RARE EARTH ELEMENTS AND PLANT GROWTH

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Summary. The effects of the rare earth elements (REEs), lanthanum (La) and cerium (Ce), on the growth of corn (*Zea mays* cv. Hycorn 82) and mungbean (*Vigna radiata* cv. Berken) were investigated in glasshouse trials. The effects of foliar application of a commercial REE fertiliser manufactured in China and analytical grade La plus Ce nitrate were studied. Plants were grown in plastic lined pots containing sterilised peat and sand potting mix. Effects of root application were examined on corn and mungbean grown in continuously flowing nutrient solutions to which low concentrations (<1.4 ?M) of La or Ce were added.

The foliar application of the commercial fertiliser from China or equivalent concentrations of pure La plus Ce nitrate did not significantly increase plant dry matter yields. Foliar spray concentrations >0.1% were toxic to plants producing foliar symptoms and reducing shoot dry weight. Mungbean growth was more sensitive than corn to foliar application. Similarly, the addition of La or Ce to the nutrient solution did not increase total plant dry matter production. Concentrations of >0.2 ?M La or Ce reduced mungbean growth, whereas total corn dry weight was unaffected by concentrations up to 1.4 ?M La or Ce.

INTRODUCTION

Currently there are eight micronutrients essential for all crop plants. However, beneficial effects of other elements have been claimed. There have been reports from China and Australia that the application of small quantities of rare earth elements (REEs) to crop plants increases the quantity and quality of yields (1, 5). The REEs are 17 metals with similar chemical properties, of which lanthanum (La) and cerium (Ce) are the major components of a fertiliser manufactured in China (1). Such La and Ce nitrate fertilisers were applied to over 3.7 million ha of land in China in 1993. The REEs have been applied as foliar sprays, seed treatments, or as additions to the root environment. Australia has considerable mineral deposits of these REEs which potentially could be mined, processed, and used to increase Australia's agricultural production if the beneficial effects can be confirmed.

Glasshouse experiments were conducted to examine the effects of La or Ce application to the shoots and roots of corn (*Zea mays* cv. Hycorn 82) and mungbean (*Vigna radiata* cv. Berken).

MATERIALS AND METHODS

Foliar application

Chemical analyses of a commercial REE fertiliser obtained from China indicated the major components were Ce (12.4%), La (8.7%) and nitrate (45.3%). Translation of the Chinese instructions and specifications on the fertiliser bag revealed the recommended rates for foliar application vary from 0.06 to 2.5% solution at 450-750 g of fertiliser per ha. Solutions containing 0, 0.025, 0.05, 0.1, 0.5 and 1.0% commercial REE fertiliser were prepared. Another set of solutions was prepared containing concentrations of analytical grade La plus Ce nitrate similar to those measured in the commercial fertiliser. A single application of commercial fertiliser or equivalent La plus Ce nitrate was sprayed onto 10 d old corn and 14 d old mungbean plants. Plants were grown in a glasshouse in 200 mm diameter plastic-lined pots filled with a steam sterilised peat and sand potting mix containing a complete basal fertiliser. The total concentration of REEs in the fertilised potting mix was very low (<1 mg/kg). Pots were watered to field capacity every 2-3 d. Each spray treatment contained 5 replicate pots with three corn (*Zea mays*

cv. Hycorn 82) or five mungbean (*Vigna radiata* cv. Berken) plants per pot. Corn was grown for 9 d and mungbean for 5 d after foliar REE application, symptoms photographed and shoot dry weights recorded.

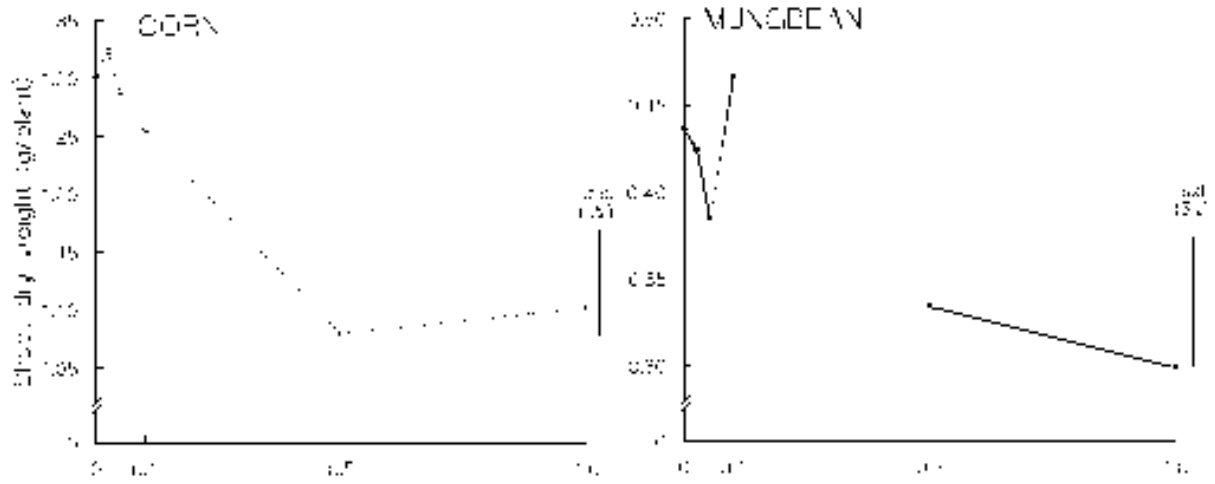
Root application

Continuously flowing solution culture systems allow solution pH and low concentrations of elements in solution to be maintained at plant root surfaces for extended periods of time. This technique was used to grow corn and mungbean plants in dilute nutrient solutions comparable in composition to soil solutions (3, 4). The solution was maintained at pH 4.5 to prevent losses of La, Ce and P due to precipitation. Separate experiments were conducted to examine the effects of firstly La, and then Ce on the growth of corn and mungbean. Lanthanum and Ce treatments were established by adding appropriate volumes of a La or Ce nitrate stock solution and the actual concentration of La and Ce in solution was measured by inductively coupled plasma mass spectrometry. The mean measured concentrations of La in solution were <0.007, 0.19, 0.42, 0.63, 0.84, 1.07 and 1.37 ?M, and those of Ce were <0.007, 0.19, 0.37, 0.63, 0.84, 1.13 and 1.31 ?M (a concentration of 1 ?M La or Ce is equivalent to 0.14 ppm). As the concentrations of La and Ce in solution remained constant, no additional La or Ce was supplied during the plant growth period. Corn and mungbean plants were grown for 14 d in the presence of La and for 16 d in the presence of Ce. After harvest, plants were separated into roots and shoots, oven dried for 48 h at 70oC, weighed, and chemically analysed for plant nutrients, La, and Ce.

RESULTS AND DISCUSSION

Foliar application

The shoots of corn and mungbean sprayed with 0% to 0.1% commercial fertiliser, or equivalent La plus Ce nitrate appeared healthy during the experiment. However, within one day of foliar application, plants in the 0.5% and 1.0% treatments showed symptoms of leaf burn on corn, and small necrotic spots on mungbean leaves. These symptoms became more severe with time. Leaves that emerged after spraying appeared healthy in all treatments. The shoot dry weight of plants measured 5-7 d after spraying with 0.5% or 1.0% solutions was substantially reduced by 17% in corn and 27% in mungbean (Fig. 1). There was no significant difference (P>0.05) between the effects of the commercial REE fertiliser or La and Ce nitrate treatments on the shoot dry weight, the data in Fig. 1 being the means of the 2 REE sources.



Concentration of commercial fertiliser or equivalent concentration of La and Ce nitrate (%)

Figure 1. Effects of foliar application of a Chinese REE fertiliser or equivalent concentrations of analytical grade La plus Ce nitrate on the shoot dry weight of corn and mungbean.

Spray concentrations less than 0.5% did not significantly affect plant growth. Symptoms observed on plants sprayed with La and Ce solution were similar to those observed on plants sprayed with commercial REE fertiliser. Further, the reduction in growth observed on plants treated with La and Ce solution was similar to that which occurred when plants were sprayed with commercial REE fertiliser. Together, these results suggest that the primary cause of the adverse effects of application of commercial REE fertiliser was due to its La and/or Ce content.

Root application

Concentrations of La or Ce in solution from 0 to 1.4 ?M did not significantly affect the total dry weight of corn (Fig. 2), but root growth was increased by Ca and to a lesser extent by La (3, 4). However, in a subsequent experiment, these positive effects on corn root growth could not be reproduce (data not shown). Concentrations of La or Ce >2 ?M have been shown to be toxic to the root growth of corn (2).

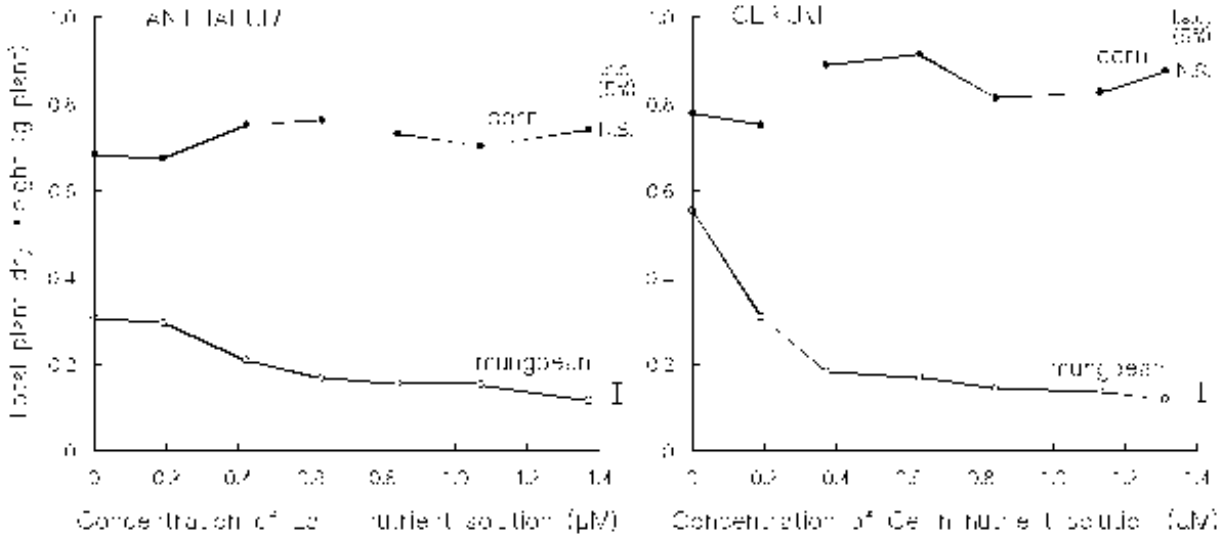


Figure 2. Effects of La or Ce concentration in the nutrient solution on the total plant dry weight of corn and mungbean seedlings grown dilute nutrient solutions. N.S. = not significant at P=0.05. (Redrawn from refs. 3, 4)

In contrast to corn, very low concentrations of La or Ce in solution were toxic to mungbean (Fig. 2). Concentrations as low as 0.42 ?M La decreased mungbean dry weight by 30%, and 0.37 ?M Ce decreased dry weight by 65%. The decrease in mungbean yield with increasing concentration of Ce in solution was accompanied by a large decrease in the concentration of manganese (Mn) in the leaves (4). Mungbean plants with trifoliate leaves containing these low concentrations of Mn displayed Mn deficiency symptoms. By contrast, no Mn deficiency symptoms were observed on mungbean plants exposed to comparable concentration of La in solution (3). Results from the two experiments suggest that Ce causes a greater depression in the Mn status of mungbean than does La.

Low solution concentrations of La and Ce were more toxic to mungbean than corn. Chemical analyses indicated that corn accumulated significantly lower concentrations of La and Ce in the shoots and roots than mungbean (3, 4) and this may contribute to the greater tolerance of corn than mungbean to La and Ce.

CONCLUSIONS

The application of La or Ce to the shoots or roots generally decreased corn and mungbean growth. In view of the toxicity of REEs to these crop plants, it is unlikely that reported beneficial effects can be due to

direct effects of these elements on a particular plant growth process. Such beneficial effects may arise from some indirect effect that impacts upon the agronomic performance of crop plants.

ACKNOWLEDGMENTS

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