Effects of cerium and lanthanum on *Arabidopsis thaliana*

Lim, C.F.\textsuperscript{1} and Loh C.S.\textsuperscript{2}

*Department of Biological Sciences, Faculty of Science, National University of Singapore, Kent Ridge Crescent, Singapore 119226.*

**ABSTRACT**

The effects of cerium and lanthanum on the vegetative and reproductive growth of *Arabidopsis thaliana* were investigated. Addition of cerium (III) nitrate (0.5-50\(\mu\)M) and/or lanthanum nitrate (0.5-50\(\mu\)M) to the culture medium and the potting mix showed varied results. Pot trials were done with uniform conditions for light, water and temperature. Factors examined include root length, height, number of leaves and dry weight. Results were inconsistent due to various factors such as environment and methods. Overall, it shows that the use of REEs does have an effect on the growth of *Arabidopsis thaliana*, whether inhibitory or beneficiary. The various problems faced with such a study are described.

**INTRODUCTION**

There are 15 trivalent metallic rare earth elements (REEs) widely distributed in igneous rocks. Das \textit{et. al.} (1988) showed them to occur mostly as basic oxides and phosphates complexes in nature. Brown \textit{et. al.} (1990) reported them to be the 15\textsuperscript{th} most abundant component in the earth’s crust as a group.

Pant (1981) reported very low concentrations of REEs in plant tissues on the whole. Pickard (1970) observed La\textsuperscript{3+}, Pr\textsuperscript{3+} and Nd\textsuperscript{3+} to inhibit the elongation of oat coleoptile. Many more early reports showed that REEs inhibit plant growth. Velasco \textit{et. al.} (1979) describing the enhancement of root and shoot growth of *Phaseolus radiatus* and *Brassica pekinensis*. Tang and Xiao (1996) reported 8-50% increase in crop yield upon a wide range of crops. The work done was mainly on cerium and lanthanum. REEs have been widely used in mainland China’s agriculture. Brown \textit{et. al.} (1990) recorded extensive work done in China, involving a large number of field experiments and pot studies.

Other results from field trials, pot trials and laboratory studies on the effect of REEs on plant growth and development were inconsistent. Possible reasons could be that REEs are influenced by factors such as soil pH, soil chelates and the available levels of fertilisers. With such conflicting results, it is important to study effects of REEs on essential growth and development stages on a model plant such as *Arabidopsis thaliana* (He 1999). He (1999) reported significant differences in the increase of primary root lengths upon addition of cerium and lanthanum at low concentration. There were no significant differences in his investigation into the increase of height, dry weight, and number of rosette. Higher concentrations of cerium and lanthanum were noted to inhibit the vegetative growth.

\textsuperscript{1} Student  
\textsuperscript{2} Associate Professor
MATERIALS AND METHODS

Seeds of Arabidopsis thaliana (L.) Heynh cv. Columbia (LEHLE SEEDS, USA) were incubated at 4°C for 7 days before germination on filter paper dampened with sterilised water to promote uniform germination and growth. Stock solutions of cerium and lanthanum were prepared separately using sterilised water and adjusted to pH 5.8 for optimum uptake (Ozaki and Enomoto 2001). These were kept in a dark area at 4°C. Solutions of cerium and/or lanthanum at 0.5μM, 1.0μM, 10.0μM and 50μM were prepared. The pH of all solutions were adjusted to pH 5.8 before application. Tap water was used and preparation for 15 litres of solutions at different concentrations were done on the same day within one hour’s time frame to minimise fluctuations in levels of minerals from the tap. Solutions were stored in capped plastic bottles at room temperature. Solutions were administered with a 60ml syringe at 5 ml aliquots. The use of a syringe with a catheter tip provided water to the roots solely. This helped ensured equal volumes were administered as compared to squirting or spraying. This also prevented ‘washing away’ of seeds as water was administered in drop forms. Potting mix was soaked with the prepared solution before transferring to a multi-pot tray. Incubated seeds were then placed and spaced out onto the mix in a Latin square arrangement to ensure similar exposure to different environmental factors. Plants were left to germinate at 22°C. Initially, solutions were administered at 5 ml aliquots as of when needed, not less than 5 ml every two days. This was to prevent the washing away of the small Arabidopsis thaliana seeds. After day five, solutions were administered at 5 ml every day and after day 17, at 10 ml every day. Pest strips were also applied to ward off insect infestations. Trays of pots were placed on shelves with 16 hours of photoperiod of 54 μmol·m⁻²·s⁻¹ provided by Cool White fluorescent lamps for further growth. Length of primary root was measured 10 days after seeds germination. At 17 days after seed germination, the number of leaves and plant heights were scored. For dry weight measurement, 25 plants were collected and dried in an oven (55°C) for one week. All experiments were repeated at least twice. At least 60 seedlings were used in each culture experiment. At least 20 seedlings were used in each potting trial. Student’s t-test (P<0.05) was used to compare the response for each treatment.

RESULTS AND DISCUSSIONS

Attempts were made to observed primary root length 10 days after germination. It was not possible to provide accurate data for this observation. Arabidopsis thaliana had very fine root. Despite attempts to slowly and carefully remove the soil from the roots by immersing them in water and separating with fine needs, it was not possible to ensure that all measurements were for unbroken roots. The number of leaves per plant prior to bolting (17 days after seed germination) was counted. There were 25 plants per treatment. Means within the same column followed by the same letter were not significantly different according to Student’s t-test (P<0.05). Additions of cerium and lanthanum singly at low concentrations had no significant effect on the average number of leaves produced per plant. At high concentrations of cerium, they showed lower leaf production. At high concentrations of cerium and lanthanum, there was significant increase.

| Table 1: Effects of cerium and lanthanum on the leaf production of Arabidopsis thaliana 17 days after seed germination. |
Plant height was measured 17 days after seed germination. Additions of cerium and lanthanum singly at low concentrations had no significant effect on the average plant height. At high concentrations of cerium and lanthanum, there was significant increase. The difference in height between the treatment using cerium and treatment using both cerium and lanthanum is not comparable as they were under different growth periods.

Table 2: Effects of cerium and lanthanum on height of Arabidopsis thaliana 17 days after seed germination.

<table>
<thead>
<tr>
<th>Concentration (µM)</th>
<th>Cerium</th>
<th>Lanthanum</th>
<th>Cerium and lanthanum</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0</td>
<td>6.12a</td>
<td>7.50a</td>
<td>7.59a</td>
</tr>
<tr>
<td>0.5</td>
<td>6.40a</td>
<td>7.12b</td>
<td>6.31b</td>
</tr>
<tr>
<td>1.0</td>
<td>6.07a</td>
<td>7.14b</td>
<td>8.42c</td>
</tr>
<tr>
<td>10.0</td>
<td>5.30b</td>
<td>7.31c</td>
<td>8.83d</td>
</tr>
<tr>
<td>50.0</td>
<td>5.06b</td>
<td>7.22b</td>
<td>8.52c</td>
</tr>
</tbody>
</table>

There were 25 plants per treatment. Means within the same column followed by the same letter were not significantly different according to Student’s t-test (P<0.05). The tray of pot trials for lanthanum was heavily infested with fungus and insects, hence, was not observed.

DIFFICULTIES FACED

Root and dry weight measurements were difficult to obtain as the root hairs were too fine. Dry weight could not be measured as the roots could not be fully extracted. Leaves tend to fall off and surface area, colour intensity were not taken into account. Stress to the plants could have promoted the growth. Fungal and insect pest contaminated the pots despite precautions taken.

CONCLUSION

REEs has a definite effect on Arabidopsis thaliana. However, stress and other environmental factors played a more critical role throughout the entire study. The findings of the effects of REEs in pot trials are inconsistent, as previous findings by other authors have also shown. New techniques could be created to explore in this field. The inconsistencies are due to fluctuations in the surrounding and lack of understanding of REEs mechanisms. There is a need to study on the
enhancement of plants, as there is a need to feed the world’s growing population. REEs are abundant in the earth’s crust. On a massive scale, the little significance it has would prove essential towards getting higher yields of food crop.

REFERENCES


