high temperature peak in MgO–Ni could be of use for high levels of radiation exposure measurement. The kinetics of the glow curves, energy level values and luminescence spectra are being investigated.

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A. C. CARTER

Rutherford Laboratory,
The Royal Military College of Science,
Shrivenham, Swindon,
Wiltshire SN6 8LA, UK

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Influence of magnesium on nickel toxicity

THE influence of calcium in ameliorating heavy metal toxicity towards plants is well known. The possibility that magnesium might possess similar properties, if to a lesser extent, has been largely ignored by ecologists although there are indications in the literature that such is the case[1,2]. We here reaffirm the effect, and point out its ecological significance.

We investigated the growth of oats (*Avena sativa* L. var. Selma) over a wide range of nickel and magnesium concentrations in water culture. We here report in detail one of our experiments in which oats were grown at magnesium levels of 1.25, 2.5, 5.0 and 7.5 mM combined with nickel at 0 and 1.5 p.p.m. The oats were pregerminated and transferred as seedlings to containers filled with 1.6 l of culture solutions. The culture solutions contained, in addition to the experimentally varied levels of $MgSO_4$ and $Ni(NO_3)_2$, 1 mM $NH_4H_2PO_4$, 6 mM KNO_3, 0.5 mM $Ca(NO_3)_2$, 7 mM $NaNO_3$, 0.1 mM NaCl, and, as micronutrients, 90 μM NaFeEDTA, 46 μM HBO_3, 9.1 μM $MnSO_4$, 0.76 μM $ZnSO_4$, 0.32 μM $CuSO_4$, 9.1 μM $(NH_4)_6Mo_7O_{24}$. The pH was adjusted to 5.2 at each weekly change of culture solution.

The experimental layout was of a randomised block design; there were 64 containers in all, each with three oat plants, with 8 blocks for each treatment. The experiment was run for 35 d in a shaded glasshouse with 18 h d $^{-1}$ supplementary light. Individuals were then scored for Ni toxicity symptoms and harvested. They were dried at 75 °C, weighed on a per pot basis, and the results (Table 1) subjected to an analysis of variance which indicated significant main effects of both Ni ($P < 0.001$), Mg ($P < 0.05$) and Ni–Mg interaction ($P < 0.025$).

Figure 1 shows that the characteristic Ni toxicity symptoms (described in detail by Vergnano and Hunter[3]) decreased in severity with increasing Mg concentrations. The dry weight measurements (Table 1) showed no significant difference between the oats grown at 0 p.p.m. Ni and 1.25, 2.5 and 5.0 mM Mg. The fall in yield at the 7.5 mM level is presumed to result from an excess of Mg. In contrast, there were marked

increases in weight over the range 1.25–5.0 mM Mg at 1.5 p.p.m. Ni. This experiment, and a number of others not reported in detail here, show that Ni toxicity can be ameliorated by increasing Mg levels. (We have no evidence that sulphate anions influence Ni toxicity over the concentration ranges used.)

A further aspect of the influence of Mg on Ni toxicity was shown in an experiment using very high levels of magnesium (25 and 40 mM) with high levels of nickel (5 and 10 p.p.m.). At 40 mM magnesium the plants were very badly stunted, but showed no symptoms of the toxicity of Ni, and were indistinguishable from plants subjected to the same high level of Mg with no Ni. At 25 mM Mg, the toxicity symptoms of Ni were completely suppressed at the 5 p.p.m. Ni level, but were visible to a small extent at the 10 p.p.m. level.

Further work is in progress to investigate the means by which Mg ameliorates Ni toxicity, but it seems worthwhile to comment on the ecological significance of these preliminary observations. Serpentine soils very often contain high levels of
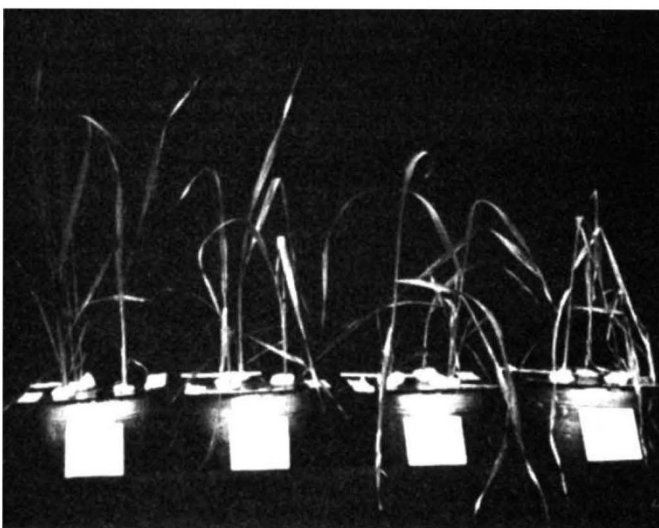

Fig. 1 Increasing symptoms of nickel toxicity in oats with decreasing levels of magnesium (from left to right: 7.5; 5.0; 2.5; and 1.25 mM).

Mg and relatively large quantities of Ni, and many authors have used oats as a bioassay for the presence of toxic levels of Ni in these soils[4,5]. The failure to detect Ni toxicity in a number of such soils (ref. 4 and J.P., unpublished) in spite of evidence that appreciable quantities of Ni were present, may arise partly from the influence of high levels of Mg. The use of oats as a bioassay for Ni toxicity can now be seen to involve an oversimplification of the soil situation and assumes that the Ni–Mg interaction is similar for other species.

The response to Mg of other Ni-sensitive species remains to be investigated, but we feel a consideration of Ni–Mg interactions must be involved in future studies on serpentine soils.

JOHN PROCTOR
IAIN D. McGOWAN

Biology Department,
University of Stirling,
Stirling, UK

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Table 1 Mean dry weight ± s.e. (g) of oat plants grown in culture solutions with differing magnesium and nickel levels. We have, for brevity, combined root and shoot data: their response is similar, although the Ni–Mg interaction is more marked for the roots

Mg (mM)	Ni (p.p.m.)	
	0	1.5
1.25	2.01 ± 0.19*	0.83 ± 0.17
2.50	1.99 ± 0.17	1.21 ± 0.17
5.00	2.02 ± 0.17	1.62 ± 0.17
7.50	1.38 ± 0.17	1.35 ± 0.17

*Mean of seven observations only.