# Effects of root pruning on physico-chemical characteristics and biological properties of winter jujube rhizosphere soil

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**ABSTRACT**

The root system of six-year-old winter jujube (*Zizyphus jujuba* Mill. cv. Zhanhua) trees were manually pruned at 3, 5 or 7 times trunk diameter distance along both inter-row sides, to study the effects of root pruning on physico-chemical characteristics and biological properties of winter jujube rhizosphere soil. The results showed that the root pruning of 3 and 5 times trunk diameter distance increased the available nitrogen, phosphorus, potassium concentrations and pH values in the rhizosphere soil and decreased organic matter concentrations, the contents of amino acids, organic acids and total sugars in the root exudates, the populations of bacteria, actinomyces and fungi, and inhibited the activities of catalase, invertase and urease enzymes in contrast to the control in early stage when root pruning was applied. The determined indexes presented a reverse trend as those in early stage after new roots appeared. Compared to the control, the trees by root pruning had higher pesticides residues of the rhizosphere soil in the whole experiment. No differences were noticed between 7 times trunk diameter distance and the control. It is proposed that root pruning had greater impacts on physico-chemical characteristics and biological properties of the rhizosphere soil depending on root pruning intensity.

**Keywords**: nutrient; soil enzyme; root exudates; microorganism; pH; pesticide residue

From about 0 to 2 mm away from the root surface, a zone of soil is located that is significantly influenced by living roots and is referred to as the rhizosphere (Bertin et al. 2003). The rhizosphere is important in terms of root growth, exudates production and community development of macro and micro biota. Its spatial extension is variable depending upon the soil structure, particle size, water content, and buffering capacity (Nye 1984). The soil matrix itself can be described as a multiphasic system consisting of a large number of interacting elements, including plant roots, nutrients, bacteria, fungi, actinomyces, mycorrhizae and soil faunas (Campbell and Greaves 1990).

Plant roots serve a multitude of functions including anchorage, provision of nutrients and water, and production of exudates with growth regulatory properties and affect soil structure, aeration, biological activity and depletion of inorganic compounds. One of the functions, the production of exudates is mainly performed by living root hairs. Because root hairs, as well as actively growing primary and secondary roots, can typically release large quantities of root exudates (Bertin et al. 2003) including organic acids, sugars, amino acids, secondary metabolites, peptides, proteins, ureides and lipids (Walker et al. 2003, Bais et al. 2006). It is well known that exudates serve as an important carbon and energy source for microorganisms in the rhizosphere (Cheng et al. 1996, Quian et al. 1997), whereas rhizosphere microbial community transforms and selectively utilizes exudates and therefore results in changes in residual carbon and nitrogen in the root environment. This, in turn, can have immediate and longer term effects on nutrient cycling and organic matter accumulation in plant-soil system (Coleman et al. 1985, Martin 1997). Enzymes in rhizosphere soil play essential roles in soil processes such as nutrient cycling and energy transformation by catalyzing numerous chemical, physical and biological reactions. They are mainly exuded by roots and microorganisms and their activities can also have significant effects contributing to the changes of nutrients (Estermann

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and McLaren 1961). In the plant rhizosphere, organic acid-exuding microorganisms are typically numerous (Drever and Vance 1994), which will contribute to the increase of organic acid in the rhizosphere soil and thus contribute to the lowered pH. The change of pH has also significant effects on mineral weathering and elemental solubility as suggested by the work of Tan (1986).

Previous authors studied the influences of root pruning on aboveground organs as it serves as a measure for regulating plant growth. Moreover, less information is available on the effects of root pruning on physico-chemical characteristics and biological properties of the rhizosphere soil. Therefore, the objective of this study was to evaluate the effects of root pruning on correlative indexes of the rhizosphere soil and mechanical functions.

## MATERIAL AND METHODS

**Plant material and experimental design**. The experimental site was located in the Yellow River Delta, China. The field experiment was carried out at the winter jujube orchard, Binzhou city, Shandong province (37.22°N, 108.02°E). Six-year-old jujube trees were used in the experiment and the rows were planted 3 m apart with plant spacing of 3 m within each row. The mean trunk diameter was 7.5 cm. The height of the trees ranged from 2.1 m to 2.5 m.

The experiment involved a randomized, complete block design with three replications. Each block consisted of 10 trees arrayed in the same row. Prior to bud break, four treatments were applied to the examined trees on April 26, 2008: (1) control, with intact root system; (2) severe, removing root system at 3 times trunk diameters distance from trunk, 22.5 cm; (3) moderate, removing root system at 5 times trunk diameters distance from trunk, 37.5 cm; (4) light, removing root system at 7 times trunk diameters distance from trunk, 52.5 cm. Root system was cut with a sharp spade at different distances from the trunk on both inter-row sides of jujube trees to the depth of 20 cm. The treated trees were managed in accordance with routine care.

**Determination methods**. After new root appeared, rhizosphere soil was collected five times (namely, 1: early October 2008; 2: early June 2009; 3: early October 2009; 4: early June 2010; 5: early October 2010). The collection of rhizosphere soil was conducted using the method of Wang and Zabowski (1998). The assays of available nitrogen, phosphorus, potassium and organic matter concentrations were carried out according to the methods described by Liu and Yang (1996). Root exudates determination was performed using the method of Klein et al. (1988). Microorganism populations were determined by the surface planting technique (Estermann and McLaren 1961). pH was measured using 1:2.5 (w/v) water extraction and PHM 92 Radiometer pH Meter (Radiometer America, San Diego, USA). Soil enzyme activities were assayed in air-dried samples as described by Guan (1986). The extraction of malathion and cypermethrin and subsequent clean-up of the extracts were in accordance with the method presented by Kumari et al. (2001) and the analysis was carried out with Agilent gas chromatography system on a 6890 N model (Agilent Technologies, Santa Clara, California, USA).

**Statistical analysis**. All experiments were repeated as indicated. Values presented are means. The effects of the treatments were tested by one-way analysis of variance (ANOVA). Means were compared between the treatments using the *LSD* (least significant difference) test at the 0.05 probability level.

## RESULTS

**Nitrogen, phosphorus, potassium and organic matter concentrations**. Figure 1 showed that compared to the control, the concentrations of available N, P and K in rhizoshpere soil of severely or moderately root pruned jujube trees were higher than those of the control in early October 2008. However, in the following stage, they were always lower relative to the control. Figure 1 also suggests that organic matter concentrations in rhizosphere soil of the severely and moderately decreased in the years of 2008 and 2009 but increased in 2010 in comparison to the control.

**Enzyme activity**. The influences of root pruning on the enzymes activities of rhizosphere soil are summarized in Figure 2. The enzymes activities of treated trees declined, but this effect only arose in early October 2008 for invertase and catalase. Subsequent the years 2009 and 2010, they all increased in contrast to the control. Root pruning also affected the urease activity, no variations among treatments were noticed until early October 2009 although it had a bit decrease or increase. Significant increases of urease activity by severely and moderately treated were only observed in early June 2010.

**Root exudation**. Figure 3 illustrated that jujube trees under severe root pruning had the lowest levels of amino acid, organic acid and total sugar in early June 2008. As roots gradually recovered with time, root pruning led to another conclusion

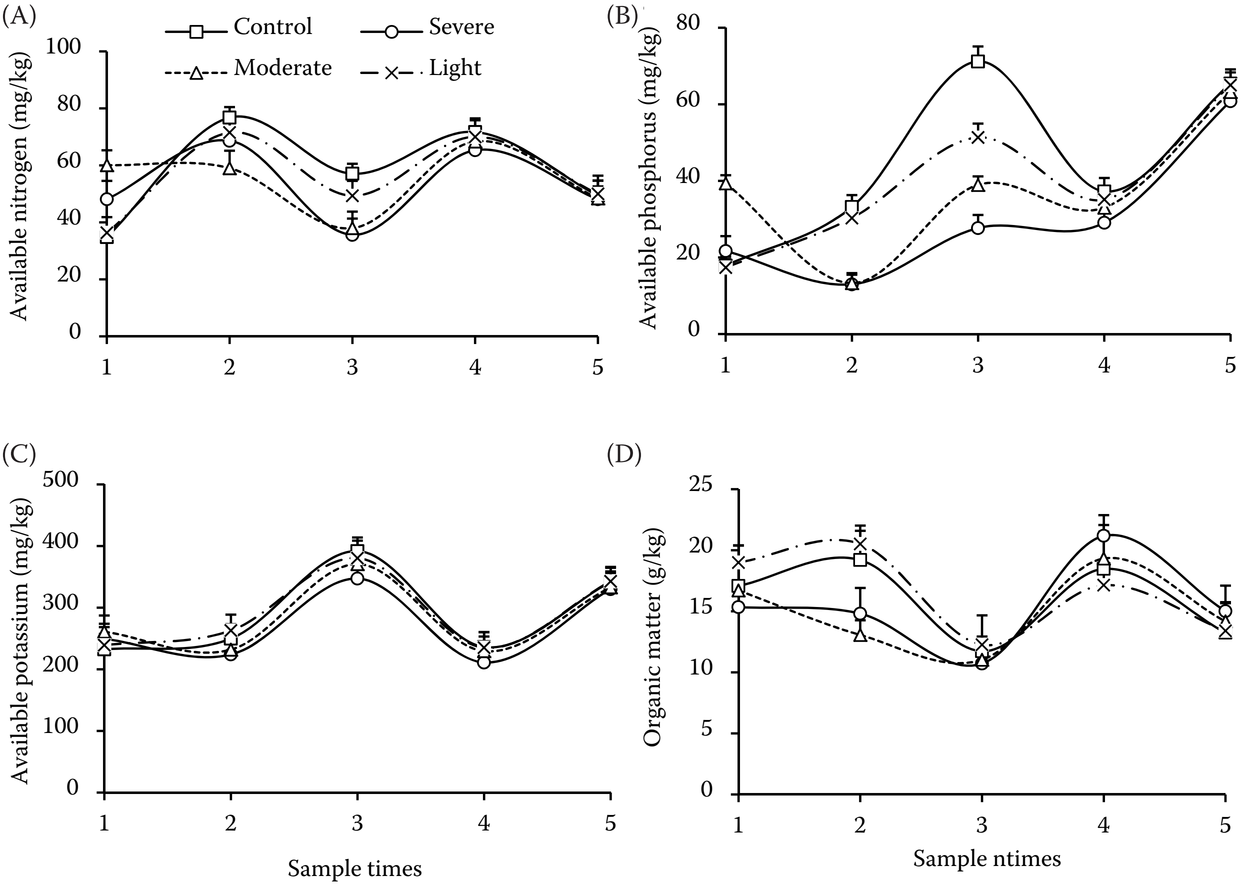
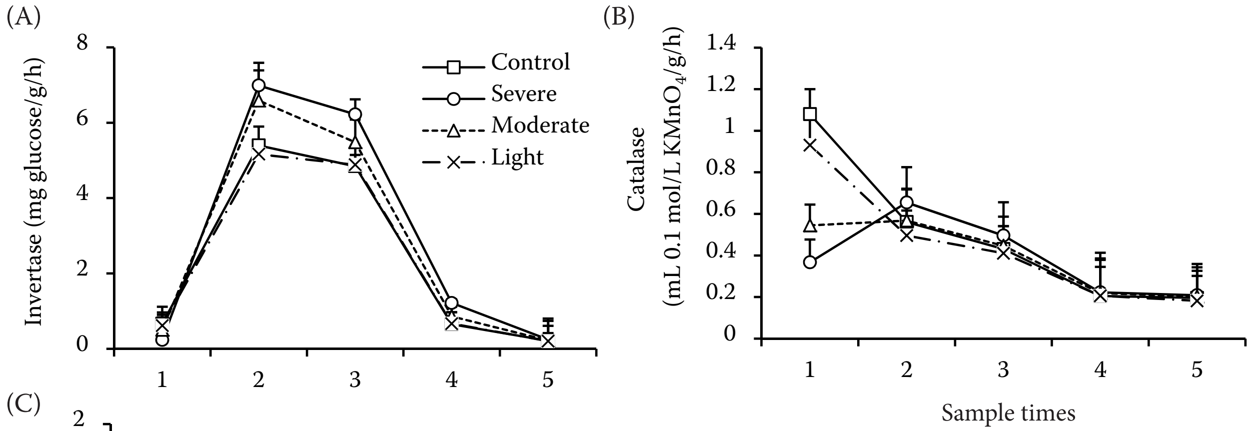



Figure 1. The effects of root pruning on the available nitrogen (A), phosphorus (B), potassium (C) and organic matter (D) of rhizosphere soil. The results are expressed as means ($n$ = 3)



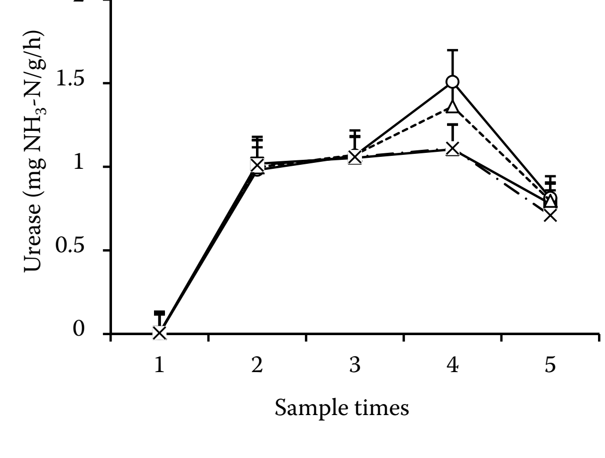




Figure 2. The effects of root pruning on the activities of invertase (A), catalase (B) and urease (C) of rhizosphere soil. The results are expressed as means ($n$ = 3)

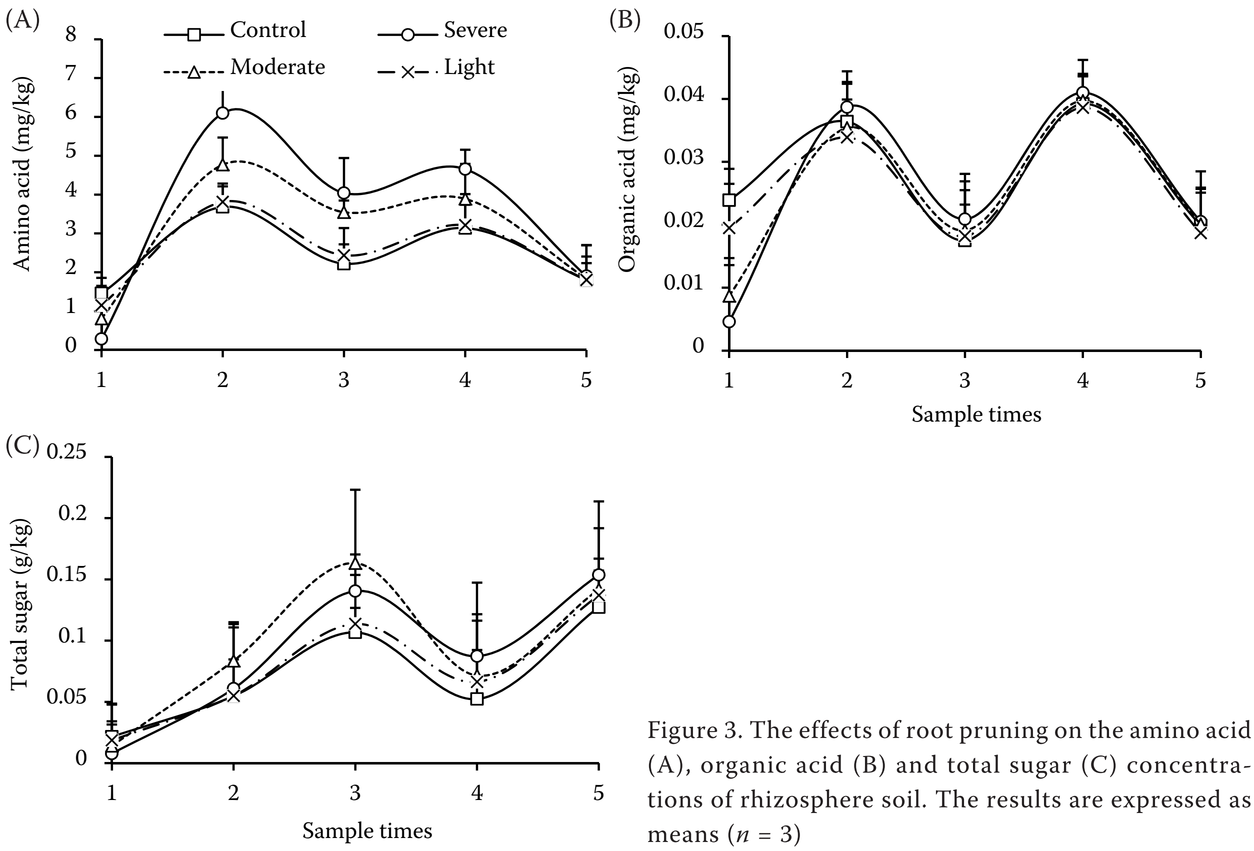



Figure 3. The effects of root pruning on the amino acid (A), organic acid (B) and total sugar (C) concentrations of rhizosphere soil. The results are expressed as means ($n$ = 3)

that the amounts of three exudates with severely and moderately pruned increased in contrast to the control. No difference between light root pruning and control was noticed within the entire experiment duration. This may indicate that the quantities of exudates were dependent on the root pruning distance.

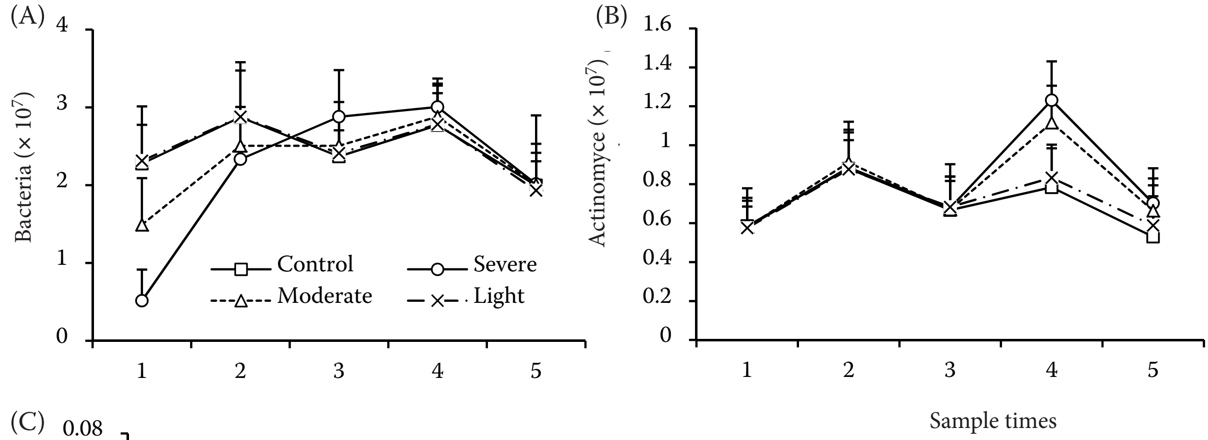
**Microorganism population**. Compared with the control, the amounts of bacteria and fungi were significantly reduced by severe and moderate root pruning but unaffected by light root pruning in early October 2008. In early June 2009, the influence of root pruning on bacteria population remained the same trend as in early October 2008, but on fungi population the effect was different, with large increases by comparing severe and moderate treatments to the control. With a start of early October 2009, their populations of the severely and moderately were higher than those of the control. Although actinomyces populations were affected by root pruning with a bit decrease or increase, no significant differences were found among all treatments until early October 2009. In the following stage, actinomyces populations of severe and moderate root pruning treatments increased as compared to the control (Figure 4).

**pH value**. The pH of rhizosphere soil was affected by root pruning as noted in Table 1. In comparison to the control, the pH values of root pruning treatments sharply increased in the early October 2008 and differently decreased in the years of 2009 and 2010. Data showed a significant interaction between pH variations among treatments and sampling time, indicating that variations were declined as sampling time prolonged.

**Pesticide residue**. During the period of this experiment, malathion and cypermethrin were used for leaf spraying five times. The results showed that only cypermethrin was detected. The significant correlation between root pruning and cypermethrin residue was observed in Table 2. Compared with the control, cypermethrin concentrations in the rhizosphere soils of severely and moderately root-pruned jujube trees were increased throughout the experiment. There were few statistically significant treatment effects between light root pruning treatment and the control.

## DISCUSSION

In the experiment, a portion of fine roots was removed more or less through root pruning that destroyed the original growing environment of roots and changed the correlation between roots and soil. This undoubtedly resulted in some variations in physico-chemical and biological characteristics of rhizosphere soil. Compared to the control, the



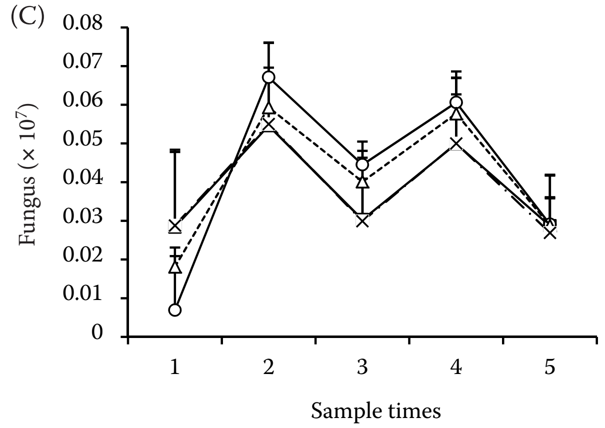




Figure 4. The effects of root pruning on the bacteria (A), actinomyces (B) and fungi (C) populations of rhizosphere soil. The results are expressed as means ($n$ = 3)

N, P and K concentrations in rhizosphere soil of severe and moderate root pruning treatments were higher in 2008. It possibly correlated with the fact that the nutrients were less absorbed by damaged root system after root pruning. Although the intact trees had higher microorganism populations, enzyme activities and lower Ph contributing to the increases of nutrients concentrations by mineral weathering, organic matter decomposing and catalyzing reaction, nutrients uptake of roots was dominant. Due to newly formed roots being capable of greater water and resource uptake than older roots, the N, P and K concentrations in rhizosphere soil of severe and moderate treatments were lower than in the control after new roots appearance, consistent with the finding of Wang and Zabowski (1998).

The role of the rhizosphere microorganisms in processing and retention of nutrients in plant-soil systems was considered in general terms and in relation to broad attributes of ecosystem functioning (O'Neil and Reichle 1980). At the same time, microorganisms can secrete enzymes into soil in their process of propagation (Chen 1996). Because roots were cut, the capabilities of the root system in physiological metabolism and secretion were weakened, and the root exudation and shed matters on root surface were decreased, which jointly resulted in lower microbial populations, organic matter contents, pH values and enzymes activities relative to the control. On the contrary, they were higher than in the control with the new roots emergence. No differences of actinomyces among treatments were found before October 2009, probably because different classes of microorganisms selectively utilize carboxyl acids and amino acids, and therefore different plant species have different

Table 1. The effect of root pruning on the pH of rhizosphere soil

| Treatment | pH | | | | |
|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 |
| Control | 7.83[c] | 8.26[a] | 8.50[b] | 7.98[a] | 8.34[a] |
| Severe | 8.23[a] | 8.05[c] | 8.28[c] | 7.85[c] | 8.31[a] |
| Moderate | 7.98[b] | 8.18[b] | 8.56[a] | 7.91[b] | 8.33[a] |
| Light | 7.76[c] | 8.21[a] | 8.57[a] | 7.96[a] | 8.36[a] |

The results are expressed as means ($n$ = 3) and different letter in same column means a significant difference at 5% levels. 1–5 – sampling times

Table 2. The effect of root pruning on Cypermethrin residues in rhizosphere soil

| Treatment | Cypermethrin concentration (mg/kg) | | | | |
|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 |
| Control | 0.022[c] | 0.008[c] | 0.025[c] | 0.011[c] | 0.023[b] |
| Severe | 0.048[a] | 0.015[a] | 0.032[a] | 0.018[a] | 0.028[a] |
| Moderate | 0.035[b] | 0.011[b] | 0.029[b] | 0.015[b] | 0.025[b] |
| Light | 0.023[c] | 0.009[c] | 0.026[c] | 0.012[c] | 0.024[b] |

The results are expressed as means ($n$ = 3) and different letter in the same column means a significant difference at 5% levels. 1–5 – sampling times

growing provocations on microbial classes in the rhizosphere (Grayston et al. 1988).

Due to root pruning, trees would allocated more photosynthates into the root system to support its farther growth and development (Farmer and Pezeshki 2004), and simultaneously speed up malathion and cypermethrin residues to be lavishly transported into roots and exuded into soil by roots, which caused higher pesticide residues in rhizosphere soil (Yang et al. 2010). Malathion is extremely decomposed (Chen 1996), so it was not detected in rhizosphere soil.

In conclusion, the results of ANOVA analysis indicated that root pruning could have remarkable impacts on physico-chemical and biological characteristics of rhizosphere soil and the effects were dependent on root pruning strength.

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