W. J. Horst et al. (Eds.), Plant nutrition – Food security and sustainability of agro-ecosystems. 524~525, 2001

Effect of lanthanum on growth and composition of mineral nutrients of *Phaseolus vulgaris* L var. *nanus* and *Zea mays* L. conv. *saccharata*

S. von Tucher, C. Goy and U. Schmidhalter

Department of Plant Sciences, Chair of Plant Nutrition, Technical University of Munich, Am Hochanger 2, 85350 Freising, Germany, tucher@weihenstephan.de.

Key words: lanthanum, plant mineral composition, rare earth elements

Abstract

The effect of a moderate supply of available lanthanum (La)(0-20 µmol l^{-1}) on plant growth and mineral composition was studied in nutrient solution experiments with two plant species, *Phaseolus vulgaris* and *Zea mays*. Neither for maize nor for bean were beneficial effects on plant growth observed, and shoot growth of *Phaseolus* was markedly reduced by about 60% in the 20 µM La treatment. Lanthanum strongly accumulated in the root system of both plant species, but shoot La content increased only in *Zea mays* not in *Phaseolus*. Lanthanum changed the plant mineral composition. These changes were much more pronounced in *Phaseolus*, where all measured minerals (N, P, K, Ca, Mg, S, Mn) were significantly affected. The marked reduction of shoot K and Ca contents is supposedly involved in the decrease in *Phaseolus* shoot growth. The application of rare earth elements (REE) in agricultural production for example as REE-enriched organic fertilisers calls for a more basic understanding of the consequences of the use of these metals for the plant-soil system.

Introduction

Since the early 1970s Chinese research groups have been investigating the effects of rare earth elements (REE) on agricultural production. The application of REE, particularly of lanthanum (La) and cerium (Ce), increased yields of a number of agricultural and horticultural crops from 8 up to 50 percent, with a common response being of the order of 8-15 %. Beneficial effects on the physiological plant status i.e. drought tolerance (Peverill *et al.*, 1997) have been reported. The nutritional quality of food – including the content of protein, fat, Vitamin C, and the uptake of nutrients – was found to be improved (for review see Brown *et al.*, 1990). However, the influence of REE on plant growth is assessed controversially. Toxicity effects, growth reduction of roots and shoots, decrease in the uptake of K and Ca, and manganese deficiency, have been demonstrated at relatively low concentrations of La and Ce (Brown *et al.*, 1990; Diatloff *et al.*, 1995). Recent investigations have confirmed positive effects of REE in animal production. REE (La, Ce, and Pr) amended diets significantly increased the body-weight gain and feed conversion ratio of piglets (He and Rambeck, 2000). Supplementing animal diets with REE, with the objective of increasing growth performance and as a substitute of antibiotics, is supposed to result in REE enriched animal excrements. Their application as organic manure demands a more basic understanding of the consequences for the soil-plant system. This study investigates the effect of lanthanum on growth and nutrient uptake of two plant species cultivated under controlled conditions in hydroponics.

Materials and methods

Ten plants each of *Phaseolus vulgaris* L. var. *nanus* cultivar 'Daisy' or *Zea mays* L. var. *saccharata* cultivar 'Starlite' were grown for 30 or 47 days in containers with 65 litres nutrient solution. Macronutrient concentrations [mM] were: N 2.5, K and Ca 1, P 0.05, Mg 0.75, S 1.25, and for micronutrients [µM]: Fe 60, B 11, Mn 5, Zn 0.5, Cu 0.2, Mo 0.01 . Lanthanum was applied in concentrations of 0, 1, 5, 10, and 20 µmol l^{-1}. NH_4^+/NO_3^- ratio was adapted to plant demand in order to keep the adjusted pH value at 4.2 and to maintain the solubility of La. Lanthanum, macronutrient concentrations, and pH were measured and adjusted every two days. Growth chamber conditions were: day/night period, 14/10 h, temperature, 24/18 °C (day/night), relative humidity, 60/75% (day/night). Plants were analysed for La and mineral nutrients by ICP after microwave digestion with HNO_3 and H_2O_2.

Results and discussion

Increasing the La supply in nutrient solution affected biomass production differently for the two plant species (Figure 1). Shoot and root growth of maize as well as root dry matter production of bean were unaltered, but shoot dry weight of bean was strongly depressed. The reaction of shoot growth is comparable to the results obtained with maize and mungbean (Diatloff *et al.*, 1995), except that mungbean seems to be even more sensitive than *Phaseolus*. With respect to the root dry weight production, neither the increase for maize nor the decrease for bean could by confirmed. But even at 1 µM La lateral root growth of *Phaseolus* was markedly reduced (data not shown).

Lanthanum supply increased La content in plant tissues, but the distribution between root and shoot was different in both plant species (Figure 2). In *Phaseolus*, La strongly accumulated in the root system, whereas the La content of the shoot was low and did not change with La supply. In *Zea mays*, both shoot and root La content increased, the root level exceeding the shoot level by far. Higher La accumulation in the root system compared to shoots, followed by stems and grains, is well documented (Li *et al.*, 1998; Diatloff *et al.* 1995). Increased shoot La contents of mungbean explained the higher sensitivity compared to maize (Diatloff *et al.*, 1995). But for *Phaseolus*, other factors must have accounted for the growth reduction, as La was successfully excluded from transport to shoots.

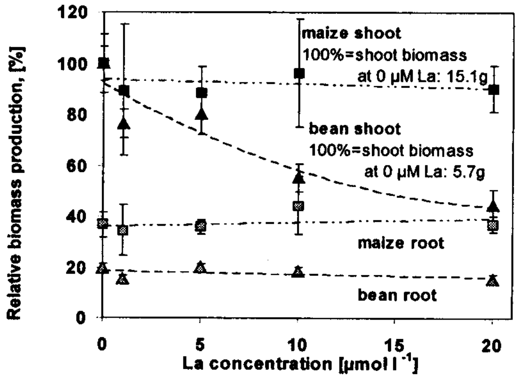

Figure 1. Effect of lanthanum on shoot and root dry matter production of *Phaseolus vulgaris* and *Zea mays* grown in nutrient solution for 30 d and 47 d, resp.). Vertical bars indicate the standard deviation.

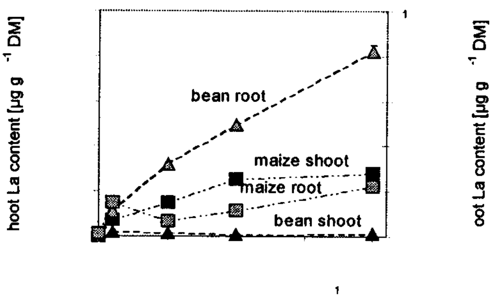

Figure 2. Lanthanum contents of shoot and roots of *Phaseolus vulgaris* and *Zea mays*. Vertical bars indicate the standard deviation.

Lanthanum induced changes in the nutrient composition of both *Phaseolus* and *Zea mays* (Table 1). These effects were much more pronounced in *Phaseolus*. Nitrogen and in particular root Mg contents increased, whereas the contents of K, P, Ca, and Mn were considerably reduced. Comparing shoot and root nutrient changes, it is noteworthy, that only K (and to a lesser degree S) content, was decreased in shoot and root to a similar extent. For Ca, P, and Mn, the transport to the shoot seemed to be particularly inhibited. For *Zea mays*, only Ca, Mg and root Mn contents were significantly changed. In contrast to *Phaseolus*, these changes were obviously without effect on biomass production. Despite the lack of deficiency symptoms, *Phaseolus* shoot K and Ca contents reached levels (K 16.1, Ca 4.9 mg g^{-1}), that are reported to be critical for plant growth (Greenwood *et al.*, 1980; Fageria and Baligar, 1997).

The changes in plant nutrient composition - i.e. increase in N content, decrease in K and Mn contents, La interference with Ca - partly agree with results reported elsewhere (Brown *et al.*, 1990; Diatloff *et al.*, 1995).

Table 1. Lanthanum-induced maximum relative changes in the mineral composition. Control without La = 100 [%]

	Phaseolus vulgaris		**Zea mays**	
	shoot	root	shoot	root
nitrogen	112*	92-112*	102	98
potassium	34*	36*	93-103	96-106
phosphorus	44*	87*	95-112	119
calcium	39*	84*	73*	42*
magnesium	129*	183*	200*	230*
sulfur	83*	70*	-	-
manganese	34*	196*	90-109	53*

*significantly different from the control without La with $p < 0.05$

Conclusions

A moderate supply of available La did not promote biomass production, but reduced the shoot yield of *Phaseolus vulgaris*. Reasons for this decline may be associated with the accumulation of La in the root system and changes in the nutritional status of *Phaseolus* plants. The availability of REE from mineral and organic fertilisers to plants under different soil conditions require further detailed investigations. As the influence of REE depends on plant species, various crops have to be considered and general mechanisms of the effects of REE need to be clarified.

References

Brown PH, Rathjen AH, Graham RD and Tribe DE 1990 *In* Handbook on the Physics and Chemistry of Rare Earths Vol 13. Eds. KA Gschneidner Jr and L Eyring. pp. 423-453. Elsevier, Amsterdam.

Diatloff E, Smith FW and Asher CJ 1995 J. Plant Nutr. 18, 1977-1989.

Fageria NK and Baligar VC 1997 J. Plant Nutr. 20, 1279-1289.

Greenwood DJ, Barnes A, Liu K, Hunt J, Cleaver TJ and Loquens SMH 1980 J. Sci. Fd. Agric. 31, 1343-1353.

He ML and Rambeck WA 2000 Arch. Anim. Nutr. 53, 323-334.

Li F, Shan X, Zhang T and Zhang S 1998 Environ. Poll. 102, 269-277.

Peverill K, Meehan B, Buckingham S and Maheswaran J 1997 Rare Earths 31, 69-85.