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Research Article

A STUDY ON EFFECT OF EARTH ELEMENTS ON GROWTH OF MEDICINAL PLANTS

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Abstract

A set of 17 chemical elements is called to rare earth elements, including the lanthanide series from lanthanum (La) to lutetium (Lu), scandium (Sc), and yttrium (Y) in the periodic table. There has been a huge interest in the context of rare earth elements to medicinal plants in recent years, however, rare earth elements are used in industry and agriculture. In the present article, previous studies on the effects of rare earth elements on the germination of seeds, the absorption of minerals and metals by medicinal plants, the growth of roots, total biomass, and the production of its secondary metabolites have been mentioned. With regard to analysis of these data, it can perceive that rare earth elements have promoting negative effects at comparatively high concentrations. Although numerous studies have been conducted concerning a few REEs, i.e., La, cerium (Ce), neodymium (Nd) and europium (Eu) and put emphasis on effects of rare earth elements on regulation of secondary metabolism in tissue-cultured plants, high quality studies should be conducted on the effects of rare earth elements on yields of medicinal plants.

Key words: Earth elements on growth of medicinal plants.

Introduction

A set of 17 chemical elements is called to rare earth elements, including the lanthanide series from lanthanum (La) to lutetium (Lu), scandium (Sc), and yttrium (Y) in the periodic table. 100 million metric tons of rare earth elements have been mentioned as the total world reserves found in United States, South Africa and Brazil. China owns most of the rare earth elements, mentioned as the major exporter of rare earth elements. More specifically, rare earth elements have been used as iron and steel additives for glass polishing and ceramics in industry. Further, they have been used in agriculture for over 35 years in china. Biological effects on plants have been shown in rare earth elements. Depending on dosage and other conditions, rare earth elements can exert physiological effects on plants [1]. Since rare earth elements enable to influence growth of medicinal plants in a direct or indirect way, the application of rare earth elements in medicinal plants has been taken into consideration. Use of rare earth elements result in promotion of germination of seeds and roots growth, increase of plant biomass and improvement in quality of fruiting bodies. If the concentration of rare earth elements exceeds the optimum level, they will inhibit the plant growth resulting in mortality. In the present article, previous studies on the effects of rare earth elements on the germination of seeds, the absorption of minerals and metals by medicinal plants, the growth of roots, total biomass, and the production of its secondary metabolites have been mentioned[2].

Materials and methods

The rare earth elements (REEs) are a set of 17 chemical elements. They include the lanthanide series from lanthanum (La) to lutetium (Lu), scandium (Sc), and yttrium (Y) in the periodic table. Although REEs are used widely in industry and agriculture in China for a long time, there has been increasing interest in application of REEs to medicinal plants in recent years. In this paper, we summarize researches in the past few decades regarding the effects of REEs on the germination of seeds, the growth of roots, total biomass, and the production of its secondary metabolites, as well as their effects on the absorption of minerals and metals by medicinal plants. By compilation and analysis of these data, we found that REEs have promoting effects at low concentrations and negative effects at comparatively high concentrations. However, most studies focused only on a few REEs, i.e., La, cerium (Ce), neodymium (Nd) and europium (Eu), and they made main emphasis on their effects on regulation of secondary metabolism in tissue-cultured plants, rather than cultivated medicinal plants. Advanced research should be invested regarding on the effects of REEs on yields of cultivated plants, specifically medicinal plants.

Effects of rare earth elements on biomass of medicinal plants

Chlorophyll, a green pigment produced by all green plants, is vital for photosynthesis by which plants transform light energy into chemical energy. Therefore, photosynthesis is extremely important for plant growth. Studies showed that appropriate concentrations of REEs can increase the chlorophyll content of leaves and helps plant growth .For Ginkgo biloba, treatment with 100 mg/L rare earth increased the leaf yield by 11.64% compared with the control group. In contrast, a higher concentration decreased the leaf yield by 19.3%[3].

Effects on root of medicinal plants

One of the most important organs of the plant is the root system, which absorbs water, nutrients and synthesizes organic compounds. The growth of the plant will be affected by physiological activities of the root system in a direct way. Rate earth elements assist for the growth of the root system through improving the formation of the roots and affecting root morphogenesis. $La(NO_3)_3$ and $Eu(NO_3)_3$ cause increase in the rooting rate and root fresh weight, promotion in root elongation and enhancement in the activities of nitrate reductase by adding concentrations of $La(NO_3)_3$ and $Eu(NO_3)_3$ to the rooting medium of cultures of Eriobotrya japonica[4]. A study on effects of La, Ce and Nd on Dendrobium densiflorum indicated that root regeneration was affected by rate earth elements rather combination of rate earth elements together with the plant growth regulator indole-3-butyric acid. The effect of Nd^{3+} was stronger than La and Ce with the mean number of roots per seedling 23.9 treated at Nd^{3+} concentration. A variety of studies have reported that low concentrations of La^{+3} lead to promotion of root vigor, considering the fact that La^{+3} displayed an inhibitory effect at higher concentrations. In an article, Ce^{3+} at 1-15 mg/L led to promotion of formation of seedling root tissue. The strongest effect was observed with 5 mg/L Ce^{3+}, whereas it inhibited root growth at a higher concentration [5].

Effects on production of secondary metabolites in medicinal plants

In nature, plants are exposed to a variety of adverse factors, including microbial invasion and different damages. Plant body has to produce all kinds of secondary metabolites as a part of their resistance responses for defense. The bio-synthesis of secondary metabolites is complex and diverse, which involves a series of metabolic pathways. Over the past few decades, there are several researches regarding the effects of REEs on cell cultures of medicinal plants depending on the different dosages and other conditions [6].

Addition of REEs promotes bio-synthesis of secondary metabolites, such as flavonoids, isoflavones and benzyl ethanol glycosides in medicinal plant cells. In a study, lanthanum nitrate was added to cell cultures of Catharanthus roseus, leading to a dose-dependent accumulation of alkaloids. Lanthanum nitrate promoted accumulation of alkaloids at low concentration (20ppm), but it had an inhibitory effect at a higher concentration(60ppm)[7]. In T. yunnanensis cell cultures, La^{3+} stimulated taxol production and the maximum stimulation was found at 5.8 mM La3+ increasing the volumetric taxol yield by nearly three-fold from 2.61 to 9.89 mg/L. under adding La^{3+} into the other three Taxus cell lines, just stem cells displayed a significant effect on taxol production.

Another article indicated that adding 1 mg/L EU^{3+} influenced production of metabolites of Glycyrhiza uralensis; for instance, lower concentration of EU^{3+} promoted callus growth. This effect was most pronounced on medium containing 0.1 mg/L Eu^{3+}[8]. At that concentration, the EU^{3+} treated plant tissues contained 2.7-fold greater flavonoid content than the control and a 4-fold increase in liquiritigenin content. Similarly, compared with that of the control, adding Ce2O3 and CeCl3 to the medium of C. roseus improved the production of raubasine by 11-fold and 9-fold and adding Y2O3 and NdCl3 improved the production of catharanthine by 30-fold and 25-fold. It has been reported that Ce played a major role in increasing the content of intracellular polysaccharides. The highest production of polysaccharides was achieved after 18 days' cell culture in medium containing Ce, and this level was 1.53-fold of the control. A mixture of rare earth elements indicated the huge effects. After 30 days' culture, 0.02 mM MRE gave the highest content and production of PeG, which were 104% and 167% higher than those obtained in control.

Effects on absorbing other minerals of medicinal plants

Plants need many mineral elements during the normal processes of growth and development. Specifically, they require high levels of the major inorganic elements (e.g., N,P and K),moderate amounts of other nutrients (including atoms Ca, Mg and S), and other trace elements (including Mn, Cu, Zn, B, Mo and Cl), as well as beneficial elements (such as Se, Na and REEs. Scientists believed that REEs can regulate absorption of other mineral elements in plants. When G. lucidum was cultivated with different concentrations of REEs (25, 50, 100, 150, 200 and 250 mg/g), change of the contents of other minerals was observed in the plant tissues. For example, the contents of Fe, Zn and Mg were increased by 2.40-3.98%, 1.54-1.81% and 0.70-3.12%, whereas that of Cu was decreased by 0.65-1.15%. The experimental data indicated that the fruiting bodies contain rare earth elements less than 0.02 Mg/g, observed no difference in the value among different rare earth elements concentrations. More specifically, rare earth elements inhibit absorption of heavy metals. La^{3+} reduced the absorption of Pb^{2+} in plants growth under lead-contaminated conditions [9].

Effects on the seed germination of medicinal plants

The seed germination rate (SGR) is a standard parameter to reflect the quality of seeds. REEs at appropriate concentration can affect the germination of seeds, which have been proved by a large number of published papers. One of the papers reported that treatment with REEs improved seed vigor, water absorption and cytoplasmic membrane permeability of seeds of a medicinal plant during the seed imbibition and germination. In addition, the oxygen evolution rate of the REEs- treated seeds was greater than those of non-REEs-treated ones, indicating greater metabolic activity and more energy for growth.

It was also reported that the appearance of low concentration of neodymium cation(Nd^{3+}) significantly promoted seed germination of Cassia, whereas the Nd^{3+} at a concentration higher than 5mg/L inhibited its germination. Ultimately, the optimum concentration of Nd^{3+} was set as 3mg/L. there was a synergistic effect of Nd^{3+} with a burdock fructooligosaccharide. Nd^{3+} at a concentration of 6mg/L had a significant effect on the germination of the seed of Astragalus, stronger than that of the burdock oligosaccharide or NaCl[10].

Conclusion

Rare earth elements have a variety of effects on seed germination, growth of roots, total biomass accumulation, production of secondary metabolite and absorption of minerals and metals for medicinal plants. They have promoting effects at low concentrations while negative effects at comparatively high concentration. However, most studies have focused only on a few Rare earth elements (La, Ce, Nd and Eu) and made main emphasis on its effects of regulation of secondary metabolism in tissue-cultured plants, rather than cultivated medicinal plants.

Further research in this area should be strengthened for the effects of REEs on yields of cultivated plants, specifically medicinal plants. Some other functions of REEs, for example, the ability to inhibit absorption of harmful minerals, may be a solution for cultivation of plants that tend to accumulate heavy metals. Finally, the safety of REEs should be investigated in detail with in-depth studies on the effects of REEs on the environment, plants, humans and the ecology of complex ecosystems. In general, REEs may stimulate cell growth and production of secondary metabolites at lower concentrations but become toxic to the cells at higher concentrations. As REEs alter membrane permeability, so that the secondary metabolites are able to be secreted more rapidly into the medium. REEs also increase the production of secondary metabolites via promoting the transcriptions of essential biosynthetic genes. Finally, the safety of REEs should be investigated in detail with in-depth studies on the effects of REEs on the environment, plants, humans and the ecology of complex ecosystems.

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