated, in the vincinity of the mine.

The single plant samples were grown for 8–10 weeks prior to metal tolerance testing, in standard potting soil in a glasshouse at 25° C with a 16 hours photoperiod supplied by mercury vapour lamps.

The method of tolerance testing followed the technique of JOWETT (1964) using concentrations of 3.75 $\mu g \cdot cm^{-3}$ zinc, 6.0 $\mu g \cdot cm^{-3}$ lead, and 0.25 $\mu g \cdot cm^{-3}$ copper. When the material for each site was tested, at least two tillers were included from each of the ten single plant samples. Material from the control population was also included for comparison. Tillers from each site were put, on the one hand, in a beaker with only $Ca(NO_3)_2$ and on the other hand, in a beaker having $Ca(NO_3)_2$ acompanied by the desired concentrations of various metals. The plants were kept in a cabinet and were continuously illuminated by fluorescent lamps. The temperature was kept at 23–25° C and the humidity at 80–90%. The content of the beakers was changed every other day to provide aeration and to keep the solution concentration unaltered. After 12 days the largest root of each tiller was measured and the index of tolerance (IT) was calculated as follows:

$$IT\ (\%) = \frac{\text{Mean length of longest root in solution with metal}}{\text{Mean length of longest root in solution without metal}} \times 100.$$

There were three replicates made of all this.

Soil samples 6–12 cm deep were taken from the rooting zone adjacent to the tillers sampled in the field. Analysis of soils for total lead, zinc, copper,

Table 1

Metal concentration of soils in $\mu g \cdot g^{-1}$ (Nitric/Perchloric acid 4 : 1 v/v extractable)

Populations	Zn	Pb	Cu	Ca
a) Minera				↑
1	8.000–22.000	3.000–5.000	30–100	
2	7.000–12.000	2.000–4.500	60– 90	
3	5.000–13.000	2.500–5.000	30– 70	16.000–52.000
4	3.500–10.000	2.000–3.000	30– 60	
5	4.500–11.000	2.000–4.000	35–110	
6	2.500– 8.000	2.000–3.000	40– 90	
b) Control	50–90	40–110	30– 70	↓

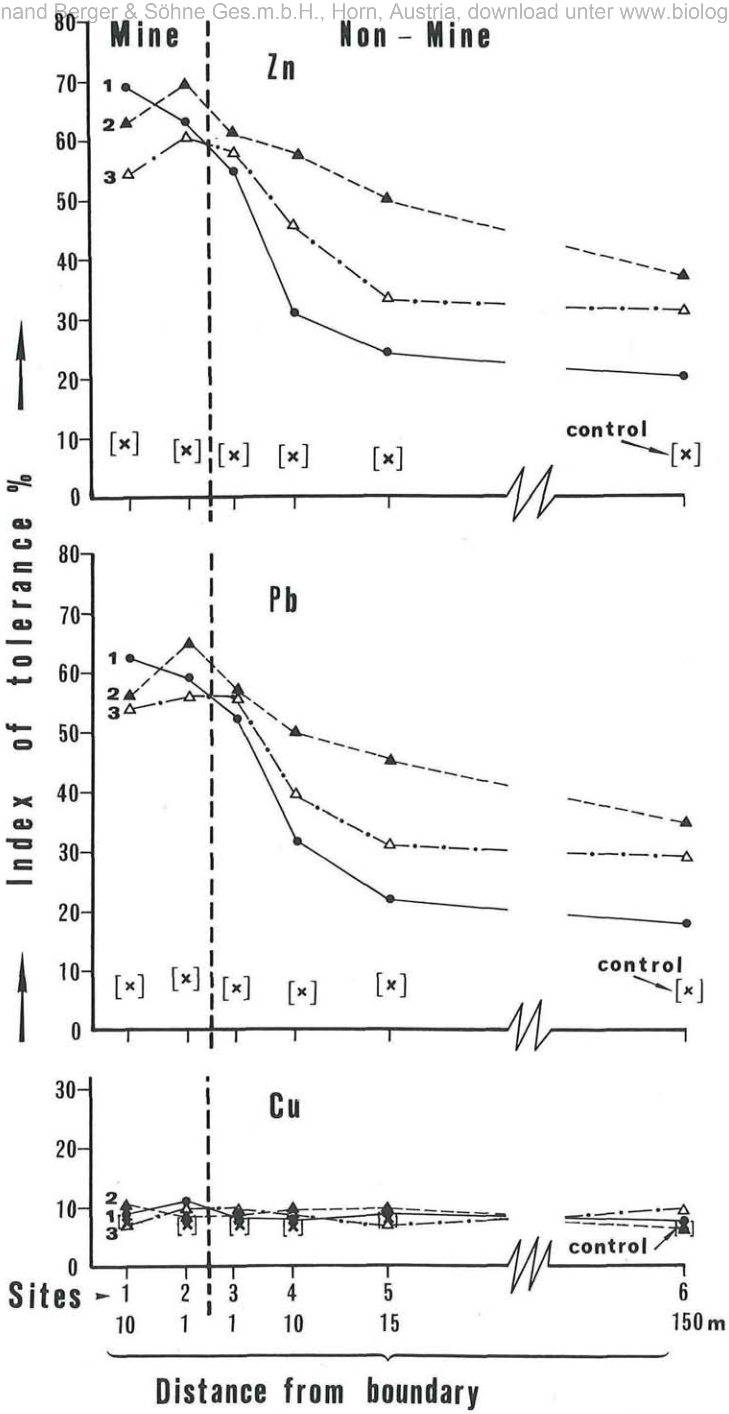

Fig. 1. Mean index of zinc, lead and copper tolerance of *Agrostis capillaris* L. populations sampled across mine-pasture boundary at Minera, Clwyd, North Wales.

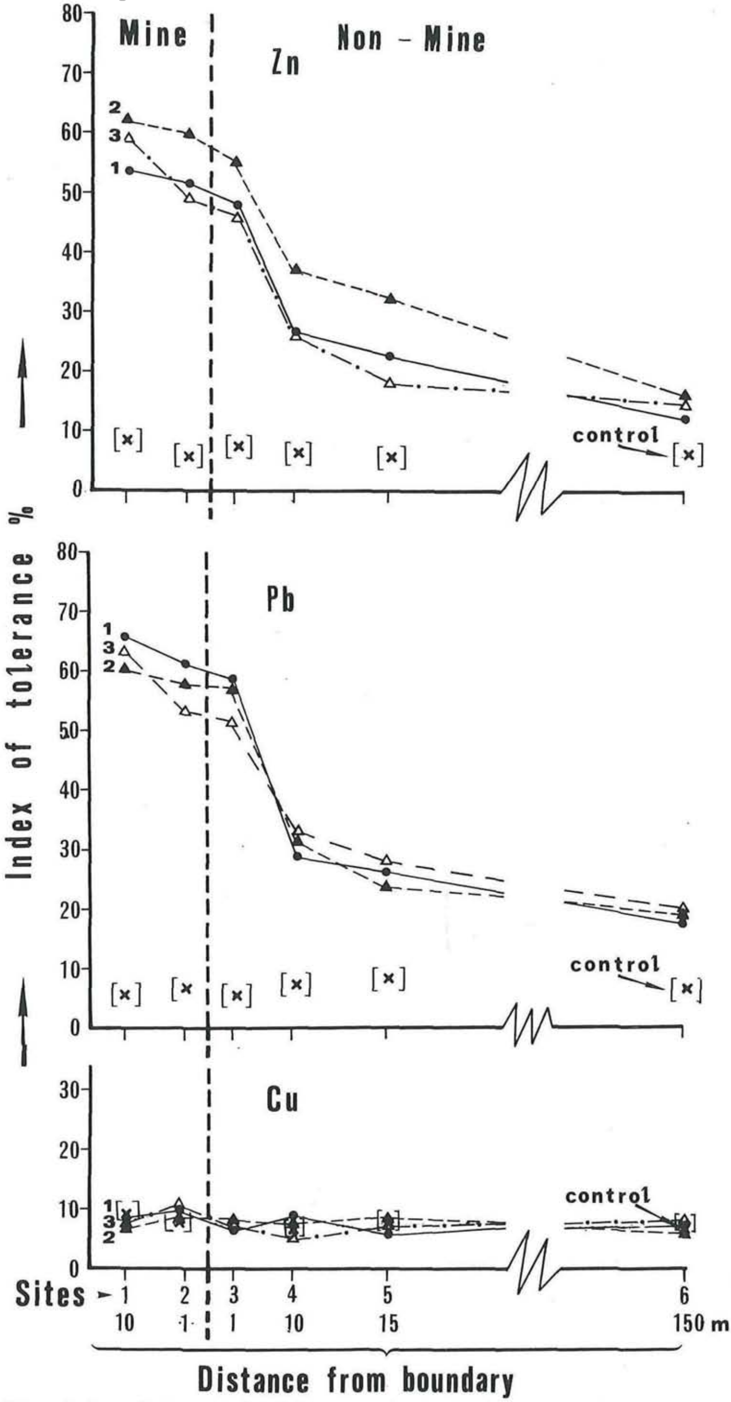

Fig. 2. Mean index of zinc, lead and copper tolerance of *Festuca rubra* L. populations sampled across mine-pasture boundary at Minera, Clwyd, North Wales.

and calcium followed the method of KARATAGLIS (1981, 1982) (Table I). Unfortunately the individual values for each transect are no longer available. Soil pH values ranged from 6.8 to 7.3, and calcium from 1.6% to 5.2% but in no consistent manner.

Results

The distribution of mean tolerance to lead, zinc, and copper for *A. capillaris* and *F. rubra* at each site along each of the three transect, together with the performance of the control, are given in Figs. 1 and 2 respectively.

Mean tolerance to lead and zinc for both species at sites 1,2 and 3 fall within the range previously reported for tolerant populations growing on mine soils.

In *F. rubra* populations from sites 4, 5 and 6 have significantly lower mean lead and zinc tolerances than those from sites 1, 2 and 3. There are significant differences ($p<0.05$) between the mean tolerances of populations 4, 5 and 6. They nonetheless have tolerance means considerably greater than those for the control site. There are also some differences between the transects, particularly zinc tolerance in transect 2.

Differences between site means were less clear in *A. capillaris* than in *F. rubra*. Sites 1, 2 and 3 mean tolerances to lead and zinc did not differ significantly but were significantly different from the site 4, 5 and 6 means. There were also significant differences between site 6, and sites 4 and 5 mean lead and zinc tolerances. The individual transects show considerable differences from each other.

No tolerance to copper was found in any of the populations sampled from the transect, and tolerance was similar to that of the control population.

Discussion

The pattern of distribution of lead and zinc tolerance along the transects sampled are in marked contrast to data for lead and zinc tolerance (JAIN & BRADSHAW 1966) and zinc tolerance (ANTONOVICS & BRADSHAW 1970), who found very sharp transitions over very short distances from tolerant to non tolerant populations. The data presented here show considerable colonisation of soils adjacent to the mine site by tolerant individuals.

There is evidence (HICKEY & MCNEILLY 1975, NICHOLLS & MCNEILLY in preparation) that in *A. capillaris* individuals having low or medium heavy metal tolerance are better competitors against normal populations than individuals with high tolerance. The mean tolerance of the individuals found on transect sites 4, 5 and 6 are intermediate between those of the control site (non-tolerant) and the fully tolerant individuals on the mine soil. The balance between the rather high metal burdens of the soils at sites

4, 5 and 6 which would supress the growth of non-tolerant individuals, and the superior competitive ability of medium or low tolerance individuals in relation to individuals with high tolerance could explain the occurrence of intermediate levels of mean tolerance in such sites. The difference found between the three transects is also probably due to differences in metal burdens, suggested by Table I.

Vegetation density on the area of waste material from which populations 1 and 2 were sampled is low, and such plants as occur could seem to provide little potential as sources of pollen to contaminate adjacent pasture plants. But the adjacent pasture is itself heavily grazed during spring and summer, and the frequency of flowering plants of *A. capillaris* or *F. rubra* is, as a consequence, very low. It is thus likely that the major source of pollen capable of pollinating these pasture plants is the population of tolerant mine plants. As a result there is the potential for gene flow occurring into the pasture, and it is therefore likely that the populations along the transect have their characteristics determined both by gene flow from the mine populations and by selection for individuals with intermediate tolerance on the partially contaminated soils of the transect.

Whether gene flow or elevated metal level is the primary determinant in causing the non mine populations to possess elevated levels of tolerance is not possible to say. However previous work on populations outside a small copper mine at Drws y Coed (McNeilly 1968) and outside a large copper mine at Parys Mt. (Karataglis 1980) show clearly that elevated levels of metal tolerance can occur in populations unaffected by metal contamination which therefore must be due to gene flow, although the populations were 100 and 300 meters away, respectively, from the mine.

It has been argued previously that evolutionary processes in clines in these boundary populations are very interesting on theoritical grounds (Jain & Bradshaw 1966, May & al. 1975). The present results suggest that the situation in mature can be complex and certainly deserves further investigation.

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