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Effects of Lignin on Root Activity and Soil Nutrients of *Malus hupehensis*. var. *pingyiensis* under the Use of Organic Fertilizer

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Abstract

One-year *Malus hupehensis*. var. *pingyiensis* seedlings potted in soil mixed with 10% or 40% organic fertilizer were treated with two concentrations of lignin (1.5 and 2.5 g·kg^{-1}), and detected the effects of lignin on root activity and soil nutrients in rhizosphere soil of *Malus hupehensis*. var. *pingyiensis*. (1) Lignin improved root activity of *Malus hupehensis*. var. *pingyiensis*, increased soil available nitrogen contents and soil organic matter contents. (2) Under 10% organic fertilizer, lignin improved soil available P and K contents. The root activity in *Malus hupehensis*. var. *pingyiensis* was the largest in 2.5 g·kg^{-1} lignin treatment. (3) Under 40% organic fertilizer, compared with the CK2 (the treatment of soil with organic fertilizer content 40%), lignin decreased the content of rhizosphere soil available K. 1.5 g·kg^{-1} lignin treatment had obviously increased the content of soil available P. The root activity was the largest in 2.5 g·kg^{-1} lignin treatment, while the content of rhizosphere soil available K lowered 8.5% compared with that of CK2 in the same treatment. Lignin changed the soil nutrients, 2.5 g·kg^{-1} lignin significantly improved root activity of *Malus hupehensis*. var. *pingyiensis*. The results provided a theoretical basis for the regulation of root activity and soil nutrients in *Malus hupehensis*. var. *pingyiensis*.

Keywords

Malus hupehensis. var. *pingyiensis*, Lignin, Organic fertilizer, Nutrients

1. Introduction

Lignin is the only resource that provides renewable aromatic compounds. A

large amount of alkaline lignin from paper-making waste liquor, its utilization rate is very low, nowadays, less than 10% of the lignin can be converted into a valuable product [1]. Lignin improved soil aggregate structure, reduced the soil adsorption capacity to fix the soil nutrients, and raised the fertilizer efficiency of the nitrogen and phosphorus [2] [3] [4]. Lignin regulated non-organic nitrogen release, benefited the soil N supplying and the N and P uptake, increased the growth and quality of plant and reduced the soil pollution [5] [6]. Lignin has also the absorption capacity of heavy metal ion such as Cu^{2+}, Pb^{2+}, Hg^{2+}, Cd^{2+} [7] [8] and the high antioxidant capacity [9].

Therefore, how to effectively use lignin is an important hot problem. Because of single nutritional components of lignin, it is unstable to be single used or applied in poor soil. *Malus hupehensis.* var. *pingyiensis* as afforestation tree species is a type of Malus hupehensis and also an excellent apple stock. One-year *Malus hupehensis.* var. *pingyiensis* seedlings potted in soil mixed with organic fertilizer were treated with different concentrations of lignin, detected the effects of lignin on root activity and soil nutrients in rhizosphere soil were analyzed. The purpose of this research is to provide a theoretical basis for the better use of lignin, regulation root soil nutrients and the rational cultivation of *Malus hupehensis.* var. *pingyiensis* in China and other countries.

2. Material and Methods

2.1. Study Sites

This study was conducted in march-september in 2015 in Science and technology innovation park in the south campus of Shandong agricultural university, Taian, China. The tested plants are one-year *Malus hupehensis.* var. *pingyiensis* seedlings potted in soil. The pot used in this test has 36 cm mouth diameter, 27 cm height, the soil weight of each pot is 10.2 kg. The soil has the following properties: soil available nitrogen 54.9 $mg \cdot kg^{-1}$, available phosphorus 27.3 $mg \cdot kg^{-1}$, available potassium 33.9 $mg \cdot kg^{-1}$, organic matter 12.4 $g \cdot kg^{-1}$, pH 7.3. The organic fertilizer has the following nutrients: soil available nitrogen 255.5 $mg \cdot kg^{-1}$, available phosphorus 50.7 $mg \cdot kg^{-1}$, available potassium 65.9 $mg \cdot kg^{-1}$, organic matter 164.3 $g \cdot kg^{-1}$. The tested lignin is alkaline lignin manufactured from the company of Shandong province.

2.2. Experiment Treatment

Firstly, 0, 1.5, 2.5 $g \cdot kg^{-1}$ lignin was added in the soil with organic fertilizer content 10% and 40%, respectively (**Table 1**), secondly, the above materials as experimental soil fully mixed with were put into the pots. The one-year *Malus hupehensis.* var. *pingyiensis* seedlings were planted in these pots, each treatment was designed in triplicate.

2.3. Determination

The roots and soil were picked up, and the sorted out roots were used to measure. The soil was sampled in September in 2015. After the surface soil was re-

Table 1. Experimental treatments.

Organic fertilizer applied (quanlity fraction %)	Lignin applied (g·kg^{-1})
	0(CK1)
10	1.5
	2.5
	0(CK2)
40	1.5
	2.5

moved, root activity, the seized soil through natural air dry was applied to determine soil nutrient content and soil enzyme activities.

Root activity was measured according to the triphenyltetrazolium chloride method [10]. Soil organic matter was measured according to the method [11]. The content on soil alkaline N, soil available P, soil available K was measured based on the method [12].

2.4. Data Analysis

The data in the article were analyzed through Excel statistical software and SPSS 17.0 statistical software package.

3. Results

3.1. Root Activity

The root activity of *Malus hupehensis*. var. *pingyiensis* became larger with the increase of lignin concentration, regardless of 10% or 40% organic fertilizer content. The root activity of the species in 2.5 g·kg^{-1} lignin treatment became bigger by 89.5% compared with that of the CK (**Figure 1(a)**). Under the condition of 40% organic fertilizer, the root activity of the species in 1.5 g·kg^{-1} lignin treatment was no significant difference compared with that in the 2.5 g·kg^{-1} lignin treatment, and that of the species in 2.5 g·kg^{-1} lignin treatment was higher 55.0% than that in the CK2 (**Figure 1(b)**).

3.2. Rhizosphere Soil Nutrients

Soil nutrients differently varied in those lignin treatments (**Figure 2**). Soil available N and organic matter became gradually larger with the increase of lignin used. Among those treatments, that of soil available N and organic matter were largest in 2.5 g·kg^{-1} lignin treatment, they raised by 27.3, 68.4% compared with that of CK1 under 10% organic fertilizer, respectively, and increased by 42.8%, 15.2% compared with that of CK2 under 40% organic fertilizer, respectively.

Under 10% organic fertilizer, the content of soil available P and organic matter of 1.5 g·kg^{-1} lignin treatment became larger by 5.6%, 49.1%, respectively, soil alkaline N of 1.5 g·kg^{-1} lignin treatment had an decrease compared with that of CK1. The 1.5 g·kg^{-1} lignin treatment elevated the content soil available K by 16.0% compared with that of CK1.

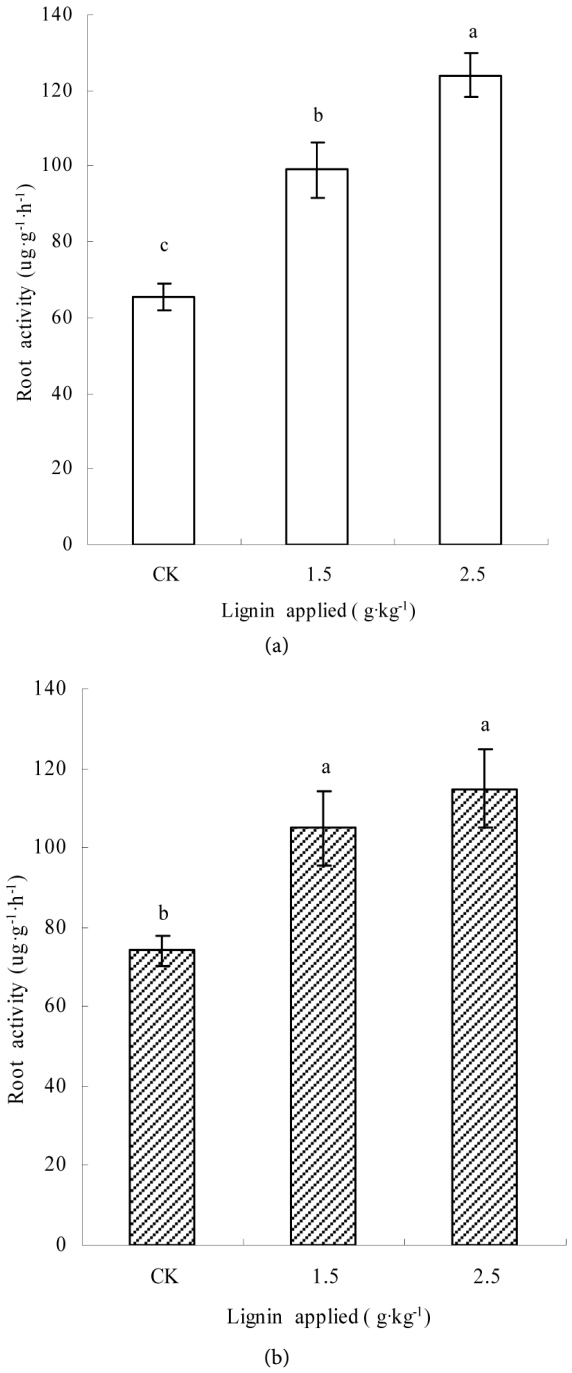

Figure 1. Changes of root activity of *Malus hupehensis* var. *pinyiensis.* Note: Figure 1A represents 10% organic fertilizer condition; Figure 1B represents 40% organic fertilizer condition.

Under 40% organic fertilizer, the two concentrations of lignin treatment elevated the content of soil available P, but had no significant difference compared with that of CK2. Different concentrations of lignin treatments decreased the content of rhizosphere soil available potassium, and that of rhizosphere soil available K in 2.5 g·kg^{-1} lignin treatment lowered 8.5% compared with that of CK2 (**Figure 2**).

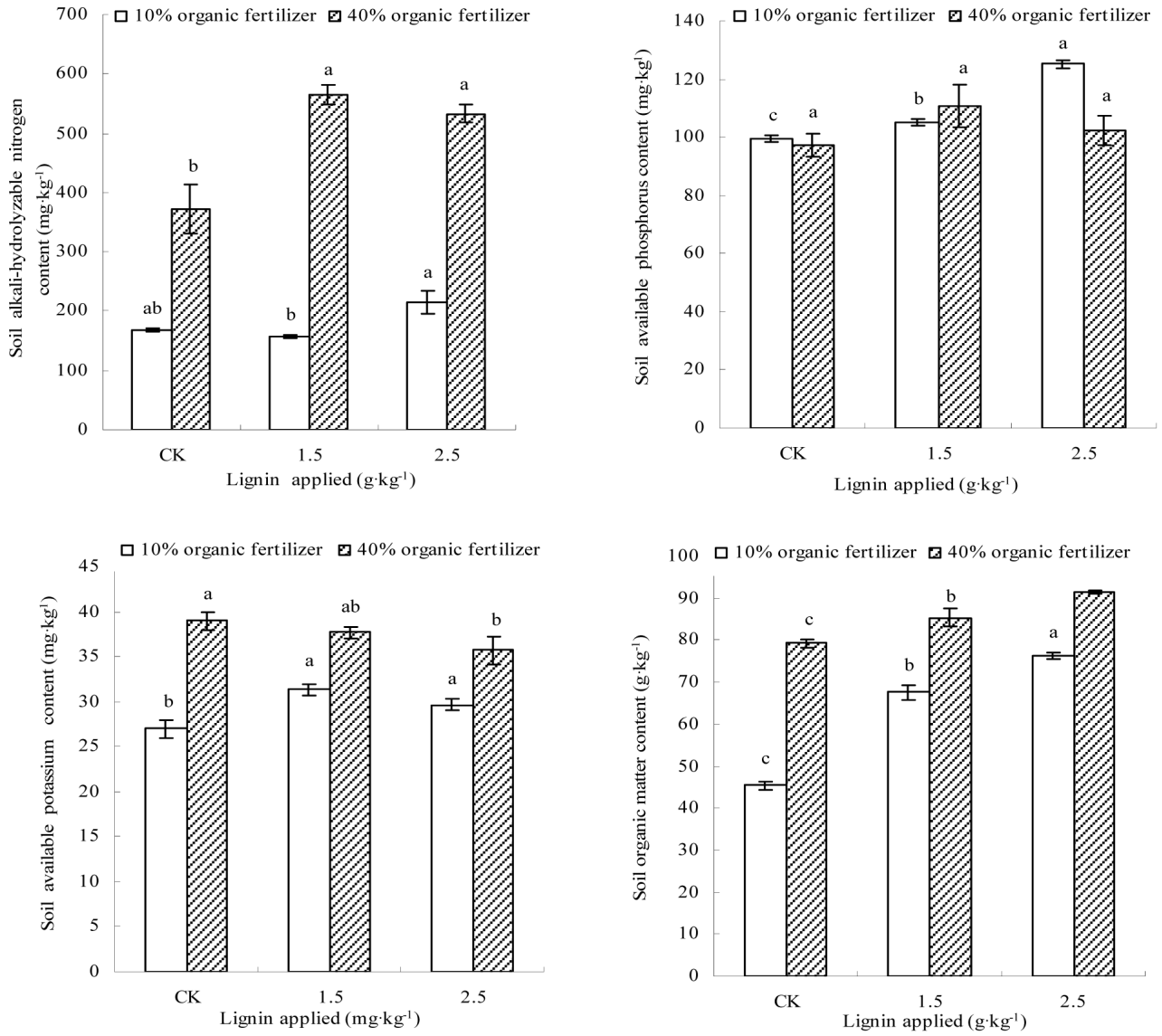

Figure 2. Changes of soil nutrient contents in rhizosphere soil of *Malus hupehensis* var. *pinyiensis*.

4. Discussion

4.1. Soil Nutrients

Soil fertility mainly depends on the amount of soil nutrients. The content of soil nutrients significantly raised after soil was applied with organic compound fertilizer. Soil organic matter correlated positively with soil organic carbon (SOC). Straw, lignin and biochar obviously increased the content of SOC [13]. Lignin could reduced the Fixation of soil P by metal ions, insoluble P could be rapidly resolved, which promoted the plant growth [14]. After used the lignin slow-release fertilizer in soil, the content of effective K raised, the K requirement for plant had an increase with its growth, which resulted in the steady declination of soil available K content [15].

Under the application of organic fertilizer, lignin increased the content of alkaline N and organic matter. In the condition of 10% organic fertilizer, the

amount of soil available P and K became larger, the result was coincided with the informed report [16], the reason lied in that lignin enlarged the effectivity of soil P and N, promoted the accumulation of soil available K [15]. However, the content of soil alkaline N in 1.5 $g \cdot kg^{-1}$ lignin treatment had an decrease, the reason might be that the thriving trees in 1.5 $g \cdot kg^{-1}$ lignin treatment had assimilated much more soil alkaline N. In the condition of 40% organic fertilizer, the amount of soil available K became much smaller with the concentration of lignin among the treatments, which might be that lignin promoted the *Malus hupehensis*. var. *pingyiensis* growth, this tree absorbed more soil K, the study was similar to the reported research [16]. The amount of soil available P was lower in the 2.5 $g \cdot kg^{-1}$ lignin treatment than that in the 1.5 $g \cdot kg^{-1}$ lignin treatment, it might be that the trees of 2.5 $g \cdot kg^{-1}$ lignin treatment were higher among the treatments and they consumed more soil P.

4.2. Root Activity

Root activity is an important index reflecting the ability of root to absorb soil nutrients and water and directly affecting the growth of plant. Root activity was affected by organic matter, fertilizer, plant cultivars, microbial number and other environmental factors [16] [17]. The application of lignin increased root activity of *Malus hupehensis*. var. *pingyiensis*, the reason may be that lignin improved the content of soil nutrients (**Figure 2**), promoted the absorption of root to soil nutrients.

5. Conclusion

Lignin improved its root activity, increased soil available nitrogen and soil organic matter contents. Under 10% organic fertilizer, lignin improved soil available P and K contents. Under 40% organic fertilizer, lignin decreased the content of soil available K, the root activity was the largest in 2.5 $g \cdot kg^{-1}$ lignin treatment, while the content of soil available K lowered. In all, lignin changed the soil nutrients, 2.5 $g \cdot kg^{-1}$ lignin significantly improved root activity of *Malus hupehensis*. var. *pingyiensis*.

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