Effects of application of nitrogen, phosphorus and potassium on soil fertility and enzyme activities of pear jujube under straw mulching

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Abstract: In this experiment, the effects of different fertilization treatments on soil nutrient content and enzyme activity under straw mulching conditions were studied by using the soil of jujube garden for 4 consecutive years. The results showed that different fertilization treatments significantly improved the soil fertility of the pear jujube garden in the loess hilly region. In the vertical section of the soil, the soil organic matter content decreased with the increase of soil depth, showing 0~20 cm>20~40 cm>40~60 cm. And the total nitrogen content of N3P3K1 was the highest at 40~60 cm, which was 0.28 g/kg, which was 47.4% higher than that of CK. The available phosphorus content of N3P3K1 treatment was higher than other treatments at 20~40 and 40~60 cm, and its content was 4.4 and 3.6 g/kg. Different fertilization treatments affected soil enzyme activities. The urease activity of N3P3K1 treatment was 299.27 μg/g, which was 88.2% higher than that of CK. The effect of single application of phosphate fertilizer was the most significant, 54.17 μg/g, which was 98.1% higher than that of CK. Comprehensive analysis N3P3K1 treatment can more effectively improve soil fertility, improves soil enzyme activity, and is conducive to planting and producing pear dates.

1. Introduction

The sustainable development of modern agriculture focuses on the sustainable use of land, maintaining soil fertility, improving soil quality and soil health as a guarantee for sustainable land use. With the development of agriculture, people pay more attention to the application of fertilizer. Fertilization technology has become the main means to cultivate soil fertility and stable yield of crops. Studies have shown that rational fertilization measures can maintain soil nutrient balance, improve soil fertility and improve fertilizer agronomic utilization, and can increase crop yield and economic benefits [1-2]. Some researchers believe that uneven fertilization will lead to soil acidification, large amounts of nutrients and accumulation, which in turn affect crop yield and quality [3]. Therefore, the study of different fertilization methods according to local conditions can not only provide a theoretical basis for improving local soil fertility and fertilization systems, but also serve local agricultural practices. Scholars believe that soil enzyme activity can be used as an indicator of soil fertility evaluation [4-5]. Soil enzyme is a kind of biocatalyst for specific biochemical reactions in soil. It is an important driving force for soil ecosystem metabolism [6]. Soil enzyme activity is easily affected by rotation, cultivation systems, and
agricultural management measures, so it can be used as a change in soil quality caused by agricultural practices and to indicate the health of soil ecosystems [7].

At present, the red jujube production area in northern Shaanxi has begun to promote the standardized cultivation techniques of jujube dwarf and dense planting. This puts forward higher requirements for fertilization management and nutrient regulation under standardized planting techniques. Fertilization should not only increase the yield of jujube, but also protect and improve the ecological environment, prevent soil quality degradation, and contribute to the sustainable soil fertility of jujube forest. Therefore, it is necessary to study the effects of fertilization on soil enzymes and soil fertility, and explore the mechanism of soil enzymes and soil fertility in red jujube forests, and provide theoretical basis for the development of red jujube yield and the improvement of soil fertility and fertilization system in the loess plateau.

2. Materials and methods

2.1. Overview of the test site
The test is located in the mountain red jujube test base of Mengzi Village, Yinzhou Town, Mizhi County, Yulin City, Shaanxi Province. It is a typical loess hilly and gully area. It is a temperate semi-arid climate with drought and little rain, with an average annual rainfall of 451.6 mm. The form of heavy rain appears and the intensity is high. Under such few precipitation conditions, a considerable part of precipitation occurs every year to form runoff loss. The average annual temperature is 8.4 °C. The sunshine hours are 2716 h. The test area is dominated by Lossiah soil. The soil organic matter content of 0-30 cm soil layer is 2.1 g/kg, total nitrogen is 34.73 mg/kg, effective phosphorus is 2.90 mg/kg, effective potassium is 101.9 mg/kg, and the pH value is 8.6.

2.2. Test design
The experiment was treated the same for three consecutive years from April 2011 to 2013. In the straw mulching treatment of this experiment, the straw cover size is rounded by the trunk, 0.5 m is the radius of the circular area, the thickness is about 10 cm, and the coverage is reviewed monthly. If it is less than 10 cm, the straw is covered. The three-factor optimal D-saturation design uses three nutrient elements (Table 1). The test jujube variety is a 10-year-old mountain dwarf densely planted pear jujube (Zizyphus jujuba Mill. cv. Lizao), and the tree with the same growth is selected. The planting density is 3 m×2 m, 110 trees per mu. Each of the test plots was subjected to 10 fertilization treatments, and each treatment was repeated 3 times, and a protection tree was selected on both sides of each test tree.

Fertilizer application was urea (including N 46%), superphosphate (P$_2$O$_5$ 12%) and potassium sulfate (K$_2$O 50%). The fertilization method is acupoint application. The pits with a depth of 20-30 cm and a diameter of 40 cm are drilled around 0.5 m on both sides of the canopy. The fertilizer and soil are mixed and filled with soil. In April 25th, the base fertilizer (50% of the total nitrogen fertilizer application) was applied, and the topdressing (50% nitrogen fertilizer) was carried out on July 25. The test soil was sampled at the end of September.

Table 1. Fertilization experiment design of jujube (Quadratic saturate D-supertative design)

| Treatment | Encode | Urea(g/tree) | Encode | Superphosphate(g/tree) | Encode | Potassium Sulfate(g/tree) |
|-----------|--------|--------------|--------|------------------------|--------|--------------------------|
| CK        | -1     | 0            | -1     | 0                      | -1     | 0                        |
| N$_1$     | 1      | 1176         | -1     | 0                      | -1     | 0                        |
| P$_3$     | -1     | 0            | 1      | 2273                   | -1     | 0                        |
| K$_3$     | -1     | 0            | -1     | 0                      | 1      | 500                      |
| P$_3$K$_2$| -1     | 0            | 0.1925 | 1354                   | 0.1925 | 291                      |
| N$_3$K$_2$| 0.1925 | 706          | -1     | 0                      | 0.1925 | 291                      |
| N$_3$P$_2$| 0.1925 | 706          | 0.1925 | 1354                   | -1     | 0                        |
| N$_3$P$_3$K$_3$| -0.2912 | 475 | 1 | 2273 | 1 | 489 |
| N$_3$P$_3$K$_3$| 1 | 1176 | -0.2912 | 919 | 1 | 489 |
| N$_3$P$_3$K$_1$| 1 | 1176 | 1 | 2273 | -0.2912 | 245 |
2.3. Measurement items and methods

The test samples were taken at the end of September 2013 at the ripening stage of pear jujube, and 0-60 cm soil was taken as the soil sample for testing with 1 m soil drill, one layer for every 20 cm, and each treatment was carried out with a 5-point sampling method. When the sample is 40-50 cm away from the fertilization area, remove the debris such as gravel and plant residues, mix and sample, and dry the sample after 1 mm and 0.25 mm sieve.

The soil urease activity was determined by indophenol colorimetry. The results were expressed as the number of NH$_3$-N (mg) in 1 g soil after 24 h. The soil phosphatase activity was determined by phenyl phosphonate colorimetric method. The results were obtained after 24 h. The mass (mg) of phenol released from 1 g of soil is expressed; the soil sucrase activity is determined by 3,5-dinitrosalicylic acid colorimetric method, and the mass of glucose in 1 g of soil after 24 h (mg) The soil catalase activity was titrated with potassium permanganate, and the results were expressed as the number of ml of potassium permanganate consumed in 1 g of soil [8].

The organic matter is treated with potassium dichromate-sulfuric acid; the whole nitrogen is treated with a semi-micro Kelvin. The nitrate nitrogen and ammonium nitrogen in the extract are determined by AA3. The quick-acting phosphorus was extracted with 0.5 mol/L NaHCO$_3$-molybdenum rhenium colorimetric method. The quick-acting potassium was extracted with ammonium acetate-flame photometry. The pH value was determined by the acidity meter.

3. Results and analysis

3.1. Effects on soil nutrient content in jujube orchard under straw mulching conditions

3.1.1. Effect on soil organic matter content in jujube orchard under straw mulching conditions. As shown in figure 1, in the vertical section of the soil, the soil organic matter content decreased with the increase of soil depth. In the 0–20 cm soil layer, the organic matter content of N$_3$P$_1$K$_3$ and single application high K$_3$ increased the most, reaching 3.48 g/kg, with an increase of 104.19%. In the 20–40 cm soil layer, N$_3$P$_1$K$_3$ fertilization treatment increased the organic matter by 100.45%. At 40–60 cm, the soil organic matter content of N$_3$P$_1$K$_3$ treatment increased the most, which was 1.49 g/kg, with an increase of 57.53%. It is worth noting that the effect of adding organic matter to other fertilization treatments in this soil layer was not significant. The results showed that the soil fertility treatment in the soil cover of 0–40 cm could significantly increase the soil organic matter content and weaken with the deepening of the soil depth. Therefore, it can be considered that the depth of fertilization should be appropriately deepened by 10 cm under the condition of straw covering of jujube.

3.1.2. Changes in total nitrogen content in jujube orchard soil. In the vertical section of the soil, as shown in figure 2, the distribution of soil total nitrogen content in the three layers is 0–20 cm>20–40 cm>40–60 cm. In the 0–20 cm soil layer, the N$_3$P$_1$K$_3$ fertilization treatment increased the total nitrogen content most significantly, which was 0.23 g/kg, an increase of 88.46%. At 20–40 cm, N$_3$P$_1$K$_3$ treatment increased the total nitrogen content most significantly, which was 0.13 g/kg, an increase of 59.09%. At 40–60 cm, the effect of single application of high-volume P$_1$ fertilization treatment was obvious, which was 0.08 g/kg, an increase of 42.11%. Different fertilization treatments increased the total nitrogen content in the three layers of soil, and the effect of deepening the depth of the soil layer weakened.
3.1.3. Effect on soil available phosphorus content in jujube orchard under straw mulching conditions.

The available phosphorus content is distributed on the vertical section of the soil, as shown in Figure 3, and there is no uniform accumulation law. For the treatment without P fertilizer (CK, N₃, K₃), available phosphorus in various soil layers is 0~20 cm>20~40 cm>40~60 cm. It was probably because of the continuous application of phosphate fertilizer for 4 years. Accumulation, the effect of phosphate fertilizer is relatively slow, the fertilizer utilization rate of crops in the current season is low, and continuous fertilization can significantly increase the content of available phosphorus through accumulation. The available phosphorus content of N₃P₃K₁ treatment was higher than other treatments at 20~40 and 40~60 cm. That is, the available phosphorus content was 4.4 and 3.6 g/kg, which were 3.1 and 2.6 times of CK, and reached significant difference (P<0.05).

3.1.4. Effect of the available potassium content in jujube orchard under straw mulching.

As shown in Figure 4, the soil available potassium content is distributed in the vertical section, and there is no uniform law for each fertilization treatment. In the non-fertilization treatment (CK), 0~20 cm>20~40 cm>40~60 cm, and the upper layer available potassium content accounted for 56.68% of the total 0~60 cm. In the N₃P₁K₃ treatment, the soil available potassium content was 40.62%, 32.73%, and 26.64% in the upper, middle and lower layers. The results showed that the available potassium was mainly concentrated in the 0~20 cm soil layer without fertilization, and the application of fertilizer at the point could significantly increase the available potassium content in the middle and lower layers.

3.2. Effects on soil enzyme activities in jujube orchards under straw mulching conditions

It can be seen from Table 2 that continuous fertilization under straw mulching conditions significantly affects soil enzyme activity. Different fertilization treatments significantly increased soil urease activity. The effect of nitrogen and phosphorus combined application was higher than other treatments, and the
best treatment with N\textsubscript{3}P\textsubscript{3}K\textsubscript{1} was 299.27 μg/g, which was 88.2% higher than CK. And reached a significant difference with CK (P<0.05). Different fertilization increased the phosphatase activity in the soil. The effect of single application of P fertilizer was the most significant, which was 54.17 μg/g. It was 98.1% higher than CK. Secondly, the effect of the combination of NPK was better than single application. And the effect of the combination on the phosphatase activity was affected not obvious. The best effect of N\textsubscript{3}P\textsubscript{3}K\textsubscript{1} on catalase activity was 3.56 μg/g. It was 29.5% higher than CK, but the difference was not significant, indicating that fertilization applied to soil peroxidation. The effect of hydrogenase activity was not significant. Different fertilization treatments significantly increased soil sucrase activity, and NPK treatment was better than phosphate fertilizer and potassium fertilizer. Different fertilization treatments significantly increased soil sucrase activity. The combined treatment is better than the single application of phosphate fertilizer and potassium fertilizer. The effect of single application of nitrogen fertilizer was the most significant, which was 121.25 μg/g. Then the N\textsubscript{3}P\textsubscript{3}K\textsubscript{1} treatment was 100.28 μg/g. Then were respectively higher 82.5% and 50.9% than CK. Comprehensive analysis, different fertilization treatments affected the activity of different enzymes in the soil, and the effect of N\textsubscript{3}P\textsubscript{3}K\textsubscript{1} treatment was the most significant.

| Treatment | Urease activity | Phosphatase activity | Catalase activity | Sucrase activity |
|-----------|----------------|----------------------|------------------|-----------------|
| CK        | 159.01         | 27.34                | 2.75             | 66.44           |
| N\textsubscript{3} | 234.08         | 40.61                | 2.53             | 121.25          |
| P\textsubscript{3} | 185.11         | 54.17 a              | 2.67             | 80.16           |
| K\textsubscript{3} | 210.27         | 40.78                | 2.82             | 80.25           |
| P\textsubscript{3}K\textsubscript{2} | 220.74         | 29.75                | 2.87             | 97.12           |
| N\textsubscript{2}K\textsubscript{2} | 249.53         | 31.39                | 2.97             | 86.40           |
| N\textsubscript{2}P\textsubscript{2} | 265.54         | 37.96                | 2.95             | 89.41           |
| N\textsubscript{1}P\textsubscript{3}K\textsubscript{3} | 196.57         | 42.38                | 2.41             | 93.32           |
| N\textsubscript{3}P\textsubscript{3}K\textsubscript{1} | 260.99         | 41.48                | 2.83             | 92.33           |
| N\textsubscript{3}P\textsubscript{3}K\textsubscript{1} | 299.27         | 45.29                | 3.56             | 100.28          |

4. Conclusion
Straw mulching is a common water management model in jujube gardens. Generally, wheat or corn stalks are covered in the tree trays and plants of jujube trees. Straw mulching can effectively change the evaporation condition of soil surface and keep the soil temperature relatively constant, which is conducive to the growth of jujube roots, reducing the ineffective consumption of dry matter in the coverage area, significantly improving the soil moisture and nutrient status of orchard soil, and providing a guarantee for high fruit yield. In this study, the effects of nitrogen, phosphorus and potassium on soil fertility and soil enzyme activity under straw mulching were studied, and the following conclusions were drawn:

i. Different fertilization treatments under straw mulching significantly improved the soil fertility, and the treatment effect with N\textsubscript{3}P\textsubscript{3}K\textsubscript{1} was the most significant; the content of organic matter in soil increased significantly, and the content of N, P and K was significantly improved.

ii. Different fertilization treatments under straw mulching increased the activity of soil enzymes.

Comprehensive analysis showed that different fertilization treatments affected soil fertility and soil enzyme activity, and the effect of N\textsubscript{3}P\textsubscript{3}K\textsubscript{1} treatment was the most significant.

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