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Phytotoxic Effects of Lanthanum Oxide Nanoparticles on Maize (*Zea mays L.*)

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Abstract. The use of lanthanum oxide nanoparticles (La_2O_3 NPs) in life products have increased dramatically in the past decades, which are inevitable released into natural environment. In this study, we determined the phytotoxicity of La_2O_3 NPs to maize (*Zea mays L.*) grown in one-fourth strength Hoagland solution. After being exposed for two weeks, the biomass, roots length and the relative chlorophyll content were measured. La_2O_3 NPs had phytotoxicity to maize at 5 mg/L. La_2O_3 NPs decreased shoot biomass (≥10 mg/L), the root biomass and length (≥5 mg/L). Moreover, La_2O_3 NPs had adverse effects on the chlorophyll content (≥10 mg/L). The decreased chlorophyll content may reduce net photosynthetic rate. This research offers vital information about the phytotoxicity of La_2O_3 NPs.

1. Introduction

The rare earth oxide nanoparticles (NPs) have various and significant applications such as high refractive optical fibers, agricultural films, electroforming electrode materials [1], catalyst promoters and/or supports [2], semiconductors, cosmetics [3], phosphate removal and biomedicine [4]. La_2O_3 NPs, as a typical rare earth oxide nanoparticle, are one of the most significant engineered nanoparticles [5]. Due to the widespread using, La_2O_3 NPs are inevitable released into the natural environment, which has adverse effects on the plants and human [6].

Plants are a significant component of ecosystems, serving as an underlying pathway for NPs transport and a way for bioaccumulation in the food chain [7-8]. Combined with rice and wheat, maize is one of the most crucial food crops in the world and offers almost 30% of the food calories to more than 4.5 billion people in 94 developing countries [9].

The previous research manifested that 2000 mg/L CeO_2 NPs had no toxicity on the root elongation, but La_2O_3 NPs, Gd_2O_3 NPs and Yb_2O_3 NPs strictly inhibited the root elongation of seven higher plant species (radish, rape, tomato, lettuce, wheat, cabbage, and cucumber) [10]. Moreover, 2 mg/L La_2O_3 NPs obviously inhibited the cucumber root elongation, root biomass and shoot biomass were decreased at 20 mg/L [11]. The biomass of cucumber was decreased, when being exposed to 0.32 mg/L Yb_2O_3 NPs [12]. The high concentrations of CeO_2 NPs reduced the chlorophyll content, and observably decreased the biomass yield [13]. According to previous investigation, chlorophyll content was related to photosynthesis. The leaf P_N was decreased may be associated with low chlorophyll content [14].

The primary goals of this study were listed as follows (i) to investigate the effects of La_2O_3 NPs on the biomass production, (ii) to determine the phytotoxicity of the roots, and（iii）to research the effect of chlorophyll content.

2. Materials and methods

2.1. The characterization of La_2O_3 nanoparticles
La_2O_3 NPs were purchased from US Research Nanomaterials, Inc., The purity is 99.99%. Advertised particle size is 10-100 nm. Particle suspensions (50 mg/L) were prepared by putting La_2O_3 NPs powder into deionized water and one-fourth strength Hoagland solution. The solutions were sonicated (100 W, 40 kHz, Kun Shan Ultrasonic Instruments Co., Ltd) for 30 min to increase particle dispersion. Hydrodynamic diameter and zeta potentials of La_2O_3 NPs in one-fourth strength Hoagland solution were determined by Nanosizer (Nano Series ZS90, Malvern, Britain).

2.2. Plant culture and treatment
Maize (*Zea mays L.*) seeds were purchased from Qingdao Seed Station. Seeds were sterilized in 10% NaClO solution for 10 min, and then rinsed three times with sterilized H_2O. After sterilization, the seeds were germinated in Petri dishes (100 mm ×15mm). Each dish had 10 seeds, and the interval was about 1 cm. After three days, uniform seedlings were selected and transferred into plant cultured pots with one-fourth strength Hoagland solution. The seedlings were cultured in nutrient solution for two weeks. Then La_2O_3 NPs were added into nutrient solution followed by ultrasonic pretreatment for 30 min. Five treatments included 0, 5, 10, 50, 100 mg/L. The plants were continuously grown for two weeks and harvested for subsequently tests.

2.3. Determination of plant biomass and roots elongation
After two-week exposure, the fresh plants were collected and washed with deionized water. Roots and shoots were separated, and the fresh weight were measured. Morphological parameters were analysed by the WinRHIZO Pro 2005 b (Regent Instruments Inc., Canada).

2.4. Determination of chlorophyll
The chlorophyll content index(CCI) was measured by CCM-200 Chlorophyll Content Meter (Aozuo Ecology Instrumentation Ltd.). There was a significant positive correlation between CCI and chlorophyll content [15].

2.5. Statistical analysis
Each treatment was replicated three times. In this study, “$P < 0.05$” represents significant difference. All statistical datas were analysed by oneway ANOVA with a LSD test using SPSS Statistics.

3. Results and discussion

3.1. The characterization of La_2O_3 nanoparticles in suspension
50 mg/L La_2O_3 NPs suspension was used for measurement of hydrodynamic diameter and Zeta potentials. Hydrodynamic diameter and Zeta potentials of La_2O_3 NPs in deionized water were 333.8±11.8 nm and 20.8±2.9 mV. In one-fourth strength Hoagland Solution, the hydrodynamic diameter was increased to 921.6±87.5 nm and the Zeta potentials was decreased to 10.9±0.7 mV. The change of hydrodynamic diameter and Zeta potentials indicated that, La_2O_3 NPs in one-fourth strength Hoagland Solution boosted the aggregation. Possible reasons are that the Hoagland Solution has the higher ionic strength [13].

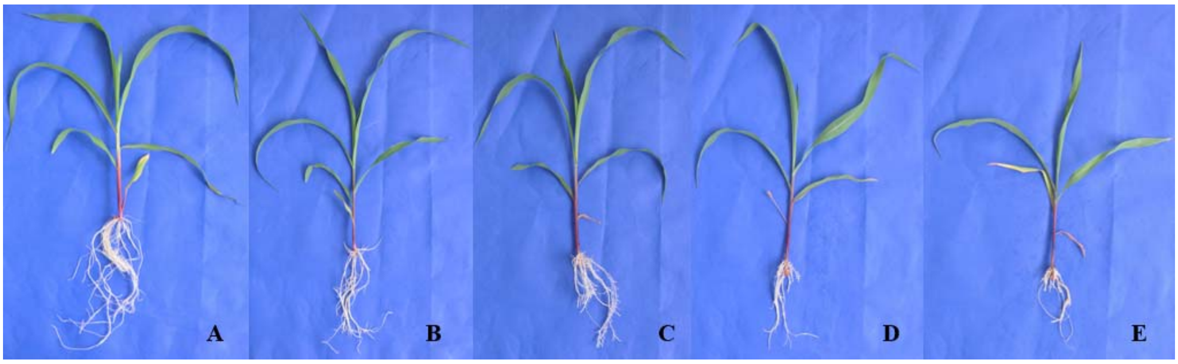

Figure 1. Images of maize seedlings with the different treatments. From left to right in each picture were: A. unexposed control plants, B-D. exposed to 5, 10, 50, 100 mg/L NPs.

3.2. *Effects of La_2O_3 NPs on biomass and root elongation*

It had been found that 2000 mg/L La_2O_3 NPs inhibited root elongation [10]. In this study, the root elongation of maize under La_2O_3 NPs exposure were investigated. From figure1A-E, the morphology of maize roots was significantly changed under the treatments, but the morphology was slightly changed on shoots. In general, La_2O_3 NPs decreased the root biomass (≥5 mg/L) and shoot biomass (≥10 mg/L) (Figure 2). Plant roots were more sensitive when exposed to NPs, possibly due to the direct contact between the roots and the NPs suspension. Figure 3 showed a significant reduction in root length at all exposure concentration. Meanwhile, the root surface, volume and diameter were decreased (data not shown). Roots were always sensitive under various abiotic stress [16-17]. Roots of plant are subjected to various abiotic stresses especially drought, salinity, flooding, heat, cold, metal, NPs etc. which length, biomass, volume, and diameter may be changed.

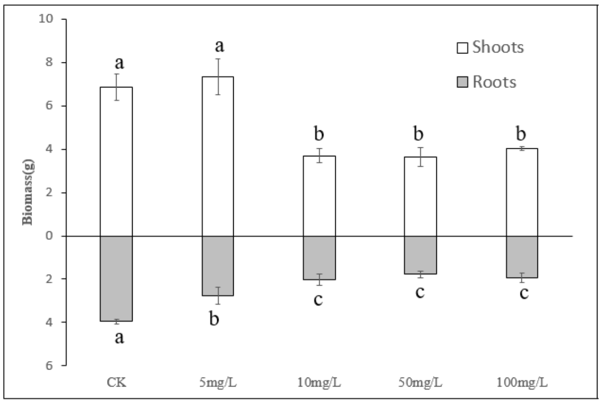

Figure 2. Effects of La_2O_3 NPs on the shoot biomass and root biomass of maize. The values were represented as mean ±SD. The different letters denote significant difference（$p<0.05$)

3.3. *Effects of La_2O_3 NPs on chlorophyll*

The CCI value of maize in response to La_2O_3 NPs, was presented in figure 4. The relative chlorophyll content was not influenced at low concentrations of La_2O_3 NPs (5 mg/L). Compared to the control, 10, 50 and 100 mg/L La_2O_3 NPs treatments led to a reduction of the relative chlorophyll content by 6.5%, 25.9% and 21.7%. The positive and linear correlation between the photosynthetic rate and chlorophyll content was strong [18]. Therefore, the photosynthetic rate may be brought down when exposed to La_2O_3 NPs.

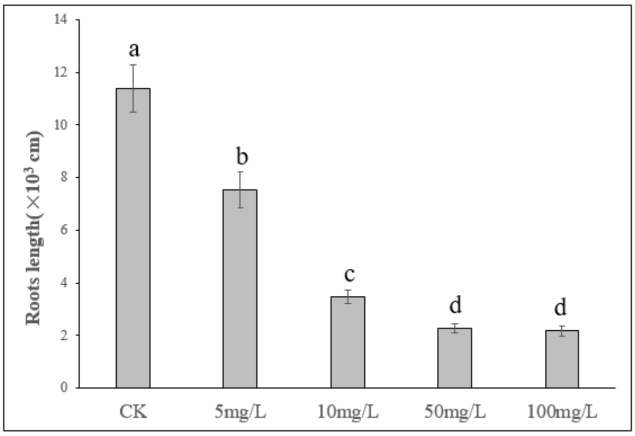

Figure 3. the root length of maize exposed to NPs. The values were represented as mean ±SD. The different letters denote significant difference（$p<0.05$).

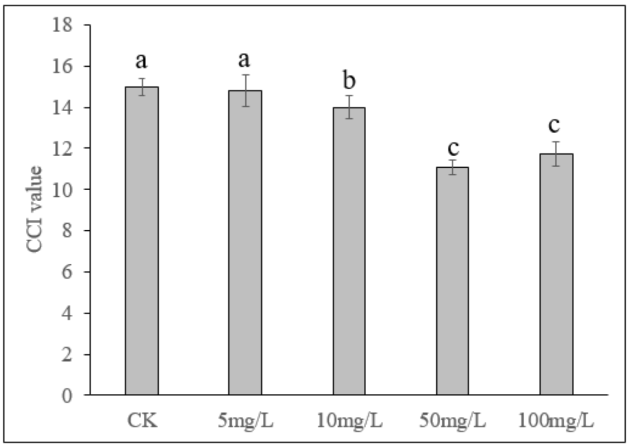

Figure 4. The relative chlorophyll content (CCI value) of maize in response to La_2O_3 NPs. The values were represented as mean ±SD. The different letters denote significant difference （$p<0.05$).

4. Conclusion

In summary, La_2O_3 NPs showed nonnegligible influence on some physiological parameters of maize. 5 mg/L La_2O_3 NPs exposure at did not distinctly influence shoots biomass, but decreased roots biomass, length and so on. In addition, the physiological parameters of shoots and roots, chlorophyll were inhibited under La_2O_3 NPs exposure (≥10 mg/L). For assessment of risk degree on both ecological environment and human health, more researches about plant growth and NPs interactions need further study.

Acknowledgments

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