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Effect of cerium on seed germination and early seedling growth of wheat

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Abstract
The effect of various concentrations of three species of cerium was studied on seed germination and early seedling growth of *Triticum aestivum* L. Seeds were germinated on moist filter papers added with 0.1, 0.5, 2.5, 12.5 and 62.5 μg g^{-1} cerium as cerium chloride, cerium sulphate and cerium nitrate and observations were made on seed germination, shoot- root length, fresh and dry weight. Lower concentrations of cerium species significantly increased shoot-root growth and relative yield of seedlings. Higher concentrations (12.5 and 62.5 μg g^{-1}) proved to be toxic for seedling growth. The root growth was affected more adversely than shoots. Though germination speed was affected, ultimate germination was always 100 %. The results of this study indicate that low levels/ concentrations of cerium are beneficial for the test plants.

Keywords: Cerium, Early seedling growth, Relative yield, Seed germination, *Triticum aestivum* L.

Rare earth elements (REEs) include 17 elements in the Periodic system with scandium (21), Yttrium (39) and lanthanides (57-71). These REEs frequently occur together in rare earth minerals and have similarities in ionic radii and physical/ chemical activities (Henderson, 1984). Lanthanum (La) and Cerium (Ce) are the main components of commercial REEs micro fertilizer and are widely used in China since 1970s. Lanthanum and Cerium belong to the group of light rare earth elements because of their atomic mass lower than 153 amu.

Studies suggest that the application of lanthanum and cerium as micro fertilizer can enhance plant growth and results in better crop production/ fruit yield. However, a general requirement by crop plants for lanthanum and cerium has not yet been established. Moreover, there are conflicting results (Diatloff *et al.*, 1995) regarding the effects of REEs on plant growth and development. This is probably due to the effect of factors such as soil pH, soil chelates and the available level of fertilizers. Fashui *et al.* (2003) reported that $La(NO)_3$ could enhance the germination rate, germination index, seedling growth and seedling dry weight of aged rice seed at 500μg/mL.

Keeping the above in view experiments were undertaken to study the effects of two REEs namely, Lanthanum (La) and Cerium (Ce) on seed germination and early seedling growth in wheat (*Triticum aestivum* L.). The results on the effect of cerium are being presented here.

Materials and Methods

Seeds of *Triticum aestivum* L. (Var. RAJ-4037) were selected for uniformity. In each Petri dish 12 certified uniform sized seeds were kept on filter paper rinsed with freshly prepared solution of various concentrations (0.1, 0.5, 2.5, 12.5 and 62.5 μg g^{-1}) of different Ce species namely, Cerium(III) chloride [$CeCl_3.7H_2O$], Cerium(IV) sulphate [$Ce(SO_4)_2.4H_2O$] and Cerium (III) nitrate [$Ce(NO_3)_3.6H_2O$] taken in triplicate. The different concentrations of Ce were prepared separately by taking corresponding amount of different cerium species (Calculated on the basis of their molecular weights). Solution without added Ce constituted the control.

Experiments were set up during the month of December (Room temperature, 20-22°c). Seed germination was noted after every one hour and percent germination was calculated. Germination was considered as complete when radicle was visible.

After 14 days treatment seedlings were harvested, washed with distilled water, cut into shoots and roots, and shoot and root length and shoot-root fresh weight recorded. Plants were dried at 80° C in an oven for 48 hours and weighed for dry weight of shoots and roots.

Results and Discussion

Conflicting results on the effect of La and Ce on different crops have been reported. Positive effect of Lanthanum and Cerium treatments on seed germination and seedling growth of aged rice seeds have been observed (Fashui, 2002; Fashui *et al.* 2003). However, Hu *et al.* (2002) have observed an inhibition in root elongation and reduction in dry weight of roots and shoots in *T. aestivum* seedlings following lanthanum and cerium treatments. Further, toxic effects of cerium and lanthanum on root growth in corn and mungbean (Diatloff *et al.* 1995) as well as an inhibition of root elongation in Barley (Vanstevinck *et al.* 1976) have also been reported.

d'Aquino *et al.* (2009) observed that seed presoaking for two and four hours with lanthanum and with a mixture of different REEs at low concentrations has no effects on the germination of *Triticum durum* seeds, whereas

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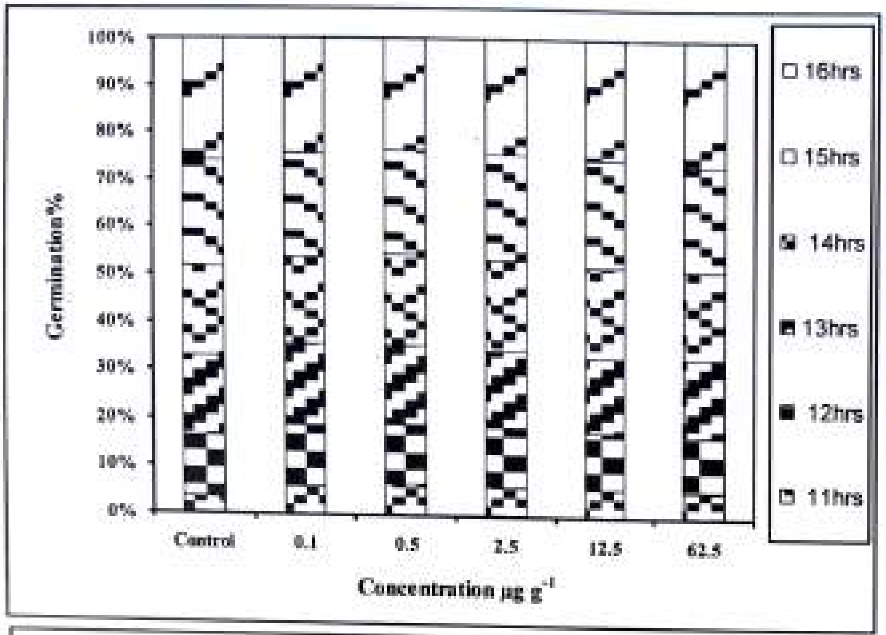

Fig. 1: Effect of various concentrations of cerium as cerium chloride on seed germination of *Triticum aestivum* L. over a period of 16 hours

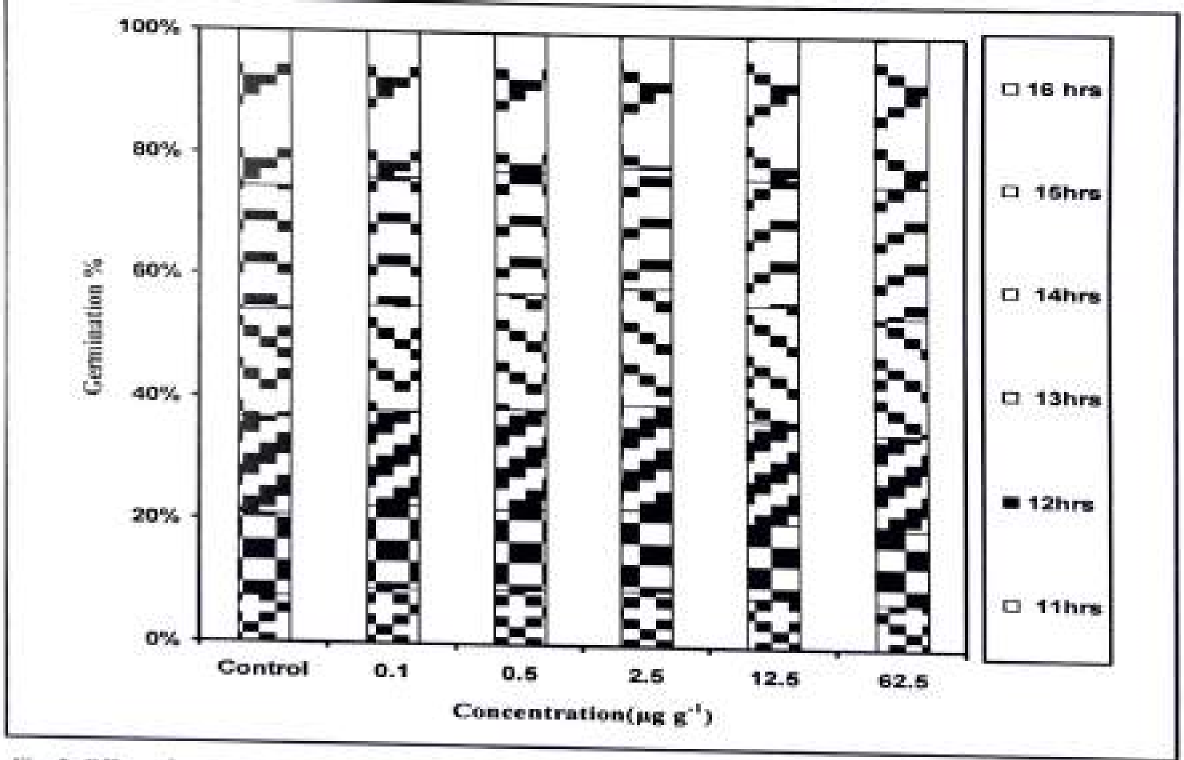

Fig. 2: Effect of various concentrations of cerium as cerium sulphate on seed germination of *T. aestivum* over a period of 16 hours.

higher concentrations inhibited seed germination.

Cerium has also shown marked effect on the cell metabolism of Chinese pine seeds with increased germination rates as well as seedling's heights and weights (Guo and Denkui, 1998). Tang and Tong (1988) demonstrated that low concentrations of 0.05 - 1 mg/l Ce increased the radicle growth of Chinese cabbage while high concentrations of rare earths (> 10 mg/l) prevented root yield. Chen *et al.* (2001) have reported stimulation in growth of tobacco seedling treated with lanthanides. Diatloff *et al.* (1995) observed stimulatory effects of cerium on root growth of corn at a concentration of 0.63µmol/l.

Different species of cerium have shown different effects on seed germination. In cerium nitrate, germination (Fig. 3) started after 9 hours and 100 % germination was achieved after 14 hours. In cerium chloride and cerium sulphate, germination started (Fig.1 and 2) after a period of 11 hours and 50 % germination was achieved after 12 hours. In almost all treatments except the higher ones

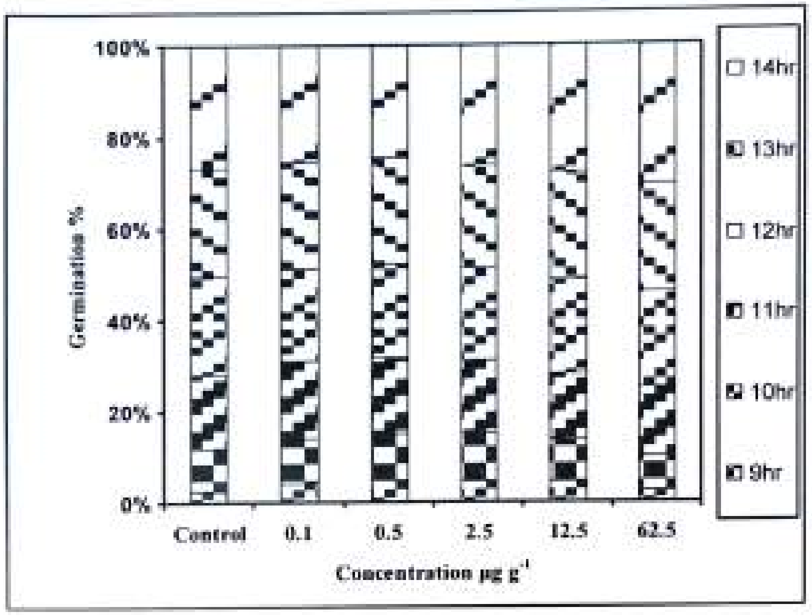

Fig. 3: Effect of various concentrations of cerium as cerium nitrate on seed germination of *T. aestivum* over a period of 16 hours

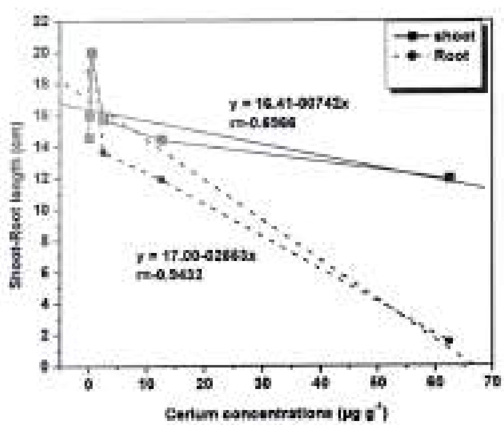

Fig. 4: Effect of various concentrations of cerium as cerium chloride on shoot-root length (cm) of *T. aestivum*

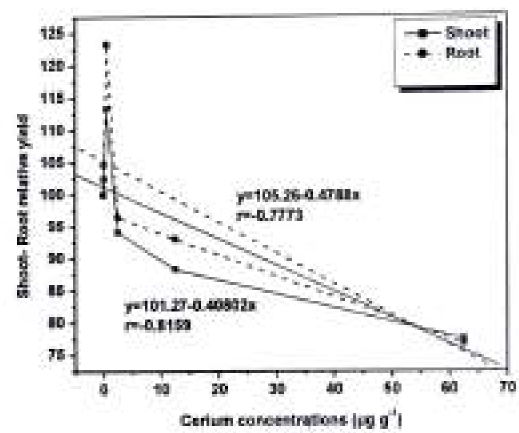

Fig. 5: Effect of various concentrations of cerium as cerium chloride on shoot-root relative yield of *T. aestivum*

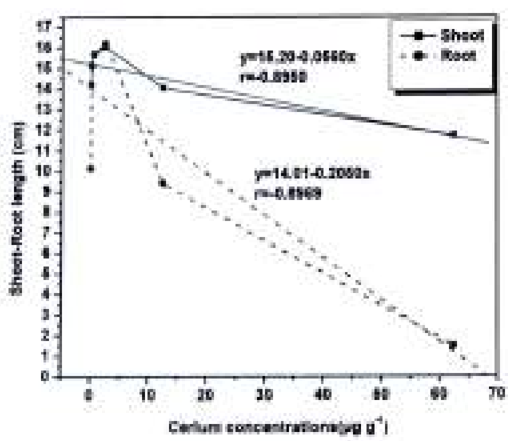

Fig.6: Effect of various concentrations of cerium as cerium sulphate on shoot-root length (cm) of *T. aestivum*

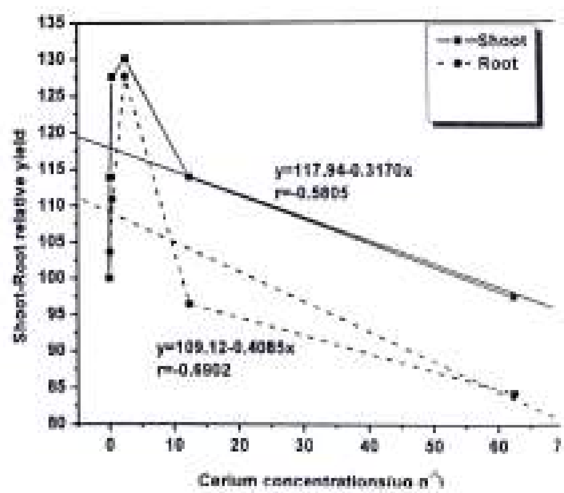

Fig.7: Effect of various concentrations of cerium as cerium sulphate on shoot-root relative yield of *T. aestivum*

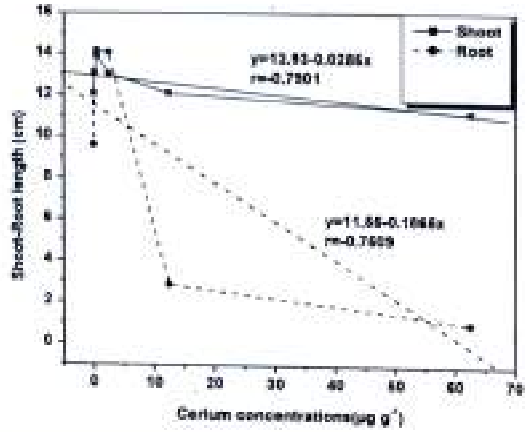

Fig. 8: Effect of various concentrations of cerium as cerium nitrate on shoot-root length (cm) of *T. aestivum*

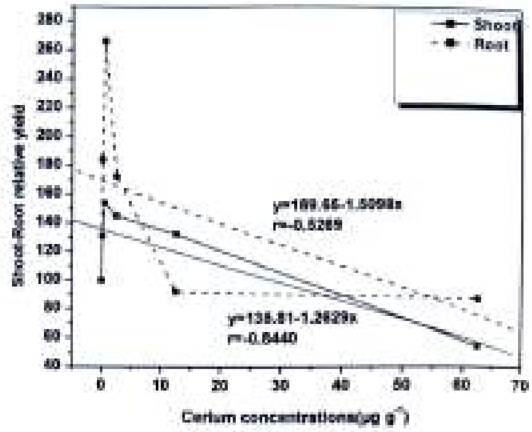

Fig. 9: Effect of various concentrations of cerium as cerium nitrate on shoot-root relative yield of *T. aestivum*

(12.5-62.5 µg g^{-1}) there was a slight decrease in the speed of germination. Whereas both in cerium chloride and cerium sulphate germination started after 11 hours and 100% germination was achieved after a period of 16 hours. However, in all applied concentrations, 100 % germination was achieved.

It seems that Ce too like La (Chao *et al.* 2008) increased the permeability of seeds which was favourable for entry of water and O_2 in the cells of the seed and increased the respiration rate *vis a vis* the germination speed (Fashui *et al.* 2003). It seems that the higher concentration of cerium destroyed the structure of seed membrane, resulting in the water retention ability of the seed membrane *vis a vis* a decrease in the speed of seed germination.

Yang *et al.* (1986) have also reported that REEs promoted seed germination due to increase in the amylase activity and respiratory rate. Fashui *et al.* (2003) have also observed an increase in the activity of α- amylase, proteinase, and lipase in rice seedlings. Ce^{3+} is very similar to Ca^{2+} in chemical properties (Ni, 2002) and like Ca^{2+} may function as activator in the hydrolytic enzymes, increasing the germination speed.

Our studies corroborate the earlier studies by Shi *et al.* (2005) and d' Aquino *et al.* (2009) which show that low concentrations of lanthanum promote plant growth in cucumber and wheat, respectively, whereas higher concentrations inhibit plant growth.

Results indicate that certain low concentrations enhanced the vegetative growth of the test plant. In case of cerium chloride (Fig. 4 and 5) and cerium nitrate (Fig. 8 and 9) the maximum increment in shoot- root length and relative yield was observed at 0.5 µg g^{-1} concentration and was 9.66%, 23.18%, 14.99%, 47.44% and 113.33%, 123.25 %, 153.75%, 266% respectively, over the control. However, higher concentrations (beyond 12.5 µg g^{-1}) reduced shoot and root length as well as fresh and dry weight. Maximum decrease in shoot- root length and relative yield (17.95%, 90.75%, 6.95%, 89.25% and 77.49%, 76.74%, 53.75%, 86% respectively), over the control, was observed at 62.5 µg g^{-1} concentration of cerium.

Figure 6 and 7 shows the effects of cerium as cerium sulphate on shoot-root length and relative yield of test plant. The results showed that 0.1-2.5 µg g^{-1} concentration of cerium as cerium sulphate increased the shoot-root length and relative yield. Maximum increment in shoot-root length and relative yield was observed at 2.5 µg g^{-1} concentration and was 12.79%, 60.01% and 130.08%, 127.70% respectively, over the control. The results show that cerium as cerium sulphate could increase the shoot-root length (seedling growth) and relative yield of test plant. Maximum decrement in shoot root length and shoot-root relative yield was observed at 62.5 µg g^{-1} level of cerium as cerium sulphate and was 17.36%, 85.38% and 97.58%, 84.33% respectively, over the control.

Growth inhibition caused by cerium can be attributed to the loss of cellular turgor (Gabbrielli *et al.* 1990; Powell *et al.* 1986) or to a reduced extensibility of the cell wall (Pandolfini *et al.* 1992; Aery and Jagetiya 1997, 2000; Mali and Aery, 2009) or it might be due to decreasing efficiency of certain enzymes involved in the food and energy utilization. d' Aquino *et al.* (2009) has attributed the reduction in root growth after the treatment of REEs to decrease in cell division.

Diatloff *et al.* (1999) also found that 0.03-0.7 mg/l La or Ce reduced the growth and the uptake rate of all nutrients for mungbean and that 0.7 mg/l La or Ce had little effect on growth, but reduce the uptake of Ca for corn.

In the present studies both ceric as well as cerous salts were used. Whereas ceric nitrate and cerous chloride were observed to be effective at 0.5 µg g^{-1} concentration ceric sulphate showed its effect at 2.5 µg g^{-1} concentration. At higher concentration also cerous chloride was found to be more effective than sulphate and nitrate in that order. The percentage reduction in the parameters studied was much higher in case of cerous chloride.

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