Effect of Different Tillage Managements on Soil Physicochemical Properties and Crop Yield

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Abstract. In order to explore the effects of different tillage managements on soil physical-chemical properties and crop yield in Tangyu town, Meixian County of Shaanxi Province, the soil physical-chemical properties and crop yield were analyzed. The study was conducted at the Qinling Field Monitoring Center Station in early September 2017, which included three tillage managements: no tillage (NT), mouldboard plow tillage (MT) and soil subsoiling tillage (ST), the soil organic matter, total nitrogen, ammonium nitrogen, available potassium, soil temperature and maize grain number per ear and yield in the project area were measured. The results showed that the NT and ST managements could better buffer and maintain the change of soil temperature, reduced soil pH value compared with MT management. NT and ST managements were helpful to increase the content of total nitrogen, organic matter, ammonium nitrogen and available potassium, soil organic matter (SOM) content under NT and ST managements was 49.6% and 31.7% more than that under MT management in the 0–10 cm soil layer, The order of total nitrogen content was ST>NT>MT, and available potassium content was NT> ST>MT in the 0–30 cm soil layer, there was no obvious difference between NT and ST managements in improving soil nutrients. Meanwhile, NT and ST managements increased maize grain number per ear and yield. Thus, it was recommended to use NT and ST managements to improve soil quality and increase crop yield, and was suitable for sustainable agricultural development.

1. Introduction

Soil is a porous medium composed of solid components and pores of different sizes and shapes, representing a complex biological material, which is the most important component of sustainable agricultural ecosystems because it provides the necessary elements for plant development, and it makes important contributions to the change in water and air. Thus, agricultural sustainability is greatly influenced by the tillage, management, and quality of soil [1-3]. Soil quality is the important factor of
sustainable agriculture, which affects the quality of the ecosystem just like air and water quality do. The purpose of soil tillage management is to improve soil physical-chemical properties through mechanical, biological and natural forces, coordinate water, fertilizer, gas and heat conditions, and create a soil ecological environment suitable for crop growth and development [4-6]. Lupwayi believes that the stratification of soil nutrients will affect the absorption of crops to some extent. Implementing soil tillage managements such as subsoiling tillage and no-tillage at an appropriate time is an effective measure to improve soil quality and production performance. It can be seen that the effects of tillage managements on soil nutrient distribution are also important, and also affect the absorption of nutrients by crops [7-9]. Thus, the objective of the study was to compare the effects of different tillage managements on the soil physical-chemical properties and crop yield. The result would provide a theoretical basis and technical support to improve the soil quality and increase crop yield.

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). Meixian County is located in the west of Guanzhong Plain, Shaanxi Province, south of Qinling Mountains and north of Weihe River. It belongs to the chuan Plateau Region in the middle reaches of the Yellow River. It has a warm temperate continental sub-humid climate, the annual mean temperature is 12.9°C, annual average sunshine hours are 2015.2 h, frost-free period is about 218 days, and annual average precipitation is 609.5 mm.

The planting experiment included three tillage managements: (1) no tillage (NT), there is no tillage management, the corn straw was smashed to cover the surface of the soil after corn harvest. (2) Mouldboard plow tillage (MT), the corn straw was smashed to cover the surface of the soil after corn harvest, mouldboard plowing to a depth of about 20-25 cm deep, and buried all the straw into the soil. (3) soil subsoiling tillage (ST), the corn straw was smashed to cover the surface of the soil after corn harvest, single deep shovelling to a depth of 30-35 cm and a width of 40-60 cm by using subsoiling shovel. The research site for the planting experiment was rectangular, and each tillage management area was 6 m long and 5.5 m wide covering an area of 33 m². Other field management methods such as fertilization and irrigation were consistent across the three tillage conditions.

2.2. Sampling and measurement methods

Soil samples were taken from each plot with a 10-cm diameter soil corer after the summer maize harvest in early September 2017, and divided into four layers of 0-10, 10-20, 20-30 and 30-40 cm. Each plot has three replicates. We minimised soil disturbance during collection and transport to avoid disrupting the soil structure. Before the soil samples were air-dried at the Qinling Wild Monitoring Center, the roots, stones and other debris in the soil were removed. The soil temperature of 5, 10, 15, 20, 25 cm soil layer was measured by WNG-11 type right angle geothermal thermometer, and repeated 3 times. The basic physical and chemical properties such as soil organic matter, total nitrogen, available phosphorus, and mechanical composition were tested according to the standard methods of related books [10-11]. Data analysis and figure generation were performed using Microsoft Excel 2013.

3. Results and analysis

3.1. Effects of different tillage managements on soil temperature at different soil layers

At ten o'clock, with the increase of soil depth, the soil temperature under the NT and ST managements decreased first and then increased, and the MT management showed a trend of decreasing (Figure 1.A). Under the three tillage managements, the variation extent of soil temperature under the NT and ST managements were the same, and they were smaller than the MT management, which could save heat. At 12 o'clock, compared with MT management, the variation extent of soil temperature under NT and ST managements were small, the MT management was higher than the NT and ST managements, and
the soil temperature varied greatly, which showed poor ability to buffer soil temperature (Figure 1.B). The temperature of different soil layers under the three tillage managements tended to decrease first and then increase, this indicated that different tillage managements can have different heat preservation effects on different soil temperature. The soil temperature variation extent under the NT and ST managements was small, the heat preservation effect was good, which could better buffer and maintain the change of soil temperature.

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

Tillage management had a certain impact on soil physicochemical properties (Table 1). The pH value ranged from 8.24 to 8.46 under the three tillage managements, the order of pH value was WT > ST > NT in the 0–10 cm soil layer. The pH value under NT and ST managements were relatively low in the 0–40 cm soil layer, which indicated NT and ST managements were helpful to reduce pH value. The conductivity value showed the same trend, the conductivity value under NT management was low. The content of soil organic matter showed a decreasing trend of NT > ST > MT in the 0–20 cm soil layer, which was decreased under the three tillage managements with the increasing of soil depth. In the 0–10 cm soil layer, SOM content under NT and ST managements was 49.6% and 31.7% more than that under MT management, respectively; the organic matter content in the bottom layer of MT management was higher than that in the surface layer, the reason may was that tillage caused disturbance of soil structure and accelerated the mineralization of organic carbon. The content of total nitrogen and available potassium in 0-30 cm soil layer decreased with the increase of soil depth, and increased at 30-40 cm, the result showed that the effective thickness of the soil layer affected by the tillage treatment may was 0-30 cm. The order of total nitrogen content was ST > NT > MT in the 0–30 cm soil layer, and available potassium content was NT > ST > MT. The content of ammonium nitrogen showed the decreasing trend of NT > ST > MT in the 0–40 cm soil. The nitrate nitrogen content was high in the 10–30 cm soil layer, which was due to both crop uptake and downward leaching with soil moisture. NT and ST managements were helpful to increase the content of total nitrogen, organic matter, ammonium nitrogen and available potassium compared with MT management.

![Figure 1. Effects of tillage managements on soil temperature at different soil layers](image-url)
### Table 1. Soil physicochemical properties at different soil layers

| Treatments | Depth (cm) | pH     | Conductivity (μS cm⁻¹) | Organic Matter (g kg⁻¹) | Total Nitrogen (g kg⁻¹) | Available Phosphorus (mg kg⁻¹) | Available Potassium (mg kg⁻¹) | Ammonium nitrogen (mg kg⁻¹) | Nitrate nitrogen (mg kg⁻¹) |
|------------|-----------|--------|-------------------------|-------------------------|-------------------------|-------------------------------|-----------------------------|-----------------------------|-----------------------------|
| NT         | 0-10      | 8.34   | 124.70                  | 6.94                    | 0.62                    | 24.31                        | 20.44                       | 174.23                      | 347.25                     |
|            | 10-20     | 8.38   | 123.40                  | 4.99                    | 0.53                    | 174.23                        | 151.71                      | 336.97                      | 166.85                     |
|            | 20-30     | 8.32   | 129.50                  | 4.07                    | 0.50                    | 21.06                        | 142.70                      | 338.96                      | 147.87                     |
|            | 30-40     | 8.34   | 145.80                  | 4.90                    | 0.66                    | 25.56                        | 134.59                      | 320.62                      | 92.14                      |
| MT         | 0-10      | 8.42   | 135.10                  | 4.64                    | 0.53                    | 16.92                        | 149.01                      | 321.01                      | 71.78                      |
|            | 10-20     | 8.46   | 158.40                  | 4.78                    | 0.32                    | 17.27                        | 148.11                      | 309.83                      | 96.17                      |
|            | 20-30     | 8.34   | 139.50                  | 7.02                    | 0.43                    | 17.93                        | 146.01                      | 212.19                      | 92.62                      |
|            | 30-40     | 8.36   | 145.50                  | 5.72                    | 0.76                    | 21.61                        | 142.70                      | 249.38                      | 44.07                      |
| ST         | 0-10      | 8.35   | 125.40                  | 6.11                    | 0.82                    | 25.65                        | 159.82                      | 334.22                      | 42.01                      |
|            | 10-20     | 8.24   | 171.50                  | 5.17                    | 0.63                    | 58.58                        | 150.81                      | 312.65                      | 113.22                     |
|            | 20-30     | 8.33   | 148.60                  | 3.95                    | 0.54                    | 37.44                        | 132.79                      | 250.09                      | 94.74                      |
|            | 30-40     | 8.24   | 157.80                  | 5.23                    | 0.52                    | 25.48                        | 126.49                      | 293.19                      | 48.72                      |

#### 3.3. Effects of different tillage managements on maize yield

Different tillage managements had a certain impact on maize yield. The order of yield was ST>NT>MT, and the ST and NT managements were significantly greater than MT management. The order of grain number per ear under ST, NT, WT managements was NT>ST>MT, and the order of 1000-grain weight was ST>NT>MT. Compared with the MT management, the yield of maize under ST and NT managements increased by 11.7% and 9.7%, and the yield was significantly improved. Different tillage managements affected the distribution of soil nutrients and crop yield in this region. Compared with MT management, ST and NT managements had little disturbance to soil structure, which helped to buffer soil temperature, increased soil nutrients in cultivated layer, promoted root growth and increased corn yield. The MT management had large disturbance to the soil, and the soil temperature changes greatly, which lead to the movement of the soil layer, and May raw soil turned to the surface, and the nutrient content in the cultivated layer was low, which reduced the corn yield.

### Table 2. Maize yield under different tillage managements

| Treatments | Number | maize row number | average kernels per row | grain number per ear | 1000-grain weight (g) | average value | Total panicle number | Theoretical yield/( kg hm⁻²) |
|------------|--------|------------------|-------------------------|----------------------|-----------------------|---------------|----------------------|-----------------------------|
| NT         | 1      | 14               | 28                      | 389                  | 315.97                | 315.97        | 239                  | 8890.4                      |
|            | 2      | 16               | 40                      | 640                  | 314.57                | 314.57        | 300.10               |                             |
|            | 3      | 16               | 35                      | 560                  | 313.29                | 313.29        | 301.23               |                             |
|            | 4      | 14               | 37                      | 515                  | 315.68                | 315.68        | 438                  |                             |
|            | 5      | 16               | 31                      | 488                  | 313.99                | 313.99        | 438                  |                             |
| MT         | 1      | 12               | 21                      | 249                  | 300.10                | 300.10        | 300.80               | 8101.1                      |
|            | 2      | 12               | 37                      | 438                  | 301.23                | 301.23        | 438                  |                             |
|            | 3      | 12               | 32                      | 387                  | 302.01                | 302.01        | 363                  |                             |
|            | 4      | 12               | 30                      | 363                  | 299.89                | 299.89        | 465                  |                             |
|            | 5      | 12               | 37                      | 438                  | 300.79                | 300.79        | 465                  |                             |
| ST         | 1      | 14               | 27                      | 382                  | 340.30                | 340.30        | 340.17               | 9045.0                      |
|            | 2      | 12               | 39                      | 465                  | 340.98                | 340.98        | 465                  |                             |
|            | 3      | 12               | 41                      | 486                  | 339.24                | 339.24        | 462                  |                             |
|            | 4      | 12               | 39                      | 462                  | 341.92                | 341.92        | 462                  |                             |
|            | 5      | 14               | 33                      | 466                  | 338.43                | 338.43        | 466                  |                             |
4. Conclusion

Different tillage managements affected the soil physicochemical properties and crop yield in this region. Compared with MT management, the NT and ST managements could better buffer and maintain the change of soil temperature, reduced soil pH value. In the 0–20 cm soil layer, NT and ST managements were helpful to increase the content of soil organic matter, total nitrogen, ammonium nitrogen and available potassium, there was no obvious difference between no-tillage and subsoiling managements in improving soil nutrients. In the 0–10 cm soil layer, SOM content under NT and ST managements was 49.6% and 31.7% more than that under MT management, respectively. The order of maize yield was ST>NT>MT. Compared with the MT management, the yield of maize under ST and NT managements increased by 11.7% and 9.7%. It is predicted that ST and NT managements were recommended to improve physicochemical properties and increase crop yield.

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