Effects of different alternative soil forming materials on soybean growth index and yield

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Abstract. Aiming at the problems of soil poor and the decrease of cultivated land in the alluvial fan area in the northern slope of the Qinling Mountains, the selection of suitable alternative soil-forming materials to improve the soil in the piedmont area could provide a scientific reference for the improvement of soil quality. Therefore, we chose six different alternative soil-forming materials treatments, including vermiculite (M1), perlite (M2), clay shale (M3), gravel (M4), sand (M5), and soft rock (M6), which mixed with soil at a ratio of 0.5 L·m⁻² for field soybean planting experiments, respectively. The results showed that the order of soybean plant height from high to low in 6 different alternative soil-forming materials treatments was M2 > M6 > M3 > M5 > M4 > M1, the chlorophyll value of M2 and M3 was larger than that of the other four treatments, and the range of increase was 20.9%-26.6%, the figures showed M2 treatment was the most suitable for soybean plant growth. For soybean root dry weight, 100-grain weight and yield, the soybean root dry weight, 100-grain weight and yield under M2 and M1 treatment were larger. Comprehensive analysis of crop growth indicators and yield showed that M2 treatment was the most suitable as an alternative soil-forming material for soybean growth and soil improvement in mountainous areas.

1. Introduction

The alluvial fan area in the front of the northern slope of the Qinling Mountains, which due to the sedimentation and accumulation of sandstone in historical times, had caused a high content of sand and gravel in the soil. In addition, the area slope was relatively large, and the rain was abundant, the soil was easily affected by rain erosion, which led the soil nutrient loss, and then seriously affected local agricultural production and people’s living standards [1-3]. With the development of urbanization and industrialization, the amount of local cultivated land had gradually decreased, and the conflict between people and land had intensified [4-6]. Therefore, in view of the problem of the barren land and the gradual decrease of cultivated land in the northern slope of the Qinling Mountains, it was urgent to find
suitable alternative soil-forming materials and carry out organic reconstruction of the soil mass to improve the local soil quality, increased the quantity of cultivated land. The result would provide a solid theoretical foundation for promoting the selection of alternative soil-forming materials and the improvement of soil quality in the northern slope of the Qinling Mountains.

2. Materials and methods

2.1. Site description and experimental design
The research site is located at the Qinling Field Monitoring Center Station, in Meixian County, Shaanxi Province, China (34°09′N, 107°52′E), which has a warm temperate continental sub-humid climate, the annual mean temperature is 12.9°C, annual average sunshine hours are 2015.2 h, and annual average precipitation is 609.5 mm. There was more gravel in the soil, soil nutrients were susceptible to rainfall and lead to poor soil fertility, and the soil type was clay.

The improvement experiment began in June-September 2017 at the Qinling Field Monitoring Center Station in Meixian County for soybean planting. A total of six different alternative soil-forming materials treatments were set up for the experiment, including vermiculite (M1), perlite (M2), clay shale (M3), gravel (M4), sand (M5), and soft rock (M6). Each soil-forming material processing area was a partition, which was 3 meters long and 2 meters wide, with a total area of 36 square meters. After smashing the 6 soil-forming materials through a 10 mm sieve, they were mixed with soil to enhance the improvement. The addition amount of M1 to M6 for each treatment was 0.5 L·m⁻². Other field management methods, such as fertilization and irrigation, were consistent across the six treatment conditions.

2.2. Measurement methods
Soybean chlorophyll value was measured with a handheld chlorophyll meter, plant height was measured with a ruler, and soybeans were air-dried after harvesting. Root dry weight and 100-grain weight of soybeans were measured by air-drying method. In this test, relevant indicators were measured from June to September. Each measurement was repeated 3 times. Data analysis and figure generation were performed using Microsoft Excel 2010.

3. Results and analysis

3.1. Effects of different alternative soil-forming materials on plant height changes of soybean
The effects of six different alternative soil-forming materials on plant height in different growth cycles of soybean were shown in Figure 1. With the extension of the soybean growth cycle, the effects of different soil-forming materials on soybean plant height were obvious. Among them, the soybean plant height increased rapidly in the early stage under M4 and M6 treatment, and in the late stage, the soybean plant height was higher under M2 and M4 treatment, reaching 105.6 cm and 102.7 cm, respectively. The order of soybean plant height from high to low under the six treatments was M2 > M6 > M3 > M5 > M4 > M1, the difference between the plant height of soybean under M2 treatment and that of M1 treatment was the largest, reaching 7.7 cm. Due to the different types of minerals contained in the six different alternative soil-forming materials, the characteristics of water and fertilizer retention were also different, and the effects on soil improvement were different. As a result, the crop root system had a greater impact on soil water and fertilizer absorption and root microbial colonies, which showed different effects on soybean growth.
3.2. Effects of different alternative soil-forming materials on chlorophyll changes of soybean
Chlorophyll is a good indicator of plant nutritional stress, photosynthetic capacity and growth status, which directly affects crop metabolic activity and yield formation [7]. Under the same irrigation and fertilization conditions, different alternative soil-forming materials had different water and fertilizer retention performances, which in turn affect the change of chlorophyll value of soybean crops. Table 1 showed the change characteristics of chlorophyll value of soybeans under the improvement of different alternative soil-forming materials. It could be seen that the chlorophyll value gradually increased with the growth of soybeans in the early stage and decreased in the later stage (Table 1). The vegetative growth was transformed into reproductive growth, the nutrient elements were transferred to the soybean fruit, and the leaves gradually turned yellow. In the middle and late stages of soybean growth, the order of chlorophyll values in the six treatments was M3 > M2 > M4 > M5 > M1 > M6. The chlorophyll values under the M2 and M3 treatments were larger, which were 36.4 and 38.1, respectively, and the increase range was 20.9% -26.6% compared with the other four treatments. M2 and M3 treatments had the best effect on plant growth improvement.

Table 1. Effects of different soil forming materials on soybean chlorophyll (CCI)

| Treatments | Date | M1 | M2 | M3 | M4 | M5 | M6 |
|------------|------|----|----|----|----|----|----|
|            | 6/27 | 20 | 26 | 27.4 | 18 | 24.6 | 17.4 |
|            | 7/4  | 28.9 | 22.6 | 25.5 | 26 | 24.5 | 25.1 |
|            | 7/12 | 30.6 | 29.5 | 31.3 | 29.3 | 28.9 | 29.3 |
|            | 7/18 | 30.2 | 28.7 | 30.6 | 19.5 | 31.4 | 26.3 |
|            | 7/26 | 27.7 | 27.1 | 30.5 | 24.2 | 24.6 | 22.6 |
|            | 8/3  | 32.6 | 22.9 | 31.8 | 35.2 | 34.9 | 31.8 |
|            | 8/8  | 37.3 | 39 | 31.8 | 34.6 | 34.6 | 33.8 |
|            | 8/15 | 32.6 | 36.4 | 38.1 | 35.5 | 34.4 | 30.1 |

3.3. Effects of different alternative soil-forming materials on soybean root dry weight and yield
Six different alternative soil-forming materials had significant effects on soybean root dry weight and yield (P <0.05). Among the six treatments, the order of the root dry weight was M2 > M1 > M3 > M4 > M6 > M5. The root dry weight under the M2 treatment was the largest, which was significantly higher than that of the other five treatments, and increased by 169.2% compared with the dry weight under M5.
The order of 100-grain weight of soybean was M1 > M2 > M3 > M5 > M6 > M4. The 100-grain weight of soybean under M2 and M1 treatment was significantly higher than that of the other four treatments, and the quality of soybean was higher. The order of soybean yield in each plot was M2 > M1 > M3 > M6 > M5 > M4. The yield of plot soybean under the M2 treatment was the highest, which increased by 202.3% compared with that of the lowest yield of M4 treatment. Six different alternative soil-forming materials affected soil water and fertilizer characteristics, and ultimately lead to different soybean yields. Among them, M2 treatment had the best effect on soybean root dry weight and yield improvement. However, it was necessary to balance physiological growth and reproductive growth, and not only focused on leaf growth, but crop yield was not high.

Table 2. Effects of different soil forming materials on soybean root dry weight and crop yield

| Treatments (0.5 L/m²) Number | root dry weight (g) | Average value (g) | 100-grain weight (g) | Average value (g) | Actual Yield (kg·6m²) |
|-----------------------------|---------------------|-------------------|---------------------|-------------------|----------------------|
| M1                          | 1 40.53             | 29.96b            | 29.52               | 27.30a            | 1.93b                |
|                             | 2 31.04             | 27.38             | 24.43               | 27.86             |                      |
|                             | 3 15.19             | 24.43             | 27.86               |                  |                      |
|                             | 4 33.06             |                   |                     |                   |                      |
| M2                          | 1 46.24             | 32.82a            | 21.11               | 26.09a            | 2.60a                |
|                             | 2 19.58             | 24.21             | 31.21               |                  |                      |
|                             | 3 36.57             | 27.84             |                     |                  |                      |
|                             | 4 28.87             |                   |                     |                  |                      |
| M3                          | 1 26.1              | 26.52b            | 19.79               | 22.32c            | 1.73b                |
|                             | 2 34.75             | 26.22             | 22.61               |                  |                      |
|                             | 3 23.99             | 22.61             |                     |                  |                      |
|                             | 4 21.25             | 20.65             |                     |                  |                      |
| M4                          | 1 5.16              | 18.41c            | 20.15               | 22.22c            | 0.86c                |
|                             | 2 12.14             | 24.11             | 26.37               |                  |                      |
|                             | 3 45.1              | 24.11             |                     |                  |                      |
|                             | 4 11.24             | 18.25             |                     |                  |                      |
| M5                          | 1 8.41              | 12.19d            | 24.01               | 24.63b            | 1.07c                |
|                             | 2 19.04             | 21.09             | 28.67               |                  |                      |
|                             | 3 8.3               | 24.76             |                     |                  |                      |
|                             | 4 13                |                   |                     |                  |                      |
| M6                          | 1 8.5               | 12.69d            | 19.44               | 22.76c            | 1.76b                |
|                             | 2 22.69             | 26.74             | 20.11               |                  |                      |
|                             | 3 6.57              | 26.74             | 24.18               |                  |                      |
|                             | 4 7.01              |                   |                     |                  |                      |

Note: different lowercase letters in the same column indicate that the difference is significant under different treatments (P <0.05).

4. Conclusion

Different alternative soil-forming materials had important effects on plant height, chlorophyll, root dry weight and crop yield of soybean. The plant height of soybean under M2 and M4 treatment was relatively higher than other four treatments, reaching 105.6 cm and 102.7 cm in the later stage, respectively. The order of chlorophyll values was M3 > M2 > M4 > M5 > M1 > M6 in the six treatments, M2 and M3 treatments increased the range of chlorophyll values was 20.9% -26.6% compared with the other four treatments. As for the dry weight and yield of soybean, the M1 and M2 treatments were higher, the soybean yield of each plot was the highest under M2 treatment, and the soybean yield of M2 treatment was increased by 202.3% compared with the lowest yield of M4 treatment. The result showed that there was a certain relationship between soybean yield and crop growth indicators, but not the better
the crop grows, the higher the crop yield. M2 treatment was the most suitable alternative soil-forming material in the process of soybean growth.

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