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FFECTS OF DIFFERENT TILLAGES, WITH STRAW RETURNING, ON SOIL CHARACTERISTICS AND THE YIELD OF WINTER WHEAT

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ABSTRACT

The research aimed to study that the effects of three different tillages on soil characteristics and yield in winter wheat for straw returning in the open field with the variety wheat Jimai 22. There were three treatments that deep tillage with depth 25 cm, the 2+1 program (two years were rotary tillage and third year was deep tillage) with rotary tillage depth 11 cm, and the CK, traditional farming tillage with depth 15 cm. The implementation of experiment was 3 years. Each area of treatments was 667 m^2, with the same filed every year. The results showed that the effects of three different tillages on soil bulk density for the 0-20 cm soil layer were significant while the soil bulk density in overall performance were deep tillage <2+1 programs <CK, while in the facts of water use efficiency and the soil organic matter were deep tillage >2+1 programs >CK, and this also showed that the three different tillage's treatments had little influence on the content of soil organic matter below 40cm soil layer. For the factors on the yield and yield components of the first year, the grain number per spike of the 2+1 programs was just higher than that of the deep tillage treatment and CK treatment. Moreover, in the other two years the grain number per spike of the deep tillage was the highest. But in agriculture production, the tillage method of 2+1 program was more simple and easy to operate than deep tillage, and the costs such as mechanical power were less than deep tillage. Soil bulk density of deep tillage, water use efficiency and the increase of soil organic matter were beneficial to the wheat growth. So, the results indicated that deep tillage was helpful to the improvement of soil and the high yield of wheat for straw returning.

Key words: different tillages, soil characteristics, straw returning, winter wheat, yield.

INTRODUCTION

Plant straw is a natural resource of rural area, and rural sustainable production for the multi-use of resources. The rational use of straw is useful for agriculture and rural development now and in the future (Liu et al., 2006; Jie et al., 2010). The traditional usage mode of straw was to feed, to field for fertilizers, to burn in fields, to textile straw hats, mats and other crafts, the cultivation of edible fungi, the biogas and so on (Svensson et al., 2006). Discarded or incineration dropped were included (Damatty et al., 2009). In fact, straws contain lots of potential, abundant energy and nutrients as well, so they contain very huge enormous potential for using deeply. Most studies showed that: roots and straws of crops which were stayed in soil had a big impact on leaf area of maize, dry matter accumulation, components of yield and so on (Jiang et al., 2011; Hu et al., 2013; Li et al., 2012). However, it had particularly significant difference on root development and drought-resistant ability of plant (Zhou et al., 2004).

The results of research (Wang et al., 2000) showed that wheat straw could significantly promote the growth of wheat and peanut, compared with no straw returning, the yield of wheat can increase by 6.4%, the yield of peanut increase by 9.2%. After two years continuous for wheat straw returning, the yield of peanut can increase by 14.2%. The studies for different tillages in dry-land winter wheat had showed that those different tillages had a significant impact on soil structure, physicochemical properties of soil (Xu et al., 2000; Li et al., 2006), the fertility of the soil (Li et al., 2000) and other factors (Yang et al., 2013; Li et al., 2013). Also, the results of researches showed that the straw returning may increased the content of soil organic matter, and improved the yields of crops effectively (Ren et al., 2011; Li et al., 2015; Wang et al., 2015).

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But the studies about physicochemical nature properties of soil and fertility of soil for straw returning were less reported. Presently, in the rural, large amount of straw was abandoned out of field farms or burned directly. So, it not only caused great wastes of straw resources, but also caused series of environmental problems. Besides, it was the most main task to how to use efficiently and transform of straw in agricultural cycle of using. This experiment was about to investigate the effects of three different tillages on soil characteristics and yield of winter wheat for straw returning, and explore the best farming methods of wheat for straw returning, provide the basis theoretical and practical significance for keeping soil fertility and the sustainable development of rural land.

MATERIAL AND METHODS

Materials

The experiment was conducted in the Qingdao Agricultural University filed (119.97°E, 33.85°N) in the years of 2008-2011 with wheat variety Jimai 22 as experimental material. The basic fertility of sandy loam soil was that the content of organic matter was 12.09 g/kg, total nitrogen 0.99%, available nitrogen 85.12 mg/kg, available phosphorus 23.48 mg/kg and available potassium 83.52 mg/kg.

Methods

This is a three-year field experiment with wheat-maize rotation every year. The experiment had three different tillages treatments with three repeats. The treatment 1 was deep tillage with depth 25 cm, the treatment 2 was the 2+1 programs (two years' rotary tillage fore and third year's deep tillage last) with rotary tillage depth 11 cm, and the treatment 3 was CK, traditional farming tillage with depth 15 cm. The implementation of experiment was 3 years. Each area of treatments was 667 m^2, with the same farming every year, and application of fertilizer nitrogen fertilizer (pure N), phosphorus fertilizer (P_2O_5), potassium fertilizer (K_2O) was 225 kg/hm^2, 75 kg/hm^2, 105 kg/hm^2, respectively. The phosphorus and potassium and 50% of the nitrogen fertilizer were applied before tilling, and the other 50% of the nitrogen fertilizer was applied at the jointing stage of winter wheat.

The wheat was sowed in early October of each year with the seedlings about 2,250,000/hm^2 after the maize was harvested which the maize planted at the in late June in the same year and the all cornstalk pulverization returning and mulching returning by the Rotary Cultivator within the straw pulverizer. And the straw of wheat was all returning when the wheat was harvested with wheat combine.

Experiment Index

The relative water content of the soil before sowing and relative water content of the soil after harvesting were measured by drying method. The organic matter content of soil was measured by $K_2Cr_2O_4$ method. At the harvest time, 4m^2 square districts with five repeats in each treatment were selected and sampled randomly, and the biomass production, grain yield and the components of yield were analyzed, then converted hectare yield were calculated based on samplings.

Statistical analysis

All experiments were performed in triplicate. The experimental data were processed by Microsoft Excel 2010 (Microsoft Corporation, Redmond, WA, USA) and related mathematical statistical software (SAS Institute Inc., 2003) for statistical analysis and charting. A one way analysis of variance (ANOVA) was performed to determine significant differences, which were subsequently verified using Duncan's multiple range test at $p<0.05$.

RESULTS

Weather characteristics

The weather characteristics which mainly included the precipitation and the temperature were showed in the Tables 1 and 2 during the experiment from the 2008 year to 2011 year. The weather in the experiment can be divided rain season mainly from June to September (the precipitation of this period was 70-80% in the all of the year) and dry season mainly from October to May of the next year. The

annual mean evaporation of the period was 800-900 mm. The months of the average temperature (<5℃) was from November to February or March.

Table 1. The precipitation of the 2008-2011 years on the experiment (unit: mm)

Years	Months (SUM)												
	Jan.	Feb.	Mar.	Apr.	May	June	July	August	Sep.	Oct.	Nov.	Dec.	SUM
2008	10.6	7.4	16.2	62.6	77.1	49.7	370.0	205.4	30.2	71.9	24.5	7.6	933.2
2009	0.6	14.4	31.8	45.1	60.3	77.0	258.6	85.2	19.5	33.0	22.8	17.1	665.4
2010	1.1	32.0	28.0	29.2	105.8	42.6	148.4	194.8	113.7	17.9	0.0	0.4	713.9
2011	0.1	25.8	4.5	8.4	36.2	57.9	256.0	148.5	98.7	13.7	46.6	20.8	717.2

Table 2. The temperature of the 2008-2011 years on the experiment (unit:℃)

Years	Months (Average)											
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
2008	-1.11	0.47	7.05	11.53	16.02	19.37	24.35	25.08	21.72	17.37	9.67	3.01
2009	-0.18	3.48	6.08	11.70	18.16	21.63	23.79	25.07	21.98	18.29	6.25	1.50
2010	-1.39	1.23	3.80	9.10	16.64	20.67	25.34	25.72	22.50	16.22	10.71	3.13
2011	-2.93	1.56	5.97	11.40	17.55	20.01	23.82	25.00	21.19	16.31	11.29	1.79

Soil bulk density

The results indicate that the soil bulk density of 20-40 cm soil layer for different tillages treatments was greater than that of the 0-20 cm; the trend of soil bulk density of 0-20 cm soil declined after one year which soil bulk density was 2+1 programs> deep tillage >CK (Figure 1).

However, after three years, the soil bulk density was CK> deep tillage>2+1 programs with the 2+1 programs the largest changes. However, the trend of soil bulk density of 20-40 cm soil also declined year by year. Compared to the results two years ago, it showed that the soil bulk density of deep tillage decreased faster than that of others, however, soil bulk density of 2+1 programs treatment was less than that of deep tillage after the 3rd year but not significantly; soil bulk density of CK treatment showed stationary with no obvious change. Only from the soil bulk density, only in the third year the soil bulk density of 2+1 programs was less than that of deep tillages while it was higher than that of deep tillages for the first two years.

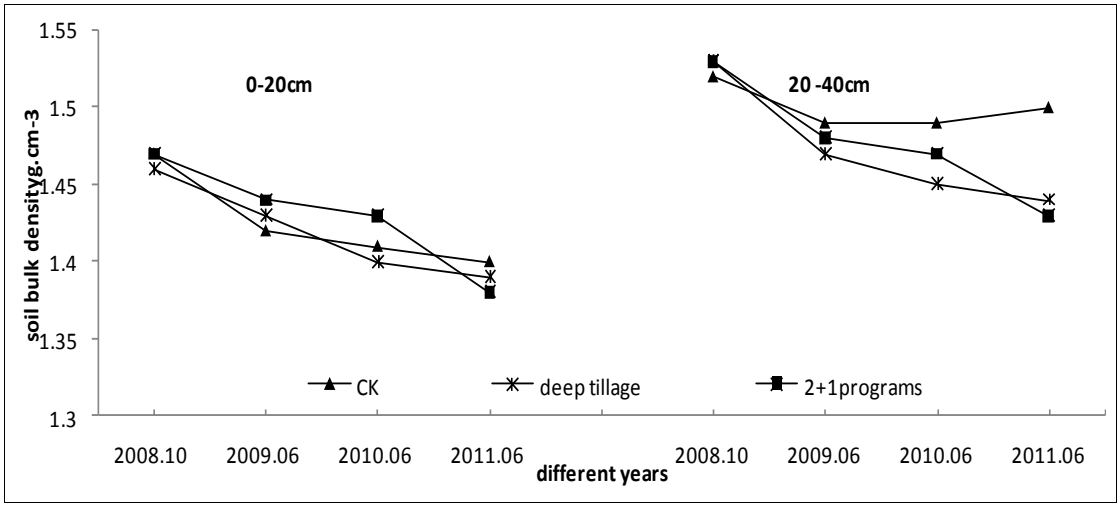

Figure 1. The effects of different tillages on soil bulk density in winter wheat for straw returning

Organic matter of different soil layers

With the increase of the soil depth, the content of organic matter of soil decreased systematically, but the decrease range is not obvious (Figure 2). The content of soil organic matter was 0-20 cm>20-40 cm>40-60 cm>60-80 cm. In the 0-20 cm soil layer, the organic matter content was upward trend, the increases of deep tillage was the maximum, followed by the 2+1 programs and CK was the lowest. During 40-60 cm and 60-80 cm soil layers, the content of soil organic matter did not changed significantly. Figure 2 showed that the 0-40 cm soil organic matter content in the straw returning increased more significantly than previous while there was none of significant change for soil organic matter content in the deeper levels.

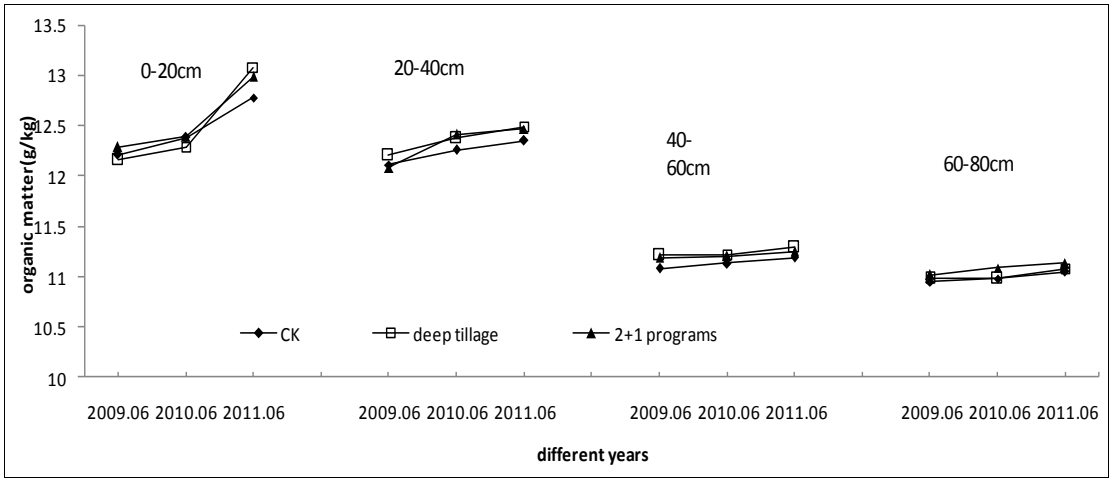

Figure 2. The effect of different tillages on organic matter in winter wheat for straw returning

Water use efficiency

The trend of soil water use efficiency increased after the straw returning year by year (Figure 3). Water use efficiency of deep tillage and 2+1 programs were higher than that of CK treatment. During 2008-2009 year, the water use efficiency was that the 2+1 programs > deep tillage >CK treatment, while during 2010-2011year, it showed that deep tillage >2+1 programs >CK treatment.

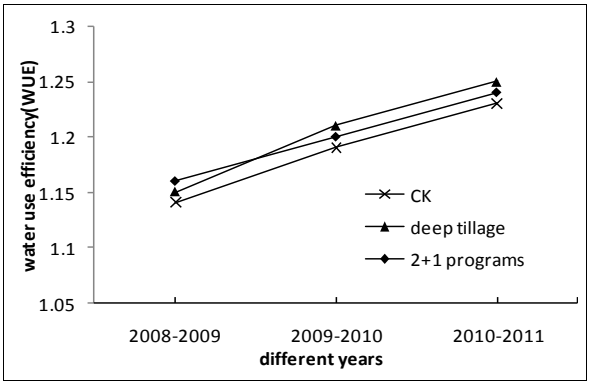

Figure 3. The effect of different tillages on water use efficiency in winter wheat for straw returning

This showed that the water use efficiency of deep tillage treatment remained at the highest level for straw returning. In the experiment, the water use efficiency of deep tillage was higher than that of CK and the 2+1 programs in the highest level. This would support the supply of water for the late wheat growth.

The yield and yield components

With straw retuning by three years, the yield and yield components of wheat all increased (Table 3). And the increase rate of the deep tillage and 2+1 programs was higher than that of CK treatment. In 2009 year, grain number per spike of wheat showed the 2+1 programs > deep tillage >CK treatment, but in 2010-2011 year it showed deep tillage >2+1 programs >CK treatment. About the weight of 1000 kernels, it increased year by year for the same tillage treatment, and in each year for different treatments, it showed deep tillage >CK treatment >2+1programs, but was not significant difference between treatments. For the total yield, the yield of deep tillage and 2+1 programs were higher than that of CK treatment. In 2011 year, the yield showed deep tillage >2+1 programs >CK treatment. Similarly, harvest index of deep tillage maintained the highest in all treatments; and it would be more useful to gain a higher yield.

Table 3. The effect of different tillages on the yield and yield components of winter wheat for straw returning

Treatments	Years	Spike no. ($\times 10^4$/hm^2)	Grain no. per spike	Weight of 1000 kernels (g)	Yield (kg/hm^2)	Biomass (kg/hm^2)	Harvest index (HI)
CK	2009	603.1	32.5	39.8	7014.7a	17986.41	0.39
	2010	605.2	33.1	40.1	7125.8a	18271.28	0.39
	2011	610.5	34.5	41.2	7256.6a	18141.50	0.40
Deep tillage	2009	625.9	35.1	41.2	7991.8b	19830.77	0.40
	2010	629.8	36.8	41.8	8359.8c	19904.29	0.42
	2011	635.4	37.9	42.2	8364.5c	19452.33	0.43
2+1 programs	2009	625.9	35.9	40.9	7986.6d	20478.46	0.39
	2010	628.7	36.5	41.2	8225.6d	20564.01	0.40
	2011	634.6	37.7	42.1	8356.7f	20382.19	0.41

DISCUSSION

The basis of materials to ensure high yield of crops was that the soil can supply a steady nutrients constantly (Zhou et al., 2011). At the same time, it was very necessary to keep and improve the physical properties of soil in order to improve the soil conditions for the crops growth. As far as the level of current economic and technology of rural, only crops straw which may replace the traditional organic fertilizers is the most important organic fertilizer source. Studying different farming methods can speed up utilization of straw more effectively and rationally; straw returning will improve soil structure, increase soil organic matter, and enhance soil fertility. This is one of the most important ways of promoting agricultural production (Zhang et al., 2009).

From the results of this test we could conclude that the different tillages for straw returning can reduce soil bulk density; From the 2009-2010 years' results, the effect of soil bulk density of deep tillage was greater than that of the 2+1 programs and the CK treatment, while in 2011year, the soil bulk density of 2+1 programs was greater than deep tillage. This showed that different tillages could change the soil bulk density. According to the test results, after the 3-years cycle, the soil bulk density of 0-20 cm and 20-40 cm soil layer of deep tillage reduced, which was useful to the wheat roots growth and water conservation, and helpful to the growth of wheat.

In the experiment, the water use efficiency of deep tillage was higher than that of CK and the 2+1 programs in the highest level. This would support the supply of water for the late wheat growth. Most of researches (Zhao et al., 2011; Niu et al., 2011; Lu et al., 2006; Sun et al., 2011) proved that straw returning also could improve the content of organic matter of soil. This results indicated that different farming methods had obvious difference on the increased speed of content of organic matter in soil, which deep tillage had better role on the content increased of soil organic matter, this means that the deep tillage could make the crushed straw to decompose completely and transform organic matter in soil, and utilization more effectively for the crops with improving the soil. At the same time, the increase content of organic matter of deep tillage was greater than that of others, followed by 2+1 programs. But in agriculture production, the tillage method of 2+1 programs was more simple and easy to operate than deep tillage, and the costs such as mechanical power were less than deep tillage. For the factors on the yield and yield components of the first year, the grain number per spike of the 2+1 programs was just higher than that of the deep tillage treatment and CK treatment. Moreover, in the other two years the grain number per spike of the deep tillage was higher than that of the 2+1 programs and CK treatments.

CONCLUSIONS

In general, the experiment results showed that these three different tillages had different

effects on soil characteristics and yield in winter wheat for straw returning. Soil bulk density of deep tillage, water use efficiency and the increase of soil organic matter were beneficial to the wheat growth. And this was consistency with the later of wheat growth. The yield and components of yield of wheat in deep tillage were higher than that of CK and 2+1 programs. So, the results indicated that this way of deep tillage was helpful to the improvement of soil and the high yield of wheat for straw returning.

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