Bangladesh J. Bot. **53**(4): 931-936, 2022 (December) Special DOI: https://doi.org/10.3329/bjb.v51i40.63836

EFFECTS OF TILLAGE ON SOIL NUTRIENTS AND YIELD OF WINTER WHEAT IN DRY LOESS TABLELAND

ZHENMING LIU*, HAITAO LIU AND DONGHUI YANG

Shaanxi Provincial Land Engineering Construction Group Co. Ltd., Xi'an, Shaanxi, 710075, China

Keywords: Loess tableland, Tillage method, Total nutrient, Available nutrients, Winter wheat yield

Abstract

An experiment was carried out to find out whether long-term no-tillage poses a threat to soil fertility and crop yield at the Changwu Loess Plateau Agricultural Ecological Experiment Station of Northwest A&F University in Changwu County, Shaanxi Province. Before seeding winter wheat in September 2020, the three tillage methods, namely no-tillage, conventional and rotational tillage were conducted on the experimental field that had undergone three consecutive years of no-tillage. After the winter wheat harvest in 2021, total soil nutrients, available soil nutrients, and wheat yield in the soil layer of 0-30 cm were analyzed under various tillage methods. Results showed a decreasing trend in the contents of total nitrogen and soil organic carbon (SOC) in the soil layer of 0-30 cm under three tillage methods. The SOC content and total nitrogen in the 0-10 cm layer were no tillage > rotation tillage > conventional tillage. The contents of P and K decreased with an increase in the layer of 0-30 cm soil depth under the three tillage methods. The available P and K contents were decreased by 16.07, 32.74, 15.54 and 27.08%, respectively in the soil layer of 10-20, 20-30 cm, compared to those in the layer of 0-10 cm ($P < 0.05$). Using various tillage methods, the content of available P under conventional tillage was significantly reduced by 11.31% in the 0-10 cm layer compared to that under no-tillage. Soil available k content under conventional tillage and rotation tillage decreased significantly by 6.16 and 4.97% compared to no tillage ($P < 0.05$), respectively. In the layer of 20-30 cm soil, available P content was significantly increased under conventional tillage by 18.12% compared to that under no-tillage, and available K contents were significantly increased under conventional tillage by 17.17 and 9.22% compared to that under no-tillage and rotation tillage, respectively ($P < 0.05$). The winter wheat yield was in the order of conventional tillage > rotational tillage > no-tillage, with a significant difference between conventional and no-tillage ($P < 0.05$). Therefore, it is necessary to carry out proper conventional tillage or rotary tillage on the dry loess tableland where no-tillage has been carried out for a longer time.

Introduction

Soil is essential to the life of plants, therefore research on soil tillage and treatment is an essential element of agricultural production technology systems (Oorts *et al*. 2006, Kar *et al*. 2009). The selection of reasonable farming methods positively influences the fixation of soil nutrients along with the yield and growth of crops (Shipitalo *et al*. 2000, Sisti *et al*. 2004). Compared to traditional tillage, no-tillage, subtillage, and other protective tillage techniques have gradually emerged recently (Lampurlanes and Cantero 2003, Topa *et al*. 2021). Lei *et al*. (2008) and Varbel and Wilhelm (2011) revealed that no-tillage, less tillage, and other protective soil tillage measures can reduce wind and water erosions, improve physicochemical properties of soil, and increase crop yield. However, as the conservation tillage implementation period elongates, the drawbacks of conservation tillage emerge gradually. Long-term low or no-tillage, for instance, will result in soil nutrient accumulation on the surface. This, in turn, will not be favorable to the regular nutrient distribution in the deepest soil and will therefore have an effect on crop yield (Gathala *et al.* 2011, Hernanz *et al.* 2002).

*Author for correspondence: <568729840@qq.com>.

The dry loess tableland, which is present in a semi-arid and arid region and is a rain-fed agricultural area, is an important area of grain production in northwest China. With the development of research associated with conservation tillage, no tillage has been carried out in the experimental plots of the study area for 3 years. Long-term no-tillage conditions have been shown in recent years to result in soil nutrient enrichment in the surface layer of farmland, low nutrients in the deep soil layer, and uneven soil nutrients, limiting the increase of crop yield (Motobayashi *et al.* 2001, Li *et al.* 2015). To analyze the long-term no-tillage effect on soil nutrient content, different tillage methods on soil after long-term no-tillage were conducted. To provide a scientific reference for the establishment of a reasonable rotation tillage system, during the present study the dry loess tableland was selected and the impacts of tillage methods on total and available nutrients in the soil layer of 0-30 cm of winter wheat for a longer no-tillage through different methods of tillage were analyzed.

Materials and Methods

This field study is being conducted at the Changwu Loess Plateau Agroecology Experimental Station (107° 40'E, 35° 14'N) of Northwest A&F University in Changwu County, Shaanxi Province. This is a dry area of farming having a semi-humid continental monsoon climate and warm temperature; the crops are mainly wheat and corn with one cropping a year. For the test site, the altitude was 1200 m with 9.1℃ of average annual temperature; sunshine duration is 2226 hrs and 578.5 mm of average annual rainfall. The soil of the test field was black clay soil, with 21 ~ 24% of field water capacity, wilting humidity of 9 ~ 12%, pH of surface soil 8.4, and bulk density of 1.36g/ cm^3.

In September 2020, three tillage methods, namely no-tillage, conventional and rotary tillage, were conducted in the no-tillage experimental field continuously for three years before sowing winter wheat. The test treatment method is shown in Table 1. There was consistency amongst treatments in terms of fertilizer application rates, all of which were in line with the methods used by local farmers. The variety of winter wheat "Changhan 58" was selected with a sowing amount of 150kg/hm^2, which was sown on September 29, 2020, followed by harvesting on June 4, 2021.

Table 1. Experimental treatment under different tillage methods.

Sl. no.	Tillage methods	Specific treatment
T1	No-tillage	After the harvesting of wheat, the straw was removed and the no-tillage planter was used for the completion of sowing, fertilization, and suppression operations in one go.
T2	Conventional tillage	After wheat harvest, straw was removed, chemical fertilizer was applied, mechanical tillage (15-20 cm deep) was applied, and wheat was sown.
T3	Rotary tillage	After wheat harvest, straw was removed, chemical fertilizer was spread, and rotary tillage (tillage depth is 10 cm) was carried out by a rotary cultivator to sow wheat.

After wheat harvest, three points from the experimental field were selected. The 30 cm soil depth, divided into three layers of 10 cm, namely 0-10, 10-20, and 20-30 cm. Part of the soil sample (40-50g) was taken into the aluminum box to measure the moisture content of the soil (Gao *et al.* 2011). Another part equivalent to 350-450g of soil sample was put into a ziplocked bag to analyze the contents of total and available soil nutrients. According to the soil agrochemical analysis (third edition) edited by Bao (Bao 2000), the SOC content of soil samples was investigated by the potassium dichromate oxidation method, and the total nitrogen content of the soil was determined by semi-trace Kjeldahl. The determination of available P and K content in soil was carried out by $NaHCO_3$ (0.5 mol/l) extraction colorimetric method and ammonium acetate extraction as well as flame spectrophotometry, respectively.

At the mature stage, 1 m single row wheat was randomly selected, the grain and the aboveground part were opened to dry and weighed, and the wheat seed was tested. In addition, 3 rows of wheat were harvested randomly and continuously, and the yield was measured by threshing and drying.

Excel 2010 was used for data processing while the one-way analysis of variance was performed via SPSS 22.0. The level of significance in the differences was determined using the LSD method ($P < 0.05$), and the pictures were sketched using Origin 2018.

Results and Discussion

The decreasing trend in the contents of the soil organic carbon (SOC) was observed in the layer of 0-30 cm of the three tillage methods, and the content of SOC in 0-10, 10-20, 20-30 cm soil layer of no-tillage and rotary tillage exhibited a significant difference ($p < 0.05$) (Fig. 1a). Their difference was not significant in the SOC content of conventional tillage between the layers of 0-10 and 10-20 cm, but it was significant in the layer of 20-30 cm ($p < 0.05$). The SOC content in the layer of 0-10 cm of soil showed the order of conventional tillage < rotary tillage < no-tillage under different tillage methods. The no-tillage was considerably greater ($p < 0.05$) in comparison to the conventional tillage, and the observed order in the 10-20 cm layer was rotary tillage < conventional tillage < no-tillage, with no difference. In the layer of 20-30 cm of soil, conventional tillage > rotatry tillage > no-tillage, with significant differences ($p < 0.05$).

Total nitrogen content in 0-30 cm soil layer of the three tillage methods showed a decreasing trend along the soil profile (Fig. 1b). Significantly different content of total nitrogen was observed in the soil layer of 0-10 cm that in 20-30 cm soil layer under rotation and no-tillage ($p < 0.05$). The contents of total nitrogen in the soil showed no tillage > rotary tillage > conventional tillage in 0-10 cm soil layer, no-tillage < conventional tillage < rotary tillage in 10-20 cm soil layer, and no-tillage < conventional tillage < rotary tillage in soil layer of 20-30 cm under different tillage methods with no significant difference ($p < 0.05$).

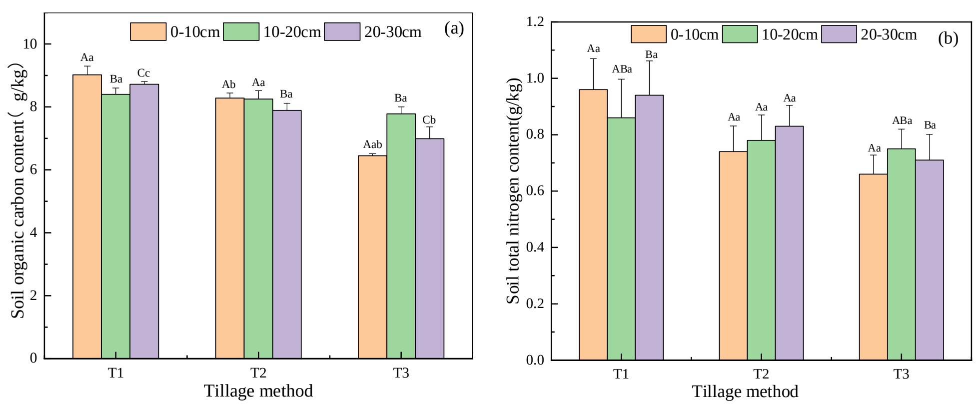

Fig. 1. Distribution of soil total nutrient contents under different tillage methods.

As depicted in Fig. 2a, available P content decreased in the soil layer of 0-30 cm with increasing soil depth under the three tillage methods. Under no-tillage tillage, the available P content in 10-20, 20-30 cm soil layer was decreased by 16.07 and 32.74% compared to the soil layer of 0-10 cm, and the available P content was decreased by 19.86% in 20-30 cm soil layer compared to that in 10-20 soil layer, with significant differences ($p < 0.05$). The available P content in the layers of 10-20, 20-30 cm of soil under conventional tillage was decreased by 2.01 and 7.38% compared to that in the 0-10 cm soil layer, while the available P content in 20-30 cm soil layer was decreased by 5.48% compared to that in 10-20 soil layer, with no significant difference ($p < 0.05$). The content of available P in the soil layer of 10-20, 20-30 cm under rotation tillage decreased by 5.96 and 18.54% compared to the soil layer of 0-10 cm, and available P content in 20-30 cm soil layer decreased by 13.38% compared to 10-20 soil layers. Between the 0-10 and 10-20 cm layers, no significant difference was observed but the differences were significant in others ($p < 0.05$). The available P content of conventional tillage in 0-10 cm layer of soil was decreased significantly by 11.31% under different tillage methods compared to no-tillage, but no significant difference was observed in other layers of soil ($p < 0.05$). In the layer of 10-20 cm of soil, the three tillage methods exhibited no significant difference. In the layer of 20-30 cm, the available P content under conventional tillage was significantly increased by 18.12% compared to no-tillage. While in other, the differences were not significant ($p < 0.05$).

As depicted in Fig. 2b, in the soil layer of 0-30 cm, the content of available K in the soil decreased with increasing depth of soil under the three tillage methods, which was the same as the change of available P. The available k content under no- tillage in 10-20, 20-30 cm soil layer was decreased by 15.54 and 27.08% compared to that in the soil layer of 0-10 cm, and that in 20-30 cm soil layer was decreased by 13.67% compared to that in 10-20 layer, with significant differences ($p < 0.05$). In comparison to the 0-10 cm soil layer, the available contents of k in 10-20, 20-30 cm soil layers were decreased by 2.54 and 6.19% under conventional tillage conditions, and available P content in 20-30 cm soil layer was decreased by 3.75% compared to 10-20 soil layer, without any significant difference ($p < 0.05$). The available K content in 10-20, 20-30 cm layer under rotary tillage was decreased by 7.81% and 15.91%, respectively, compared to that in the soil layer of 0-10 cm, and the available phosphorus content in 20-30 cm soil layer was decreased by 8.79% compared to that in 10-20 cm soil layer, and the significant difference was only found between 0-10 cm and 20-30 cm layer ($p < 0.05$). The content of available K in the soil layer of 0-10 cm under different tillage methods was significantly decreased by 6.16 and 4.97% ($p < 0.05$) in conventional and rotary tillage, respectively, compared to that in no-tillage. In the 10-20 cm layer, there were no significant differences between the three tillage methods. When compared to the no-tillage and rotary tillage, a significant increase of 17.17 and 9.22% was observed in the conventional tillage ($p < 0.05$).

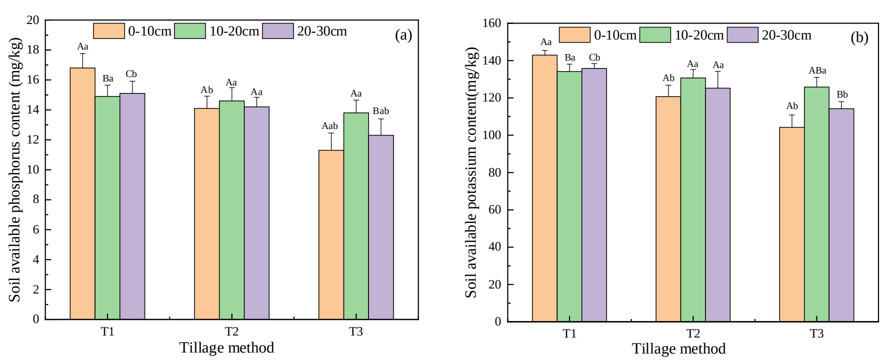

Fig. 2. Distribution of soil available nutrients under different tillage methods.

It is apparent Table 1 that there were no significant differences in grain number per spike, 100-grain weight under the three tillage methods. The order of effective panicles per hectare was rotary tillage > conventional tillage > no-tillage. The highest yield of winter wheat was significantly higher under conventional tillage than that under no-tillage ($p < 0.05$).

Changes in tillage methods primarily involve alterations in tillage depth, which are correlated with soil porosity, plant roots, soil bulk density, and soil nutrient content. In the soil layer of 0-30 cm used in the present study, total soil nutrients and available soil nutrients decreased when the soil depth increased under no-tillage, conventional and rotary tillage. This finding is consistent with the findings of Gao conducted on the Loess Plateau, in which nutrient content decreases as soil layer depth increases (Gao *et al.* 2017). This might be due to the fact that the fertilizer application and leaf litter on the surface increased the content of nutrients on the soil surface, whereas the nutrient in the deep layer was primarily secreted by the root system. No-tillage mainly affected the nutrient content of the soil in surface soil, while tillage mainly affected soil nutrient content in deep soil.

Table 2. Yield of winter wheat under different tillage methods.

Tillage methods	Spike number/hm^{-2}	Spike grain number	Hundred-kernel weight/g	Yield/kg hm^{-2}
Conventional tillage	4930000±108167a	25±2a	5.0403±0.38a	6290±277.6a
Rotary tillage	5246667±109697a	23±3a	5.0163±0.36a	6057±823.2a

The available P and K contents in the soil layer of 0-10 cm under different tillage methods showed the order of conventional tillage < rotary tillage < no-tillage. The contents of available P and available K in this layer showed little difference between rotary and conventional tillage, but the difference was significant between no-tillage and rotary tillage ($P < 0.05$). No-tillage can reduce soil surface disturbance and increase the nutrient content of soil surface upon comparison with rotary and conventional tillage. The available P and K contents in the 10-20 and 20-30 cm layers followed the order of no-tillage < rotary tillage < conventional tillage, and the difference observed between no-tillage and conventional tillage was found to be significant ($P < 0.05$). Conventional tillage has been shown through analysis to be effective at breaking the bottom layer of the plough, allowing for better nutrient absorption by crops in the lower soil, and increasing the presence of available P in the deepest soil while decreasing the available P and K content in the surface soil.

The contents of SOC and total nitrogen decreased with an increasing layer of soil. Under rotary tillage and no-tillage, the contents of total nitrogen and SOC were found to be significantly different in the 0-10 cm soil layer from those in the bottom layer. Under different tillage methods, SOC and total nitrogen contents in 0-10 cm soil layer showed the order of no-tillage > rotary tillage > conventional tillage. No-tillage made the surface nutrients accumulate, and conventional tillage made the nutrient distribution in the lower layer uniform due to the deepening of tillage depth. In the loess Plateau with long-term no-tillage, conventional and rotary tillage could reduce the accumulation of available P and K in the soil on the surface. In the layer of 0-10 cm, available P content under conventional tillage decreased significantly by 11.31% as compared to no-tillage, and available K content under conventional and rotary tillage decreased significantly by 6.16 and 4.97% compared to no-tillage, respectively. In addition, the distribution of available P and available K in deep soil could also be increased. In the soil layer of 20-30 cm, the content of available P and available K under conventional tillage significantly increased by 18.12 and

17.17%, respectively, compared to that under no-tillage. Therefore, proper conventional tillage and rotation tillage should be carried out on the loess Plateau to achieve the balance of nutrients in each soil layer and improve land productivity.

References

Bao SD 2000. Soil and Agricultural ChemistryAnalysis.3rd Ed. Beijing: China Agrice Press.

Gao XD, Wu PT, Zhao XN, Shi YG, Wang JW and Zhang BQ 2011. Soil moisture variability along transects over a well-developed gully in the Loess Plateau, China. Catena. **87**: 357-367.

Gao XD, Meng TT, Zhao XN 2017. Variations of Soil Organic Carbon Following Land Use Change on Deep-Loess Hillsopes in China. Land Degrada. Develop. **28**: 1902-1912.

Gathala MK, Ladha JK, Saharawat YS, Kumar V and Sharma PK 2011. Effect of Tillage and Crop Establishment Methods on Physical Properties of a Medium-Textured Soil under a Seven-Year RiceWheat Rotation. Soil Sci. Soc. America J. **75**: 1851-1862

Hernanz JL, Lopez R, Navarette L and Sanchez-Giron V 2002. Long-term effects of tillage systems and rotations on soil structural stability and organic carbon stratification in semiarid central Spain. Soil Tillage Res. **66**: 129-141.

Kar G and Kumar A 2009. Evaluation of post-rainy season crops with residual soil moisture and different tillage methods in rice fallow of eastern India. Agricul.Water Manage. **96**: 931-938.

Lampurlanes J and Cantero-Martinez 2003. Soil Bulk Density and Penetration Resistance under Different Tillage and Crop Management Systems and Their Relationship with Barley Root Growth. Agron. J. **95**: 526-536.

Li YJ, Wang H, Zhao JN, HuangFu CH and Yang DL 2015. Effects of tillage methods on soil physic chemical properties and biological characteristics in farmland. Chinese J. App. Ecol. **26**: 939-948.

Lei JY, Wu FQ, Wang J and Guo JH 2008. Effects of conservation tillage on soil physical properties and corn yield. Transactions of the CSAE. **24**: 40-45.

Motobayashi T, Naruoka Y and Wada H 2001. Growth and yield characteristics of rice plants on no-tillage paddy-field compared to plants in the conventional-tillage paddy-field. Japanese J. Crop Sci.**70**:18-19.

Oorts K, Nicolardot B, Merckx R, Richard G and Boizard H 2006. C and N mineralization of undisrupted and disrupted soil from different structural zones of conventional tillage and no-tillage systems in northern France. Soil Biol. Biochem. **38**: 2576-2586.

Sisti CPJ, dos Santos HP, Kohhann R, Alves BJR, Urquiaga S and Boddey RM 2004. Change in carbon and nitrogen stocks in soil under 13 years of conventional or zero tillage in southern Brazil. Soil Tillage Re.**76**: 39-58.

Shipitalo MJ, Dick WA and Edwards WM 2000. Conservation tillage and macropore factors that affect water movement and the fate of chemicals. Soil Tillage Rese. **53**: 167-183.

Topa D, Cara IG and Jitreanu G 2021. Long term impact of different tillage systems on carbon pools and stocks, soil bulk density, aggregation and nutrients: A field meta-analysis. Catena. **199**: 105102.

Varbel GE and Wilhelm WW 2011. No-tillage increases soil profile carbon and nitrogen under long-term rainfed cropping systems. Soil Tillage Res. **114**: 28-36.

(Manuscript received on 24 June, 2022; revised on 6 October, 2022)