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Effect of Y_2O_3 Nanoparticles on Growth of Maize Seedlings

Chenchen Gong, Linghao Wang, Xiaolu Li, Hongsen Wang, Yuxin Jiang and Wenxing Wang*

College of Life and Health Sciences, Northeastern University, Shenyang 110819, China

*Corresponding author e-mail: wangwenxing@126.com

Abstract. With the increasing application of rare earth nanoparticles (RENPs), the growing chances of these NPs being released into the environment highlight the importance of understanding the influence of RENPs on plant growth. In this study, we assessed the effect of Y_2O_3 NPs on the growth of maize seedlings. Germinated buds of maize were planted in pot-cultured farmland soil amended with different concentrations (0–500 mg/kg) of Y_2O_3 NPs for 25 days. Y_2O_3 NPs could inhibit root growth. Compared with control treatment, root biomass significantly decreased at high concentrations (≥100 mg/kg), while root elongation was significantly inhibited at low concentrations (≥10 mg/kg). However, the growth and photosynthesis of aboveground shoots were not affected by all Y_2O_3 NPs treatments. This study will help us better understand the phytotoxicity of Y_2O_3 NPs.

1. Introduction

Rare earth nanoparticles (RENPs) have excellent physicochemical properties and extensive applications, leading to increased demand for these RENPs around the world [1]. With the considerable production and use of RENPs, potential risks of their accumulation and migration in the environment are expanding, such as applying NPs-containing sewage sludge to agricultural soils [2]. Recent reports on the effects of RENPs on plants are emerging, including La_2O_3 NPs [3-5], Gd_2O_3 NPs [5], Yb_2O_3 NPs [5, 6] and CeO_2 NPs [7, 8].These reports show that the phytotoxicity of RENPs is affected by type, size, charge and concentration of NPs as well as plant species. As one of the representative RENPs, Y_2O_3 NPs are widely applied in ceramic stabilizers, fluorescent powder in color TV and solid laser materials due to their good thermostability, mechanical and chemical durance [9]. However, knowledge of potential risks of Y_2O_3 NPs on plants is very little.

To get a better handle on the phytotoxicity of Y_2O_3 NPs, maize was selected for the research because of one of the most important agricultural crops. In this study, we investigated the impact of Y_2O_3 NPs on biomass, shoot and root length, and chlorophyll content of maize seedlings planted in pot-cultured farmland soil. The aim is to help us better understand the potential risks of Y_2O_3 NPs in the environment.

2. Materials and methods

2.1. Y_2O_3 NPs characterization

Y_2O_3 NPs, with the purity of 99.9% and without any other modifiers on the surface, were purchased from Beijing DK Nano Technology Co., Ltd. Size and morphology of Y_2O_3 NPs was determined by a scanning electron microscope (SEM, SSX-550, and Shimadzu, Japan). The hydrodynamic sizes and zeta potential of Y_2O_3 NPs were detected by a Nano ZS90 Zeta potential/Particle system (Malvern Panalytical, British).

2.2. Maize seedlings growth and Y_2O_3 NPs exposure

Maize seeds (*Zea mays* L. cv. Zhengdan 958) were purchased from the Chinese Academy of Agricultural Sciences, Beijing, China. Uniform seeds were selected and sterilized in 10% fresh sodium hypochlorite solution for 15 min, and rinsed with ultrapure water for 5 times. The seeds were germinated in dark at 25℃. Soil samples were collected from maize fields according to the five-point sampling method. After ultrasonic dispersion of Y_2O_3 NPs for 20 min, they were mixed evenly with the farmland soil and then were loaded in 2-kg plastic flowerpot to set five concentration gradients (0, 10, 50, 100, 500 mg/kg). Six well-sprouted buds were chosen and planted at 2 cm below soil surface in each pot. Each gradient had 6 repetitions. The potted samples were placed in GZP-250 light incubator at 25℃ for 25 days. Harvested seedlings were scanned to determine morphological parameters by WinRHIZO Pro 2005 B Root Analysis System. The relative content of chlorophyll in each sample was determined by SPAD-502 Chlorophyll Meter. Fresh weight of shoots and roots were weighted with an analytical balance. Shoot and root lengths were measured by a millimeter ruler.

2.3. Statistical analysis

The results were expressed as mean ± SD (standard deviation). All statistical analyses were conducted using Statistical Packages for the Social Sciences (SPSS) Version 17.0. Significant differences among treatment groups were analyzed using LSD and Duncan test of One-Way ANOVA. All statistical significance was set $p<0.05$.

3. Results and discussion

3.1. Y_2O_3 NPs properties

The mean size of commercial Y_2O_3 NPs with nearly spheroid was about 30 nm (Fig. 1). The NPs tended to aggregate due to their minute size, large superficial area and high active surface. The hydrodynamic size and zeta-potential of Y_2O_3 NPs dispersed in ultrapure water were 400.5 ± 18.7 nm and 6.78 ± 0.06 mV, respectively. These nanoparticles were used in subsequent experiments.

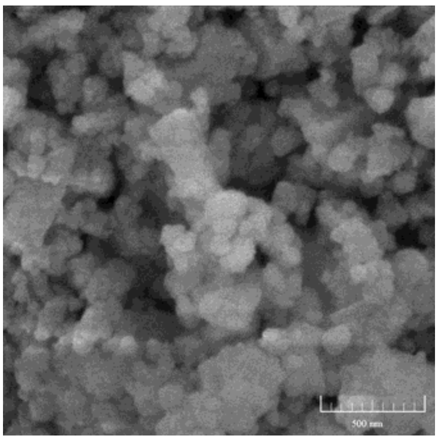

Figure 1. SEM image of Y_2O_3 NPs

3.2. Effect of Y_2O_3 NPs on biomass of maize seedlings

The concentration-response bar graphs of Y_2O_3 NPs to the maize biomass were shown in Fig. 2. The biomass of maize shoots did not differ significantly between any two concentrations ($p > 0.05$). However, the biomass of roots at concentrations higher than 100 mg/kg had significant decreases as compared with control treatments ($p < 0.05$). It indicated that the inhibition effect of Y_2O_3 NPs on roots was greater than that on shoots. Besides, the maize seedlings were harmed by the treatments at concentrations higher than 100 mg/kg.

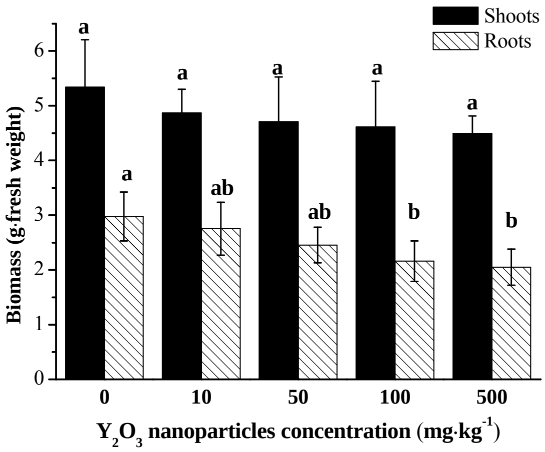

Figure 2. Shoot biomass and root biomass of maize seedlings in pot-cultured farmland soil amended with different concentrations of Y_2O_3 NPs. The values are given as mean ± SD (standard deviation). Different letters represent significant differences between any two concentrations ($p < 0.05$).

3.3. Effect of Y_2O_3 NPs on shoot and total root elongation of maize seedlings

As shown in Fig. 3, there was no significant change of shoot growth at all exposure concentrations. But Y_2O_3 NPs significantly inhibited the total root elongation at concentrations higher than 10 mg/kg. The inhibition on root elongation exhibited a concentration-dependence. The total root length represents the total length of all roots. The inhibition effect of root elongation was far greater than that of root biomass, indicated by the significant decreases at concentrations higher than 10 mg/kg. According to the results of biomass and elongation experiments, Y_2O_3 NPs within the environment would pose a potential risk to crops and therefore the ecosystem [6].

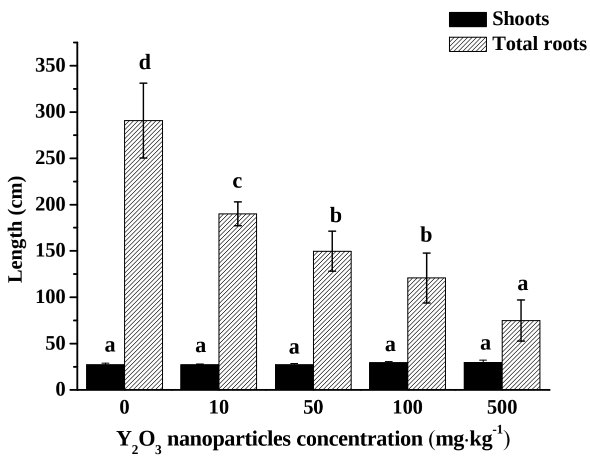

Figure 3. Shoot lengths and root lengths of maize seedlings in pot-cultured farmland soil amended with different concentrations of Y_2O_3 NPs. The values are given as mean ± SD (standard deviation). Different letters represent significant differences between any two concentrations ($p < 0.05$).

3.4. Effect of Y_2O_3 NPs on photosynthesis of maize seedlings

The content of chlorophyll is not only an important index reflecting the photosynthesis of plants, but also affects the synthesis of plant organic matter. As shown in Fig. 4, there were no significant differences of chlorophyll content at all exposure concentrations, indicating that the photosynthesis of maize seedlings was not affected by Y_2O_3 NPs exposure. Thus, biosynthesis in maize shoots could proceed normally. To a certain extent, this explained why the biomass and elongation of maize shoots did not significantly reduce at all Y_2O_3 NPs treatments. However, in the long term, the whole maize growth will be influenced by Y_2O_3 NPs exposure (higher than 100 mg/kg) due to the damage of roots responsible for the transportation of water and nutrition.

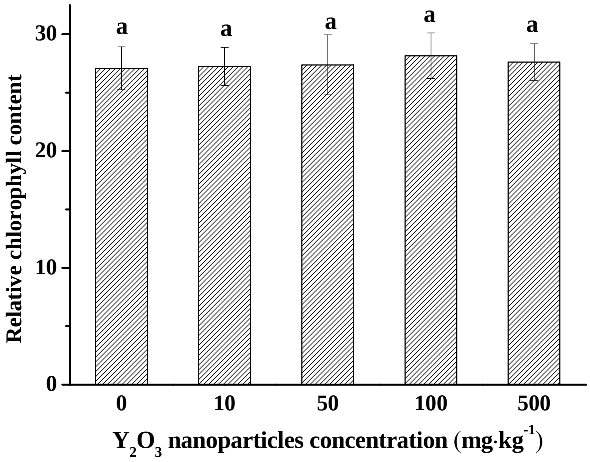

Figure 4. Relative chlorophyll content of maize seedlings in pot-cultured farmland soil amended with different concentrations of Y_2O_3 NPs. The values are given as mean ± SD (standard deviation). Different letters represent significant differences between any two concentrations ($p < 0.05$).

4. Conclusion

The present study demonstrated Y_2O_3 NPs could inhibit the growth of maize seedlings. The inhibition effect was mainly on root growth. The growth and photosynthesis of aboveground shoots planted for 25 days were not affected by Y_2O_3 NPs exposure. Therefore, the phytotoxicity of Y_2O_3 NPs in soil environment should be seriously considered, and their potential risks need to be evaluated further.

Acknowledgments

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