Effects of organic phosphonic acid on the germination characteristics of plants after remediation of Cd contaminated soil

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Abstract. The heavy metal Cd seriously affects the growth and development of humans, animals and plants, at the same time, it has the characteristics of wide sources and easy delivery. In this paper, the effects of Cd contaminated soil remediation by biodegradable organic phosphonic acids HEDP, BHMTMPA, HDTMPA and ATMP on the germination characteristics of plants were studied. The results showed that when the concentration of organic phosphonic acid HDTMPA was 4%, the germination characteristics of Zinnia elegans Jacq. are the best among the four organic phosphonic acids, the germination rate, germination potential, germination index, vigor index, root length, bud length and seedling dry weight were 62%, 25.1, 11.8, 41.3, 1.8 cm, 3.5 cm and 158 mg respectively.

1. Introduction
The Cd discharged into the soil environment by human activities is about 82%-90%[1-2]. Cd is one of the pollutants with greater toxic effects on the environment[3], Cd in the soil is first absorbed and transported into the plant by the plant, then it gathers in the liver and kidneys of the human body through the food chain[4]. Cd pollution has seriously threatened the life safety of humans and other organisms[5]. The advantage of chemical remediation of Cd contaminated soil is that it takes effect quickly, the disadvantage is that it is easy to change the soil fertility structure and destroy the soil ecology, Cd that has been fixed and repaired may be reactivated, affect the survival and development of other organisms[6]. Therefore, this paper selects suitable plants to be sown in the soil after chemical remediation, and reflects the influence of chemical remediation through the changes of plant germination characteristics.

2. Materials and methods
The test soil was from the soil mountain behind Moyan Lake of Liaoning Petrochemical University, 0-20 cm clean and pollution-free topsoil was taken. The soil samples were screened and dried in a cool and dry place, then passed a 40-mesh sieve, added CdCl2 to it and mixed well to air dry, then added
HEDP, HDTMPA, ATMP and BHMTMPA to the soil sample, the concentrations of organic phosphonic acid added were 2%, 4%, 6%, 8%, 10%, at the same time, added an equal volume of distilled water to the blank control group, it was air-dried in a cool and dry place for later use.

Weighing 30 g of experimental soil into a petri dish, and three groups of parallel experiments were carried out. 20 *Zinnia elegans* Jacq. seeds that had been soaked in H₂O₂ and disinfected to distribute the seeds evenly on the petri dish, which covered with a layer of experimental soil and incubated at room temperature in the dark. Observed the petri dish at random and added distilled water to it to keep the soil moist. Recorded the number of germinated seeds, measured the length of the roots and sprouts after germination, and the dry weight of seedlings was measured.

3. Results and analysis

3.1. Germination potential

![Fig 1. Effect of organic phosphonic acid on the germination potential of Zinnia elegans Jacq. after Cd contaminated soil remediation](image)

As shown in Figure 1, when the concentration of HEDP, HDTMPA and ATMP was 4%, the germination potential of *Zinnia elegans* Jacq. reached the maximum of the same kind of organic phosphonic acid. In the germination test, Xu Lingling found that the appropriate concentration of Cd can promote the establishment of protection mechanisms for plants, it can improve plant activity and increase plant germination potential[7]. In addition, the germination potential of *Zinnia elegans* Jacq., after the remediation of Cd contaminated soil by organic phosphonic acid HDTMPA was the highest. The application of BHMTMPA leads to excessive Cd in the soil, which in turn leads to damage to the germination of *Zinnia elegans* Jacq.

3.2. Germination rate

As shown in Figure 2, the greater the concentration of BHMTMPA applied, the germination rate of *Zinnia elegans* Jacq. decreased more obviously. After applying HDTMPA and ATMP to repair Cd contaminated soil, the germination rate of *Zinnia elegans* Jacq. was firstly promoted and then inhibited. Liu Yiyun's experiments on planting *Celosia cristata* var. *pyramidalis* and *Mirabilis jalapa* L. showed that HDTMPA at an appropriate concentration can repair Cd-contaminated soil, which can slow down the toxicity of Cd to plant seeds and increase the germination rate of *Celosia cristata* var. *pyramidalis* and *Mirabilis jalapa* L., the toxic cumulative effect of Cd in the later stage was becoming more and more obvious, which lead to the reduction of the germination rate of *Celosia cristata* var. *pyramidalis* and *Mirabilis jalapa* L.[8], this paper has a similar effect on *Zinnia elegans* Jacq.
### 3.3. Germination Index

Table 1. Effects of organophosphonic acid on the germination index of *Zinnia elegans* Jacq. after Cd contaminated soil remediation

| Concentration of organic phosphonic acid | Germination Index |
|----------------------------------------|-------------------|
|                                        | CK    | HEDP   | BHMTPMPA | HDTMPA | ATMP |
| 0                                     | 8.6±0.4 | 8.5±0.5 | 6.1±0.7 | 9.8±0.5 | 8.9±0.6 |
| 2%                                    | 7.7±0.6 | 13.4±1.1 | 30.1±1.5 | 22.3±1.5 |
| 4%                                    | 6.7±0.4 | 1.7±0.3 | 7.5±0.4 | 3.5±0.7 |
| 6%                                    | 5.9±0.7 | 0 | 3.1±0.2 | 1.5±0.3 |
| 8%                                    | 2.7±0.4 | 0 | 3.1±0.2 | 1.5±0.3 |

As shown in Table 1, when HDTMPA at a concentration of 4%, the *Zinnia elegans* Jacq. germination index increased by 37.2% compared with that of CK. After applying BHMTPMPA to repair Cd contaminated soil, the germination index of *Zinnia elegans* Jacq. was the lowest, however, *Zinnia elegans* Jacq. could not germinate when BHMTPMPA applied at a concentration of 10%. The application of HEDP and ATMP can increase the germination index of *Zinnia elegans* Jacq. at lower concentrations.

### 3.4. Vitality index

Table 2. Effects of organophosphonic acid on the activity index of *Zinnia elegans* Jacq. after Cd contaminated soil remediation

| Concentration of organic phosphonic acid | Vitality index |
|----------------------------------------|----------------|
|                                        | CK    | HEDP   | BHMTPMPA | HDTMPA | ATMP |
| 0                                     | 22.3±1.0 | 24.6±1.4 | 13.4±1.1 | 30.1±1.5 | 22.3±1.5 |
| Concentration | Zinnia elegans Jacq. vitality index | BHMTPMPA vitality index | ATMP vitality index |
|---------------|-----------------------------------|-------------------------|--------------------|
| 4%            | 21.5±1.6                          | 10.9±1.5                | 41.3±5.6           |
| 6%            | 20.7±1.2                          | 5.5±0.7                 | 24.1±2.2           |
| 8%            | 15.9±1.9                          | 2.1±0.4                 | 17.3±0.9           |
| 10%           | 7.3±1.1                           | 0                       | 7.5±0.5            |

As shown in Table 2, applying HDTMPA to repair Cd contaminated soil, the *Zinnia elegans* Jacq. had the highest vitality index, which was 85.2% higher than that of CK group. Applying BHMTPMPA to repair Cd contaminated soil, it may lead to lower soil pH or increase Cd activity, which may lead to the poisoning of *Zinnia elegans* Jacq. seed, even unable to germinate, and vitality was lost, and the *Zinnia elegans* Jacq. vitality index was significantly inhibited. The enhancement effect of organic phosphonic acid HEDP was the second, and that of ATMP was the lowest.

### 3.5. Young root length

As can be seen from Figure 3, when HDTMPA with a concentration of 4%, the root length increased by 77% compared with CK group, and further increasing the concentration of HDTMPA, the growth-promoting effect of *Zinnia elegans* Jacq. young roots in the repaired soil was weakened until it was completely inhibited. After applying low concentrations of BHMTPMPA and ATMP to repair Cd contaminated soil, the growth inhibition effect of *Zinnia elegans* Jacq. young roots was dominated. When applying BHMTPMPA concentration higher than 8% to remediated Cd contaminated soil, even *Zinnia elegans* Jacq. did not germinate and had no root growth.

### 3.6. Young bud length

As shown in Figure 4, when the concentration of HEDP did not exceed 10%, the sprouts growth of *Zinnia elegans* Jacq. increased compared with CK group. It showed that after applying HEDP to repair Cd-contaminated soil, *Zinnia elegans* Jacq. grew well, and HEDP effectively reduced the toxic effect of Cd on *Zinnia elegans* Jacq. After applying HDTMPA at a concentration of 4% to repair Cd contaminated soil, the length of *Zinnia elegans* Jacq. sprouts increased by 34.6% compared with the CK group, and the growth activity of *Zinnia elegans* Jacq. was stimulated.
3.7. Dry weight of *Zinnia elegans* Jacq. seedlings

As shown in Figure 5, applying HDTMPA to repair Cd contaminated soil, the dry weight of *Zinnia elegans* Jacq. seedlings increased by 23.4% compared to the CK group, and the effect was significant compared with the control group. Applying other organic phosphonic acid to repair Cd contaminated soil, the dry weight of *Zinnia elegans* Jacq. was lower than that of CK group seedlings, especially after applying BHMTPMPA to repair Cd contaminated soil, the dry weight of *Zinnia elegans* Jacq. was the smallest, when the applied concentration of BHMTPMPA was 10%, *Zinnia elegans* Jacq. did not germinate and no plant body was formed.

4. Conclusion

When the organic phosphonic acid HDTMPA concentration was 4%, the germination characteristics of *Zinnia elegans* Jacq. seeds reached the best of the four organic phosphonic acids, and the best values were as follow: the germination rate, germination potential, germination index, vigor index, root length, bud length and seedling dry weight were 62%, 25.1, 11.8, 41.3, 1.8 cm, 3.5 cm and 158 mg respectively. The application of organic phosphonic acid BHMTPMPA was not conducive to the germination of *Zinnia elegans* Jacq. seeds, and even at high concentrations, the *Zinnia elegans* Jacq.
did not germinate. After applying organic phosphonic acid ATMP and HEDP, all indexes of *Zinnia elegans* Jacq. were improved.

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