Effects of different fertilization treatments on soil compaction and crop growth

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Abstract. In order to explore the effects of different fertilization treatments on soil properties and crop growth during the maturation of raw soil, a pot planting experiment with different fertilization treatments was carried out. Three fertilization treatments were set up in the experiment: single organic fertilizer treatment (OF), pollution-free fertilization treatment (NP), and conventional fertilization treatment (CF). The compactness of different soil layers, maize plant height, Chlorophyll value and above-ground biomass under the three fertilization treatments were measured. The experiment results showed that: compared with CF treatment, OF and NP fertilization treatment can better improve soil compaction and increase the plant height and leaf green value of maize, the chlorophyll value of maize under OF and NP treatments increased by 22.6% and 10.6%, and the plant height of maize increased by 58.0% and 31.8% respectively. The order of the magnitude of change of soil compaction in different soil layers was CF> NP> OF. Under conventional CF treatment, the maximum compactness value of 20 cm soil layer was 1426 kPa. For the aboveground biomass of maize, the aboveground biomass of maize under OF and NP fertilization treatments were significantly higher than that of CF fertilization treatment (P<0.05). In summary, OF and NP fertilization treatments can help improve the compaction of raw soil and the growth characteristics of crops, and increase the productivity of raw soil.

1. Introduction
Fertilization is one of the key agricultural management measures that affect soil properties and crop growth. Reasonable fertilization treatment plays an important role in improving soil quality, increasing land productivity and sustainable development of soil health [1-2]. In recent years of agricultural production activities, there are still problems of excessive and unreasonable application of chemical fertilizers. The consumption of chemical fertilizers is getting higher and higher, which has led to aggravation of soil, air and groundwater pollution problems, which seriously affects the healthy...
development of agriculture in the future. The reduced use of chemical fertilizers and the application of alternative fertilizers have attracted more and more attention from scholars [3-5]. The raw soil has low organic matter content, poor structural stability, and underground productivity. It is urgent to improve the fertility of raw soil. Therefore, the purpose of this study is to compare the effects of different fertilization treatments on the properties of raw soil and crop growth, in order to provide a theoretical basis for improving the quality of raw soil and promoting the growth and development of crops on raw soil.

2. Materials and methods

2.1. Site description and experimental design

The research soil samples were collected from the Fuping experimental base of Shaanxi Provincial Land Engineering Construction Group (34°42′~35°06′N, 108°57′~109°26′E). The study area belongs to the gully of the Weibei Loess Plateau. The climate type is continental temperate semi-arid and semi-humid climate zone, with an average annual temperature of 13.4 ℃, and a total annual solar radiation of 123.9~127.8 kcal/cm². The dry and wet seasons are distinct, and natural conditions can meet the growth needs of crops. The soil samples were naturally air-dried to remove impurities such as roots and gravel, and then passed through a 5 mm sieve. The samples were then kept in pots for potting experiments in the solar greenhouse.

The type of soil tested was loessial soil, which had not been cultivated for many years with low fertility. Through indoor testing, the texture type of the background soil sample is silt loam (USDA), in which the mass fraction of sand particles (0.05-2 mm) is 17.06%, the mass fraction of clay particles (<0.002 mm) is 7.56%, the pH value is 8.20, and organic matter content is 6.78 g·kg⁻¹. The experiment was set up with 3 treatments and applied organic fertilization treatment (OF), pollution-free fertilization treatment (NP) and conventional fertilization treatment (CF), 3 replicates for each treatment. Among them, the organic fertilization treatment uses only organic fertilization, the conventional fertilization treatment uses only chemical fertilizer, and the pollution-free fertilization treatment uses 70% organic fertilizer and 30% chemical fertilizers, various treatments are applied to the soil in the same amount of nitrogen (240 kg·hm⁻²), all organic fertilizers and phosphorous and potassium fertilizers are applied as a base, nitrogen fertilizer is applied at a base rate of 50%, topdressing at a rate of 50%, and other management measures are consistent with the level. The experiment was conducted from May to August 2018 in the greenhouse of the Fuping experimental base for maize planting.

2.2. Sampling and measurement methods

Soil compaction is measured by SC900 soil compactness meter, and the soil compaction is measured at 0, 2.5, 5, 7.5, 10, 12.5, 15, 17.5, and 20 cm soil layers. The chlorophyll value of the soil is measured by a chlorophyll meter. For the measurement, the plant height was measured by a ruler, and the above-ground biomass was measured by the weighing method. The test was carried out in late June to determine the relevant indicators. After the maize was harvested, the maize plants were air-dried and the above-ground biomass was weighed on an electronic scale, and each measurement was repeated 3 times.

2.3. Statistical analyses

The test data and drawing were processed by Microsoft Excel 2013 software, SPSS22.0 software was used to analyze the significance of the test data, and the least significant range method (LSD method) was used for multiple comparisons, and the significance level was P<0.05.
3. Results and analysis

3.1. Effects of fertilization treatments on soil compactness at different soil layers

Soil compactness is one of the important properties of soil, which plays a key role in the process of material transport in the soil and the growth of animals and plants. It can be concluded from Figure 1 that as the depth of the soil layer increases, the overall soil compaction under different fertilization treatments showed an increasing trend. The order of the transformation amplitude of soil compactness of different soil layers is OF> NP> CF under the three fertilization treatments, the variation range of soil compactness under the CF and NP fertilization treatments was greater than that of the OF fertilization treatment (Figure 1). The variation of soil compactness under CF fertilization was the largest, with the maximum at 20 cm soil layer, which was 1426 kPa. Previous studies on the effect of soil compaction on the growth of crop roots had shown that the turgor pressure of crop root cells is generally about 700~1200kPa \[6\]. If the soil compactness is higher than this value, plants will be subjected to mechanical stress. This showed that OF and NP Fertilization treatment basically does not hinder the growth and development of the root system in the 0-20cm soil layer, while the conventional CF fertilization treatment will hinder the growth and development of the root system to a certain extent in the 0-20cm soil layer.

![Figure 1. Effects of fertilization treatments on soil compactness at different soil layers](image)

3.2. Effects of different tillage managements on soil physicochemical properties at different soil layers

Among the three fertilization treatments, the plant height and chlorophyll value of the maize under the OF and NP fertilization treatments were significantly higher than that of the CF fertilization treatment \((P<0.05)\), and the plant height and chlorophyll value of the maize under the OF fertilization treatment were the largest (Table 1). Among them, for the average maize height, OF and NP fertilization treatments increased by 29.8% and 21.4%, respectively, compared with CF fertilization treatments, indicating that both OF and NP fertilization treatments can effectively promote the growth and development of crop plants, and OF treatment best effect on increasing plant height. For the average value of crop chlorophyll, it showed the same trend as the plant height. OF and NP fertilization treatments had higher chlorophyll values than CF treatments, and OF and NP fertilization treatments increased 58.0% and 31.8% respectively than CF fertilization treatments. It indicates that different fertilization treatments have different effects on the chlorophyll value of plants. The leaf color of plants under the OF and NP fertilization treatments was greener than that under the CF treatment, and the photosynthetic effect of the crop was better under the OF and NP fertilization treatments. The
possible reason is that the conventional CF fertilization treatment affects the soil structure characteristics, which in turn affects the absorption of soil nutrients by the crop roots and the formation of root microbial colonies, which is not conducive to the growth of crop roots, resulting in low chlorophyll values.

Table 1. Maize plant height and chlorophyll value under different fertilization treatments

| Treatments | Number | plant height (cm) | average value (cm) | chlorophyll value (CCI) | average value (CCI) |
|------------|--------|-------------------|--------------------|------------------------|-------------------|
| CF         | 1      | 82                | 88.8b              | 18.4                   | 17.4c             |
|            | 2      | 90                |                    | 16.5                   |                   |
|            | 3      | 88                |                    | 17.5                   |                   |
|            | 4      | 95                |                    | 17.1                   |                   |
| NP         | 1      | 115               | 107.8a             | 22.5                   | 22.9b             |
|            | 2      | 108               |                    | 24.3                   |                   |
|            | 3      | 112               |                    | 21.8                   |                   |
|            | 4      | 96                |                    | 23                     |                   |
| OF         | 1      | 113               | 115.3a             | 27.4                   | 27.5a             |
|            | 2      | 110               |                    | 28.0                   |                   |
|            | 3      | 117               |                    | 26.3                   |                   |
|            | 4      | 121               |                    | 28.1                   |                   |

3.3. Effects of different fertilization treatments on the aboveground biomass of maize
The aboveground biomass of maize under OF and NP fertilization treatments were significantly higher than that of CF fertilization treatment ($P<0.05$), and the aboveground biomass of maize under OF fertilization treatment was the largest (Figure 2). For the aboveground biomass of maize, OF and NP fertilization treatments increased by 17.5% and 11.2%, respectively, compared with CF fertilization treatments. It showed that because organic fertilizer is rich in beneficial organic substances and a variety of nutrient elements, it can promote the development and growth of maize root system after adding. Therefore, OF and NP fertilization treatments can effectively promote the growth and development of maize plants, and OF fertilization treatment had the most obvious effect on increasing aboveground biomass of maize. In summary, organic fertilizer fertilization treatment and pollution-free fertilization treatment help to improve the compaction of the soil, promote the growth and development of maize, and increase the biomass of maize on the ground.

Figure 2. Effects of fertilization treatments on maize aboveground biomass
4. Conclusion
Based on the planting experiment research of different fertilization treatments on soil compaction and corn growth characteristics, it is concluded that fertilization treatments have certain effects on soil compaction, corn plant height, chlorophyll value and above-ground biomass. Compared with conventional fertilization, organic fertilization and pollution-free fertilization can effectively improve soil compaction, increase corn plant height and chlorophyll, and increase corn biomass. Under conventional fertilization methods, different soil layers have larger soil compactness values, and the subsurface layer will hinder the growth and development of crop roots to a certain extent. In summary, organic fertilization and pollution-free fertilization methods can effectively increase the plant height and chlorophyll value of crops while loosening the soil structure, and contribute to the growth and development of crops.

Acknowledgments
This work was supported by the Scientific Research Item of Shaanxi Provincial Land Engineering Construction Group (DJNY2020-25), and Key Laboratory of Degraded and Unused Land Consolidation Engineering, the Ministry of Natural Resources of China.

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