Effect of γ - polyglutamic Acid on Available Phosphorus in Soil with Phosphate Rock Powder

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Abstract. The effect of γ - polyglutamic acid on the activation of phosphorus in aeolian sandy soil was studied by soil culture in the laboratory. The results showed that compared with the control group (phosphate rock powder group), the net increase of available phosphorus content in soil of phosphate rock powder and γ - polyglutamic acid treatment group was as high as 36.15%, which suggesting that γ - polyglutamic acid increased the content of available phosphorus in soil.

1. Introduction
Phosphorus is one of the essential nutrients for plant growth and development [1,2]. Phosphorus can be directly absorbed and utilized by plants. Phosphate is added to the soil and quickly fixed, and only a small fraction of it is directly available to plants. Due to the low utilization rate of phosphate fertilizer in the season and the shortage of phosphate rock resources, phosphorus has become the main nutrient element restricting plant growth [3]. Therefore, improving the availability of phosphorus in soil is the key to solve the global phosphorus crisis. In the present study, the γ-polyglutamic acid phosphate-solubilizing agent was studied [4]. The mechanism of phosphorus release agent was revealed by analyzing the effect of addition amount and other factors on available phosphorus in the sandy soil of Changtu, Liaoning Province. This study aims to provide a theoretical basis for the use of low-grade phosphate rock powder.

2. Materials and Methods

2.1. Materials

2.1.1. Tested Soils. The soil tested is wind-sandy soil, collected from Erhe village, Qijiazi town, Changtu County, Liaoning Province. The collection of soil samples was carried out following the method described in NYT395-2012. After air-drying, the soil is ground fine and sifted through 100 Mesh. Soil chemical properties are shown in table 1.
Table 1. Some properties of the soils.

| Organic matter% (OM) | pH       | Total phosphorus (mg/kg) | Available phosphorus (mg/kg) |
|----------------------|----------|--------------------------|------------------------------|
| 1.63                 | 8.16     | 740                      | 11.35                        |

2.1.2. *Phosphate Rock*. Phosphate rock powder by a production enterprise in Henan, grade 17%, for low-grade phosphate rock powder. The phosphate rock powder is ground down to a 100 Mesh screen for use.

2.1.3. *Dephosphorizing Agent*. Γ-polyglutamic acid is supplied by a production enterprise in Henan Province.

2.2. *Experimental Design*

Indoor soil culture experiments were conducted from April to September 2019. Polyglutamic acid was used as a phosphate solubilizer, and phosphate rock powder was mixed according to the following three ratios. The ratios of Phosphate Solubilizer (g): Phosphate rock (g) : Soil (g) were 0.25: 2.5: 500, 1.25: 0.75: 500, 1.25: 2.5: 500, respectively. The Pot of 10.2 cm * 18 cm * 11 cm was used for soil culture. Each basin was filled with 500g soil, 2.5g phosphate rock powder and 1.25g phosphate solubilizer. The soil moisture was adjusted to 70% of the field water holding capacity, and the soil moisture was kept constant after fully mixing and incubation in the artificial climate chamber for 70 days. The physical and chemical properties of the soil were measured after drying and grinding. The environment is controlled by L/D = 14 h/10 H, temperature (25 ± 1) °C and relative humidity (70 ± 5)%.

2.2.1. *Determination Method*. Soil PH was determined by PHS-3C digital acidity meter (soil-water ratio = 1: 2.5). Soil total phosphorus was digested by H2SO4-HClO4. Soil available phosphorus was determined using 0.5 mol/l NaHCO3 solutions. Soil organic matter was determined by high-temperature potassium dichromate oxidation.

2.2.2. *Data Processing*. The data were analyzed with SPSS 17.0 software for one-way Anova, and the results were expressed by mean ± standard deviation. Using DPS 7.05 software for Multiple Comparisons, P & Lt; 0.05 showed significant differences.

3. *Results and Analysis*

3.1. *Effects of γ-polyglutamic Acid on Soil Available Phosphorus Content*

After 1, 30, 70, 90 days, the content of available phosphorus treated with γ-polyglutamic acid was significantly higher than that treated with phosphate rock (Figure 1). With the increase of phosphate solubilizer, the content of available phosphorus in soil increased. Within 90 days after the experiment, the content of available phosphorus in the γ-polyglutamic acid group was 20.25% higher than that in the phosphate rock group. The results indicated that γ-polyglutamic acid promoted the decomposition of insoluble phosphorus and increased the content of available phosphorus in soil. The reason may be that γ-polyglutamic acid improved the physical environment of soil and increased the utilization ratio of phosphorus. On the other hand, γ-polyglutamic acid can chelate calcium, iron and aluminum in the soil, and increase the content of available phosphorus.
3.2. Effects of γ-polyglutamic Acid on the Content of Organic and Inorganic Phosphorus in Soil

It is generally believed that the higher the correlation coefficient with soil available phosphorus forms, the higher the availability. Through the analysis of available phosphorus and different forms of phosphorus components in Aeolian Sandy soil (Table 2-3), it was found that phosphorus components were significantly correlated with available phosphorus. The Correlation Coefficient of NaHCO3-pi was the highest, the Correlation Coefficient between inactive RES-P and available phosphorus was low, and there was no correlation between NaHCO3-pi and other phosphorus components. The results showed that a series of changes in the soil environment could activate insoluble phosphorus, promote its transformation to more available forms of phosphorus, and improve the availability of phosphorus.

In the process of soil phosphorus transformation, different phosphorus components showed a certain degree of correlation, and any form of phosphorus changes will affect the content of soil available phosphorus.
Table 2. Results of different phosphorus components in soil.

| Day  | Treatment     | Phosphorus fractionation content (mg.kg⁻¹) |
|------|---------------|-------------------------------------------|
|      |               | H₂O-Pi | NaHCO₃-Pt | NaHCO₃₃-Pi | NaOH-Pt | NaOH-P₀t |
| 1    | γ-PGA:R=0.5:1 | 9.25  | 26.37     | 0.15      | 0.526   | 0.078   |
|      | RP            | 6.25   | 2.37      | 0.15      | 0.526   | 0.078   |
| 30   | γ-PGA:R=0.5:1 | 0.25   | 2.37      | 0.15      | 0.526   | 0.078   |
|      | RP            | 0.25   | 2.37      | 0.15      | 0.526   | 0.078   |
| 70   | γ-PGA:R=0.5:1 | 0.25   | 2.37      | 0.15      | 0.526   | 0.078   |
|      | RP            | 0.25   | 2.37      | 0.15      | 0.526   | 0.078   |
| 90   | γ-PGA:R=0.5:1 | 0.25   | 2.37      | 0.15      | 0.526   | 0.078   |
|      | RP            | 0.25   | 2.37      | 0.15      | 0.526   | 0.078   |

Note: Different letters indicate significant differences between different treatments (P <0.05)

Table 3. Effects of γ-polyglutamic acid on the phosphorus components in sandy soil.

|                | H₂O-Pi | NaHCO₃-Pt | NaHCO₃₃-Pi | NaOH-P | HCl-P | Residual-P | Available phosphorus |
|----------------|--------|-----------|------------|--------|-------|-----------|---------------------|
| H₂O-Pi         | 1      |           |            |        |       |           |                     |
| NaHCO₃-Pt      | 0.681  | 1         |            |        |       |           |                     |
| NaHCO₃₃-Pi     | 0.923  |           |            |        |       |           |                     |
| NaOH-P | 0.286  | 0.574     | 0.348      | 1      |       |           |                     |
| NaOH-P₀t       | 0.803  |           |            |        |       |           |                     |
| NaOH-P₀t       | *      | 0.719*    | 0.937**    | 0.4    | 1     |           |                     |
| HCl-P          | 0.62   | 0.604     | 0.730*     | 0.583  | 0.809*| 1         |                     |
| Residual-P     | -0.31  | -0.267    | -0.331     | 0.432  | -0.276| -0.22     | 1                   |
| Available phosphorus | 0.877 | 0.830*    | 0.991**    | 0.416  | *     | 0*        | -0.314 1            |

Note: * means significant difference (P <0.05), ** means significant difference (P <0.01).

4. Discussion

(1) Compared with a single application of phosphate rock, γ-polyglutamic acid significantly increased the content of available phosphorus in soil. The content of available phosphorus in soil increased with the increase in the proportion of phosphate solubilizers.

(2) γ-polyglutamic acid promoted the transformation of insoluble phosphorus into available phosphorus and increased the content of available phosphorus in soil. Therefore, γ-polyglutamic acid and phosphate rock in combination with sandy soil should be used in future studies. This study provides a theoretical reference for the direct application of phosphate rock in Aeolian Sandy soil.
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