Effects of Soybean Intercropping on Soil N, P and K Elements in High-quality Peach Orchards

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Abstract [**Objectives**] This study was conducted to investigate the impact of soybean intercropping on soil fertility in the planting areas of high-quality peach orchards in Shenxi Town, Zunyi City, Guizhou Province. [**Methods**] Soil samples were collected during the seedling, growth, and maturity stages of soybeans from both non-intercropped soil (control check group, CK) and soybean-intercropped soil (Qiandou 11, experimental group, EK). Analysis was conducted on soil fertility properties, including alkali-hydrolyzable N, available P, and available K. [**Results**] The impact of soybean intercropping on soil physicochemical properties was primarily manifested as the increased levels of alkali-hydrolyzable N and available K and the decreased level of available P in the soil during the seedling, growing, and maturity stages. Overall, this approach optimized and enhanced soil fertility in the peach orchards, providing a viable pathway for soil improvement in peach orchards located in karst areas. [**Conclusions**] The findings of this study provide a scientific basis for the high-quality development of high-quality peach orchards.

Key words Soybean intercropping; High-quality peach orchard; Soil fertility

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Peach trees, belonging to *Amygdalus* of *Prunus* in the Rosaceae family. The fruit is rich in potassium, which helps lower blood pressure, and vitamin C, which has anti-aging effects[1]. It also has significant benefits for replenishing qi and blood[2]. Shenxi Town in Honghuagang District, Zunyi City, Guizhou Province, features a karst landscape and a subtropical monsoon climate, making it highly suitable for growing fruits such as peaches and plums. Additionally, Shenxi high-quality peaches are one of Zunyi's distinctive agricultural products. Soybeans originated in China[3] and have a cultivation history of over 5 000 years[4]. They are rich in unsaturated fatty acids, minerals, various vitamins, and dietary fiber. Intercropping, as a common agricultural practice, achieves long-term productivity improvement through the complementary effects between crops. Meanwhile, intercropping can enhance resource use efficiency based on the existing cultivated land area[5-7].

In this study, the dynamic changes of key nutrients such as alkali-hydrolyzable N, available P and available K in the soil of peach orchards were analyzed under a soybean intercropping system, and how the intercropping model improved soil fertility in the peach orchards was systematically examined, aiming to provide a scientific basis for local soil improvement.

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Materials and Methods

Soil sample collection

The soil sampling site was located in Gaofang Village, Shenxi Town, Honghuagang District, Zunyi City, Guizhou Province. Soil samples were collected during the soybean seedling stage (April 29), growth stage (June 8), and maturity stage (July 20). Samples were taken from both peach orchards intercropped with soybeans and peach orchards without soybean intercropping during the same periods.

Experimental design

Two treatments was designed in this experiment: soil from the peach orchard without soybean intercropping (control check group, CK) and soil from the peach orchard intercropped with Qiandou 11 soybeans (experimental group, EK), with three replicates each. Relevant indicators, including soil alkal-hydrolyzable nitrogen, available P, and available K, were measured for both treatments during the seedling, growth, and maturity stages.

Results and Analysis

Soil alkali-hydrolyzable N

As shown in Table 1, in the CK treatment, the soil alkali-hydrolyzable N content fluctuated between 42.7 and 67.16 mg/kg. The highest content was observed during the growth stage, which was at level IV (slightly deficient), while the lowest content was found at the seedling stage, at level V (deficient). The difference between the seedling and growth stages was significant, as was the difference between the maturity and growth stages. However, the difference between the seedling and maturity stages was not significant. In the EK treatment, the soil alkali-hydrolyzable N content varied within the range of 73.44 to 123.59 mg/kg. The highest content was observed during the growth stage, reaching level II (abundant), while the lowest content occurred at the maturity stage, classified as level IV (slightly deficient). Significant differences were observed among the seedling, growth, and maturity stages in different treatments. Furthermore, compared with the peach orchard without soybean intercropping, the alkali-hydrolyzable N content in the intercropped peach orchard increased by 43.13%, 45.65%, and 28.71% during the seedling, growth, and maturity stages, respectively.

Nitrogen is involved throughout the entire growth cycle of crops, and alkali-hydrolyzable N can effectively reflect the nitrogen supply for plant uptake in soil during short-term experiments. In the CK treatment, the alkali-hydrolyzable N content remained at a slightly deficient level, requiring appropriate supplementation of nitrogen fertilizer. Both excessively high and low nitrogen levels are detrimental to crop growth and can even lead to reduced yield. In the EK treatment, the alkali-hydrolyzable N content was at a moderate level. However, during the maturity stage, the increase in soil alkali-hydrolyzable N slowed down. It might be due to the reduced activity of soybean rhizobia and their weakened nitrogen-fixing capacity at this stage. Additionally, peach trees also consume a certain amount of nitrogen for physiological activities such as fruit expansion. Therefore, it is necessary to carry out timely intertillage, pruning, and ventilation to improve light penetration for soybeans, so as to promote the development of rhizobia and enhance nitrogen fixation.

Table 1 Soil alkali-hydrolyzable N content at different growth stages under various treatments

Growth and development stage	Treatment method	alkali-hydrolyzable N//mg/kg	Standard deviation	Difference
Seedling stage	CK	42.70	13.22	Bc
	EK	75.09	5.21	Ac
Growing stage	CK	67.16	9.36	Ba
	EK	123.59	20.77	Aa
Maturity stage	CK	52.28	20.82	Bb
	EK	73.34	2.75	Ab

Different lowercase letters indicate a significant difference in the CK and EK treatments between different growth stages at the 0.05 level ($P<0.05$), while different uppercase letters indicate a significant difference between the CK and EK treatments at the same growth stage at the 0.05 level ($P<0.05$).

Research indicates that the amount of nitrogen fixed by leguminous green manure plants during the growing season, as well as the soil carbon and nitrogen content in orchards after six months of intercropping with fruit trees, both increase[8]. Therefore, increasing the alkali-hydrolyzable N content in the soil by intercropping soybeans in peach orchards is feasible. This approach allows for more efficient utilization of light, water, and nutrients, while also reducing the occurrence and spread of pests and diseases associated with monoculture to some extent, thereby promoting the healthy growth and yield of both peach trees and soybeans.

Soil available P

As shown in Table 2, in the CK treatment, significant differences in available P content were observed between the seedling stage and the growth stage, as well as between the maturity stage and the growth stage. However, no significant difference was found between the seedling and maturity stages. The available P content ranged from 10.26 to 12.84 mg/kg. The highest mean content was 12.84 mg/kg during the growth stage, while the lowest mean content was 10.26 mg/kg during the maturity stage. Both values fell within level III (medium). In the EK treatment, there were significant differences among the seedling stage, growth stage, and maturity stage. The available P content ranged from 10.06 to 11.31 mg/kg. The highest available P content was observed in the growth stage, with a mean value of 11.30 mg/kg, while the lowest was in the maturity stage, with a mean value of 10.06 mg/kg. Both values were at level Ⅲ (medium). At the same growth stage under different treatments, the CK and EK treatments showed significant differences.

Phosphorus plays a crucial role in key growth stages of plants, primarily involving photosynthetic characteristics and influencing overall crop quality[9]. Soybeans have a higher demand for phosphorus than peach trees, leading to competition for available P nutrients. Consequently, the available P content in the soil decreased after soybean intercropping, necessitating fertilization adjustments and timely supplemental application of available P fertilizers. Additionally, under weakly alkaline soil conditions, appropriately adjusting the pH value can help enhance the availability of phosphorus[10].

Table 2 Soil available P content at different growth stages under different treatments

Growth and development stage	Treatment method	Available P//mg/kg	Standard deviation	Difference
Seedling stage	CK	10.83	0.49	Ab
	EK	10.16	0.25	Bc
Growing stage	CK	12.84	2.07	Aa
	EK	11.31	0.71	Ba
Maturity stage	CK	10.26	0.21	Bc
	EK	10.06	0.35	Ab

Soil available K

As can be seen from Table 3, under the CK treatment, there was no significant difference between the seedling and growing stages, nor between the growing and maturity stages. However, a significant difference was observed between the seedling and maturity stages. The soil available K content ranged from 119.78 to 134.78 mg/kg. The highest available K content was recorded at the seedling stage, while the lowest was at the maturity stage. Both values fell within level III (medium). In the EK treatment, no significant differences were observed among the seedling, growth, and maturity stages. The soil available K content varied within the range of 143.34 to 151.92 mg/kg. The highest available

K content was recorded during the growth stage, classified as level II (abundant), while the lowest content was found at the seedling stage, classified as level III (medium). Significant differences were observed at the growing and maturity stages under different treatments, while at the seedling stage, the differences were not significant. Comprehensive analysis indicated that under the EK treatment, soybean roots secreted substances such as organic acids and sugars, which activated insoluble potassium in the soil and converted it into available K. Meanwhile, the presence of potassium-solubilizing bacteria in the soybean rhizosphere soil decomposed and released fixed potassium, thereby increasing the available K content. Compared with the CK treatment, the soil available K content under the EK treatment increased by 5.97%, 18.04%, and 17.59% during the seedling, growing, and maturity stages, respectively.

Soil available K effectively reflects the supply capacity of potassium fertility in the soil. Its content directly indicates the effectiveness of soil potassium fertilizer and its potential impact on plant growth and quality. In peach orchards without soybean intercropping, the application of potassium fertilizer can be appropriately increased. Additionally, it is essential to integrate other management measures, such as straw returning, irrigation, and pest control, to comprehensively enhance the available K content.

Table 3 Soil available K content at different growth stages under different treatments

Growth and development stage	Treatment method	Available K//mg/kg	Standard deviation	Difference
Seedling stage	CK	134.78	14.21	Aa
	EK	143.34	9.23	Aa
Growing stage	CK	124.52	9.75	Bab
	EK	151.92	11.01	Aa
Maturity stage	CK	119.78	6.94	Bb
	EK	145.34	6.84	Aa

Conclusions and Discussion

The impact of soybean intercropping on soil physicochemical properties was primarily reflected in the increase levels of alkali-hydrolyzable N and available K and the decrease level of available P in the soil during the seedling, growing, and maturity stages. Overall, this approach optimized and enhanced soil fertility in the peach orchards, providing a viable pathway for soil improvement in peach orchards located in karst landform areas. Based on the research findings, practical production can involve timely intertillage and pruning before the soybean maturity stage to maintain rhizobial activity, as well as targeted topdressing with available P fertilizers to balance soil nutrient supply and further enhance the synergistic effects of the intercropping system.

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