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EFFECTS OF TILLAGE METHODS ON SOIL PHYSICAL PROPERTIES AND CROP YIELD IN ARID AREA OF NORTHWEST CHINA

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Abstract

Effects of no-tillage, deep tillage and tillage on soil physical properties and maize yield in Weibei dryland were studied through field experiments from 2008 to 2010. The results showed that the soil bulk density was the highest under no-tillage treatment. The maximum field water holding capacity and saturated water content were both the highest under deep-plowing treatment, which were 29.66 and 31.31%, respectively. Under the condition of balanced fertilization, during the growth period of maize, the average soil water storage of no-tillage and deep-plowing treatment was 44.2 and 34.6 mm higher than that of ploughing treatment. The yield, water use efficiency and net income of deep-plowing treatment with balanced fertilization were the highest among three combinations of tillage. It can be seen that the treatment of deep loosening with balanced fertilization is the best combination of tillage and fertilization in continuous cropping corn field in Weibei Arid Plateau.

Introduction

The Weibei Arid Plateau in Shaanxi Province is located in the gully region of the southern tableland and residual plateau of the Loess Plateau. The annual precipitation is 420 - 700 mm, belonging to the semi-humid and arid region of the warm temperate zone. The total amount of precipitation is limited with the scarce surface water resources, the annual variability and seasonal variability are large which indicates that it is a typical dry farming area (Song *et al*. 2004, Zhou *et al*. 2007). Drought stress and barren soil are the main limiting factors of crop production in the Loess Plateau (Huang *et al.* 2006). Therefore, it has become the focus of dry farming research to take appropriate agricultural technical measures to reduce non-productive water consumption, increase water production efficiency, improve ecological environment and increase crop yield (Ji *et al*. 1998, Wang *et al*. 2004, Shi *et al.* 2006). Some studies have shown that conservation tillage can increase soil water content, store water and preserve soil moisture, improve soil texture and increase yield (Zhang *et al.* 2005, Li *et al.* 2006). Some scientists had shown that conservation tillage can not only increase surface soil moisture and promote crop growth and development, but also realize the use of autumn rain in spring, increase yield and increase income (Hatfield *et al.* 2001, Fang *et al.* 2003, Liu *et al*. 2004, Zheng 2004, Li *et al*. 2006,). However, researches on the combination of soil fertility fertilization and conservation tillage measures are limited. For the study of dry land, it is expected to strengthen the agricultural scientific farming and cultivation system in arid areas, and how to make efficient use of water resources is also the focus of the following research. Studying the agricultural characteristics in early dry areas can better serve the

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development of modern agriculture. Cultivation measures can improve soil properties and increase productivity, so it is of great significance to explore the practical farming methods in agricultural production in arid areas for promoting the sustainable development of agriculture in this region.

This study combined "regulating water by fertilizer" effect of fertilization measures with "storing water and preserving soil moisture" effect of conservation tillage effect, and explored the dynamic changes of soil moisture and yield effect in continuous cropping corn field under the combination of the two measures. Thus effects of water storage and soil moisture conservation, increase of yield and income under different tillage treatments were analyzed. The conservation tillage models adapted to the local precipitation resources and maize planting system were evaluated and selected in order to provide a scientific basis for sustainable water use and growth of yield and income in continuous cropping maize fields in Weibei Arid Plateau.

Materials and Methods

The experiment was set in Ganjing Town, Heyang County, Shaanxi Province (Northern latitude: 34°10′-36°20′, east longitude: 106°20′-110°40′, 910 m in elevation), which is a typical semi-humid and drought-prone area in the eastern gully region of Weibei Arid Plateau. The average annual precipitation of 420-700 mm, is mainly concentrated in July, August and September, the interannual precipitation distribution is uneven (Table 1). The annual evaporation is 1 832.8 mm, and the dryness is 1.5. The experimental soil is black loam, which belongs to middle loam, with thick soil layer and strong ability of water storage and fertilizer conservation.

Table 1. Monthly precipitation of Heyang Station from 2008 to 2010 (mm).

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Annual precipi-tation	Precipitation during growth period
2008	29.1	8.3	13.0	31.7	23.5	95.7	54.4	123.5	65.2	15.0	0.0	0.0	459.4	315.0
2009	1.2	23.5	19.8	12.8	133.5	46.8	46.6	96.8	52.4	24.8	37.4	2.3	501.0	386.0
2010	0.0	0.0	16.8	14.9-	40.3	44.3	56.7	127.5	123.4	39.1	0.0	0.0	451.8	390.7
1976-2006	5.6	9.3	19.6	31.2	44.1	57.4	111.9	114.7	77.3	46.7	15.3	5.2	538.2	380.0
Av.	9.0	10.3	18.3	25.2	61.1	61.1	67.4	115.6	79.6	31.4	13.2	1.9	487.6	368.9

The experiment was carried out during September, 2008 to September, 2010, the split zone design was adopted, with fertilization as the main treatment and tillage as the secondary treatment. The conservation tillage experiment of spring corn continuous cropping in winter fallow period was carried out under the condition of conventional full straw returning to the field by using the annual ripening system of spring corn. Three different tillage methods (no-tillage, deep-plowing and ploughing) were set up, and the plot area was 22 × 5 m =110 m^2, and there were 9 plots after tillage treatment and fertilization. The tested variety is spring maize Yuyu 22. The sowing dates of corn were April 23rd, 2009 and April 19th, 2010, and the harvest dates were September 22nd, 2009 and September 19th, 2010. No irrigation treatment was carried out during the experiment.

According to the investigation results of conventional fertilization in Weibei dry maize field and the balanced fertilization scheme of Shaanxi Provincial Agriculture Department, three kinds of fertilization treatments were set up in this experiment: Balanced fertilization: N 150, P_2O_5 120 and K_2O 90 kg/hm^2; conventional fertilization: N 255, P_2O_5 and 180 kg/hm^2; low fertilizer: N 75,

P_2O 60 and K_2O 45 kg/hm^2. Among them, nitrogen fertilizer, phosphate and potassium fertilizer are urea, diammonium phosphate and potassium chloride, respectively. During the sowing of spring corn, fertilizer was applied according to fertilization treatment, and the stubble was chopped by rotary tillage, the surface was leveled and mixed fertilizer was used to sow seeds uniformly according to the sowing rate of 60 kg/hm^2.

The following three kinds of soil tillage treatments were carried out immediately after the full straw was returned to the field during the previous corn harvest: a) Ploughing: ploughing 22-25 cm, after the previous corn harvest, all the straw residues were buried in the ploughed soil, and the surface was loose and exposed for the winter fallow period. b) Deep-plowing: when the previous corn was harvested, the surface was covered by 20-30 cm straw, and leaved straw deep pine 35-40 cm with 40-60 cm width per interval. c) No tillage: no soil tillage measures were taken after the previous corn harvest, so that the ground was covered by 20-30 cm straw.

A total of 9 treatments were designed in this experiment: (i) balanced fertilization and no-tillage treatment (BNT), (ii) balanced fertilization and deep-plowing treatment (BDL), (iii) balanced fertilization and ploughing treatment (BP), (iv) conventional fertilization and no-tillage treatment (CNT), (v) conventional fertilization and deep-plowing treatment (CDL), (vi) conventional fertilization and ploughing treatment (CP); (vii) low fertilizer and no-tillage treatment (LFT), (viii) low fertilizer and deep-plowing treatment (LFD), (ix) low fertilizer and ploughing treatment (LFP).

The soil bulk density of 0-60 cm (the soil was taken every 20 cm) was measured by ring knife method before sowing and after harvest of spring maize in 2009 and 2010. Soil bulk density (*P*) was calculated as following:

$$P=\left(m_2\text{-}m_1\right)/\,\mathrm{v}\left(1+w\right) \qquad (1)$$

m_2-ring knife and wet soil mass; m_1-ring knife mass; v-ring knife volume; w-soil water content.

Determination of maximum field capacity means that after full irrigation or precipitation on the land with deep groundwater and drainage, water is allowed to infiltrate fully and its evaporation is prevented. After a certain period of time, the stable soil water content (soil water potential or soil water suction reaches a certain value) can be maintained by soil profile, which is the upper limit of soil water available to most plants. Calculation of soil maximum field capacity (Ws):

$$\mathrm{Ws}=\left(m_3\text{-}m\right)/\left(m\text{-}m_1\right)\times 100\% \qquad (2)$$

m_3-ring knife and wet soil mass after drainage; m -ring knife and dried soil mass.

Determination of maximum saturated water content refers to the maximum water content when all soil pores are full of water. The maximum saturated soil water content (Ww) was calculated as follows:

$$\mathrm{Ww}=\left(m_4\text{-}m\right)/\left(m\text{-}m_1\right)\times 100\% \qquad (3)$$

m_4-ring knife and wet soil mass after water absorption.

The soil moisture of 0-200 cm（the soil was taken every 20 cm） was measured by soil drill drying method during the winter fallow period and main growth period of spring maize in 2009 and 2010. Soil water storage and water use efficiency were calculated.

Soil moisture content = (wet soil mass-dried soil mass) / dried soil mass × 100%

Calculation of soil water storage (Shang *et al*. 2010; Guo and Huang 2005).

$$W = Wi \times Di \times Hi \times 10 / 100 \quad (4)$$

W represents soil water storage (mm); W*i* represents soil mass moisture content of layer *I* (%); D*i* represents soil volume mass of layer *I* (g/cm^3); H*i* represents the thickness of soil layer *I* (cm), in which the volume mass of more than 2 m was calculated according to the measured value.

Water use efficiency (WUE) refers to the economic yield per unit (mm) of evapotranspiration per unit area (Jin and Huang 2005).

$$\mathrm{WUE} = Y / \mathrm{ET} \quad (5)$$

$$\mathrm{ET} = P - \Delta S \quad (6)$$

Y stands for economic yield (kg/hm^2); *ET* for evapotranspiration during crop growth (mm); *P* for precipitation during crop growth (mm); ΔS for the difference in soil water storage between harvest and sowing of 0-200 cm (mm). The experimental land is dry land without irrigation.

Economic benefits are net income (yuan/hm^2) = output income – total input, output income (yuan/hm^2) = grain yield × market price, in which the total cost input includes mechanical expenses of sowing and tillage treatment, pesticides, chemical fertilizers, seed costs and labor inputs.

In the experiment, Excel 2003 was used to process the data and charts, and DPS3.01 data processing software were used to analyze the variance of the data and multiple comparisons of the new Duncan complex difference method (Tang and Feng 2007).

Results and Discussion

In the annual maturity of Weibei area, soil bulk density is affected by soil moisture, climate and other factors. The change of different crop growth periods was the first considering factor to study its change law. It can be seen from Table 2 that the bulk density of soil after harvest was higher than that before sowing, because after a growing period, under the influence of its own gravity and other factors, soil bulk density increases significantly, and tillage measures have little effect on soil bulk density before sowing, but have a significant effect on post-harvest. The results of 2-year experiment showed that the soil bulk density of 0 - 20 cm and 20 - 40 cm had the trend of no-tillage > deep-plowing > ploughing, and the change of soil bulk density was not significant in the two years (2009 and 2010). The bulk density increased significantly under no-tillage treatment, even reached the highest (1.63 g/cm^3), which was related to the poor air permeability of soil under no-tillage treatment. In the three different soil layers of 0-20, 20-40 and 40-60 cm, the soil bulk density of no-tillage and deep-plowing increased by 9.9, 6.6, 4.1, 2.6 and 5%, respectively. The field capacity and saturated water content in the surface layer were higher than those in the deep layer, and the results of different tillage treatments in 0-20 and 40-60 cm soil layers were as follows: deep-plowing > no-tillage > ploughing. Compared with ploughing, the average field capacity of deep-plowing and no-tillage treatments increased by 15.6, 3.4, 5.1 and 0.2%, respectively, and the saturated water content increased by 18.4, 3.1, 6.7 and 0.6%, respectively. Different tillage treatments of 20 - 40 cm soil layer showed deep-plowing > ploughing > no-tillage. The average field capacity of deep-plowing and ploughing was 13.4 and 11.5% higher than that of no-tillage treatment, and the saturated water content was 14.6 and 12% higher than that of no-tillage treatment. From this point of view, compared with no-tillage and ploughing, deep-plowing is a better tillage treatment, which is more beneficial to increase field water capacity and saturated water content.

Table 2. Effects of balanced fertilization and different tillage methods on soil bulk density, field capacity and saturated water content of 40 cm soil layer in corn field.

Year	Soil layer (cm)	Treatments	Before sowing			After harvest		
			Bulk density (g/cm^3)	Maximum field capacity (%)	Saturated water content (%)	Bulk density ($g \cdot cm^{-3}$)	Maximum field capacity (%)	Saturated water content (%)
2009	0-20	NT	1.39	28.96	30.49	1.46	27.87	31.17
		DL	1.37	30.54	31.8	1.36	30.68	33.94
		P	1.25	26.99	28.57	1.40	26.14	29.43
	20-40	NT	1.42	29.9	31.23	1.53	26.14	28.45
		DL	1.31	35.57	37.43	1.51	27.74	30.81
		P	1.34	34.02	35.24	1.41	27.08	30.08
	40-60	NT	1.44	27.15	28.20	1.51	29.92	31.70
		DL	1.46	25.98	27.22	1.49	27.95	30.94
		P	1.37	25.36	27.30	1.45	25.54	28.56
2010	0-20	NT	1.49	27.95	28.37	1.52	27.17	28.3
		DL	1.48	35.77	36.58	1.47	30.38	31.67
		P	1.28	26.82	27.42	1.40	26.66	27.7
	20-40	NT	1.58	22.69	22.99	1.63	22.45	23.44
		DL	1.49	28.71	29.70	1.61	22.74	23.69
		P	1.46	25.65	26.22	1.57	26.07	27.34
	40-60	NT	1.46	26.72	27.07	1.47	24.54	25.49
		DL	1.47	28.02	28.76	1.44	31.83	33.12
		P	1.42	25.93	26.38	1.36	31.35	29.55

NT: no-tillage treatment; DL: deep-plowing treatment; P: ploughing treatment.

During the whole growth period, the average soil water storage of no-tillage, deep-plowing and ploughing treatments were 398.4, 383.9 and 352.3 mm, respectively, which were 46.1 and 31.6 mm higher than that of ploughing treatment (Fig. 1). The water consumption of the three cornfields was 425.3, 412.3 and 406.7 mm, respectively. The order of water consumption was no-tillage > deep-plowing > ploughing. The results of 2-year experiment showed that the average soil water storage of 0 -200 cm under no-tillage, deep-plowing and ploughing were 400.7, 391.2 and 356.5 mm, respectively. The average soil water storage of no-tillage and deep-plowing treatment was 44.2 and 34.6 mm higher than that of ploughing treatment at 0-200 cm. As a result, it may be concluded that no-tillage deep-plowing and ploughing have a good effect of storing water and preserving soil moisture.

Before the big trumpet stage, the soil water storage decreased rapidly due to the large amount of water consumed by the vegetative growth of spring maize, and the change trend of soil moisture content of the three different tillage treatments was similar in the big trumpet stage. Results presented in Fig. 2 showed that during the corn trumpet mouth period in 2009, the soil moisture content of 0-200 cm under no-tillage, deep-plowing and ploughing treatments varied from 9.3 to 17.2%, 10.7 to 17.4% and 9.5 to 15.6%, respectively. The average soil moisture content of 0-200 cm under the three tillage treatments were 14.9, 15.2 and 13.6%, respectively. Compared with ploughing, no-tillage and deep-plowing were increased by 1.3 and 1.6%, respectively. In the corn trumpet mouth period in 2010, the soil moisture content of 0-200 cm under no-tillage, deep-plowing and ploughing treatments varied from 10.5 to 14.7%, 10.1 to 15.2% and 11.6 to 15.8%, respectively. The average soil moisture content of 0 - 200 cm under the three tillage treatments was 14.5, 13.7 and 12.9%, respectively. Compared with ploughing, no-tillage and deep-plowing were increased by 1.6 and 0.8%, respectively. The results of 2-year experiments showed that no-tillage and deep-plowing tillage had better water storage effect than ploughing.

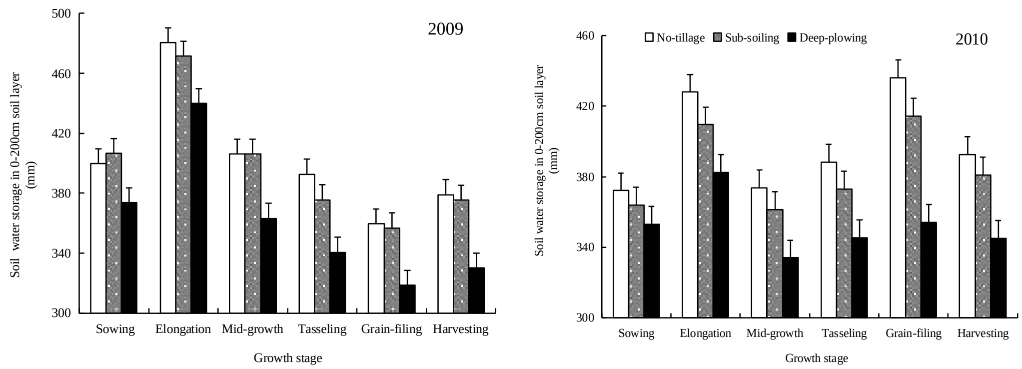

Fig. 1. Dynamic changes of soil water storage in 0-200 cm soil layer during the growth period of spring maize.

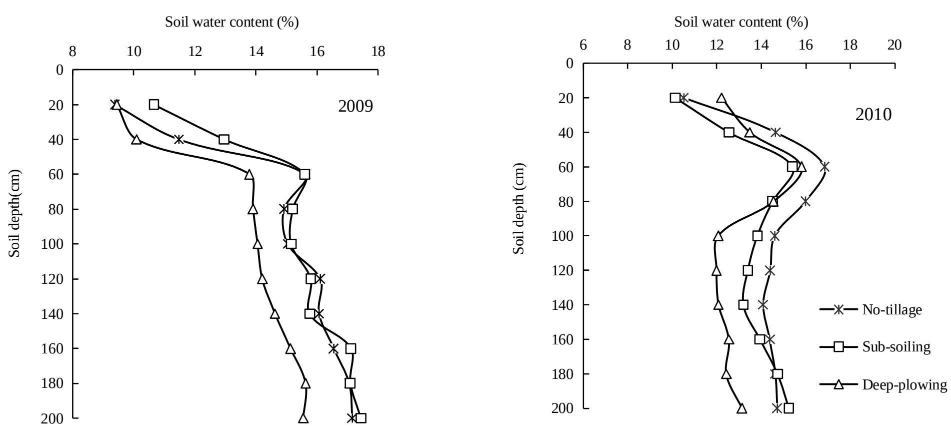

Fig. 2. Comparison of soil moisture in soil layer of 200 cm under different tillage treatments in big trumpet mouth stage of spring maize.

Effects of different fertilization levels and different tillage measures on the main yield characters of spring maize were different (Table 3). It can be seen that in 2009, under balanced fertilization treatment, maize yield was balanced deep-plowing > balanced no-tillage > balanced ploughing, and balanced deep-plowing was significantly different from balanced no-tillage and balanced ploughing ($p < 0.05$), but there was no significant difference between balanced no-tillage and balanced ploughing. In conventional fertilization, the 1000-grain weight of no-tillage was 20.7 g higher than that of conventional deep-plowing, while in the low fertilizer treatment, the 1000-grain weight of no-tillage was the highest, which was 35.9 g higher than that of low-fertilizer deep-plowing. Generally speaking, different fertilization treatments had significant effects on yield and its components. The number of hectare panicles of balanced fertilization and conventional fertilization were 1.9 and 7.5%, respectively higher than that of low fertilizer treatment. In terms of 1000-grain weight, the balanced fertilization treatment was 11.4 g higher than that of the low fertilizer treatment, and the difference between two treatments was significant. In terms of yield, balanced fertilization > conventional fertilization > low fertilizer treatment, and the difference of maize yield between balanced fertilization and low fertilizer treatment reached a significant level ($p < 0.05$).

Table 3. Comparison of yield and components of spring maize under different fertilization and tillage treatments.

Year	Treatments	Number of panicles per unit area (10^4/hm^2)	Number of grains per spike (No.)	1000-grain weight (g/1000)	Output (kg/hm^2)
2009	BNT	46542	511	329.1	8236.7b
	BDL	47505	532	312.7	8979.6a
	BP	45809	506	306.0	8021.4b
	LFT	47032	435	303.4	5877.8 e
	LFD	45619	457	267.5	6561.1d
	LFP	44549	525	280.2	5855.6 e
	CNT	49101	449	311.7	7169.3c
	CDL	50641	524	291.0	8026.4b
	CP	47798	498	327.0	6968.9cd
2010	BNT	48333	565	345.7	9440.4ab
	BDL	49067	569	346.9	9685.1a
	BP	44000	513	334.2	7543.6d
	LFT	47600	492	319.0	7470.7cd
	LFD	46367	538	319.8	7977.6 e
	LFP	47600	506	295.3	6929.7 f
	CNT	47833	512	313.3	7672.9de
	CDL	47933	567	334.7	9096.5b
	CP	48700	476	312.2	7571.7cd

BNT: balanced fertilization and no-tillage treatment; b) BDL: balanced fertilization and deep-plowing treatment; c) BP: balanced fertilization and ploughing treatment; d) LFT: low fertilizer and no-tillage treatment; e) LFD: low fertilizer and deep-plowing treatment ; f) LFP: low fertilizer and ploughing treatment; g) CNT: conventional fertilization and no-tillage treatment; h) CDL: conventional fertilization and deep-plowing treatment; i) CP: conventional fertilization and ploughing treatment. In the same column, lowercase letters represent significant differences at the 5% level of statistical test. The following is the same.

In 2010, under the treatment of balanced fertilization, the yield of maize of balanced deep-plowing was the highest, and followed by deep-plowing balanced no-tillage and balanced ploughing. There was no significant difference between balanced deep-plowing and balanced no-tillage, while the difference between balanced no-tillage and balanced ploughing was significant ($p < 0.05$), there was also significant difference between balanced no-tillage and balanced ploughing ($p < 0.05$). In the conventional fertilization, the 1000-grain weight of deep-plowing was 21.4 g which was higher than that of conventional no-tillage, and in the low fertilizer treatment, the 1000-grain weight of low fertilizer deep plowing was the highest, 24.5 g which was higher than that of low fertilizer ploughing. The effect of fertility on yield was balanced fertilization > conventional fertilization > low fertilizer treatment.

According to the analysis of Tables 3 and 4, the yield and water use efficiency (WUE) of spring maize were significantly different among different fertilization treatments. In different years, the yield and WUE of deep-plowing treatment was the highest, followed by no-tillage, and ploughing treatment was the lowest. In 2009, the average maize yield of no-tillage, deep-plowing and ploughing treatments were 7 094.6, 7 855.7 and 7 855.7 kg/hm^2, respectively. Compared with ploughing, the average maize yield of no-tillage and deep-plowing treatments increased by 2.1 and 13.1%, respectively. The average WUE of no-tillage, deep-plowing and ploughing treatments were 17.45, 18.79 and 16.51 kg/(hm^2·mm), respectively. Compared with ploughing, the WUE of no-tillage and deep-plowing treatments increased by 5.7 and 13.8%, respectively. In 2010, the average maize yield of no-tillage, deep-plowing and ploughing treatments under the three fertilization treatments were 8094.7, 8686.4 and 7681.7 kg/(hm^2·mm), respectively. Compared with ploughing, the yields of no-tillage and deep-plowing treatments increased by 5.4 and 13.1%, respectively. The average WUE of water use efficiency of no-tillage, deep-plowing and ploughing treatments were 19.96, 22.10 and 19.25 kg/(hm^2·mm), respectively. The WUE of no-tillage and deep-plowing treatments was increased by 3.7 and 14.8% compared with the ploughing treatment.

Table 4. Changes of water use efficiency (WUE) of spring maize under different fertilization and tillage treatments.

Treatment	WUE09	WUE10	Average
BNT	19.77	21.49	20.63ab
BDL	20.53	23.49	22.01a
BP	18.38	21.01	19.70ab
LFT	14.29	18.43	16.36d
LFD	16.09	20.38	18.24bc
LFP	14.4	17.1	15.75 e
CNT	18.29	19.96	19.13bc
CDL	19.75	22.43	21.09ab
CP	16.76	19.63	18.20bc

Under different tillage treatments, there were significant differences both in maize yield and WUE among different fertilization treatments, with the highest in balanced fertilization, the second in conventional fertilization and the lowest in low fertilizer treatment in the above two indexes (maize yield and WUE). In 2009, the average yield of maize under balanced fertilization, conventional fertilization and low fertilizer treatment were 8412.6, 7388.2, 6098.2 kg/hm^2, respectively, and the yield of balanced fertilization and conventional fertilization were 38.0 and 17.5% higher than that of low fertilizer treatment, respectively. The average WUE of balanced fertilization, conventional fertilization and non-fertilizer treatments were 19.56, 18.27 and 14.93 kg/(hm^2·mm), respectively, balanced fertilization and conventional fertilization increased 31.0 and 22.4% compared with low fertilizer treatment WUE. In 2010, the average yield of maize under balanced fertilization, conventional fertilization and low fertilizer treatment were 9 123.1, 7880.4 and 7459.3 kg/hm^2, respectively. Compared with low fertilizer treatment, the yield of maize with balanced fertilization and conventional fertilization were increased by 22.3 and 5.6%. The average WUE of balanced fertilization, conventional fertilization and non-fertilizer treatment were 22.00, 20.67, 18.63 kg/(hm^2·mm), respectively, balanced fertilization and conventional fertilization treatment increased 18.1 and 10.9% compared with non-fertilizer treatment WUE. The results of 2-year experiments showed that among the 9 combinations of fertilization and tillage, the yield and WUE treated with balanced fertilization and deep-plowing were the highest, and the average yield and WUE in 2-year were 9 332.4 kg/hm^2 and 22.01 kg/(hm^2·mm), the following was the combination of balanced fertilization and no-tillage, and the average yield and WUE in 2-year were 8 688.6 and 20.63 kg/(hm^2·mm), respectively. Therefore, balanced fertilization and deep-plowing treatment are the best combination to increase yield and improve water use efficiency.

Under the fertilization treatments from 2009 to 2010, the average input costs of no-tillage, deep-plowing and ploughing treatments were 6 937.2, 7 612.2 and 7 462.2 yuan/hm^2, respectively (Table 5). The average net income of each tillage treatment were 4 090.1, 4 393.3 and 3 155.8 yuan/hm^2, respectively. Compared with ploughing, the income of no-tillage and deep-plowing treatments increased by 934.3 and 1237.6 yuan/hm^2, and the increase rate were 29.6 and 39.2%, respectively. Under each tillage treatment, the average input cost of balanced fertilization, conventional fertilization and low fertilizer treatment were 8163.4, 6932.1 and 6916.1 yuan/hm^2, respectively. The average net income of each fertilization treatment was 4560.6, 4145.1 and 2933.5yuan/hm^2, respectively. The average net income of balanced fertilization and conventional fertilization were 1627.1 and 1211.5 yuan/hm^2 higher than that of low fertilizer treatment, and the increase rates were 55.4 and 41.3%, respectively.

Table 5. Corn production cost and economic benefit unit of different fertilization and tillage treatments (yuan/hm^2).

Year	Treatment	Fertilizer input	Mechanical operation input	Other input	Total input	Output income	Net income
2009	BNT	2494.7	1200.0	4068.8	7763.4	11696.1b	3932.7abc
	BDL		1875.0		8438.4	12751.1a	4312.7a
	BP		1725.0		8288.4	11390.4b	3101.9bc
	LFT	1247.3	1200.0		6516.1	8346.4d	1830.4bc
	LFD		1875.0		7191.1	9316.8cd	2125.7abc
	LFP		1725.0		7041.1	8314.9d	1273.8c
	CNT	1263.4	1200.0		6532.1	10180.5bc	3648.3ab
	CDL		1875.0		7207.1	11397.5b	4190.4a
	CP		1725.0		7057.1	9895.9c	2838.8bc
2010	BNT	2494.7	1200.0		7763.4	13527.8ab	5764.4ab
	BDL		1875.0		8438.4	14333.9a	5895.5a

Contd.

BP		1725.0	8288.4	12644.5bc	4356.1abc
LFT	1247.3	1200.0	6516.1	11056.6cd	4540.5bc
LFD		1875.0	7191.1	11806.8c	4615.7ab
LFP		1725.0	7041.1	10255.9d	3214.9d
CNT	1263.4	1200.0	6532.1	11355.8cd	4823.8bc
CDL		1875.0	7207.1	12426.8bc	5219.7abc
CP		1725.0	7057.1	11206.16d	4149.0cd

The mechanical operation input includes sowing, straw returning and subsoiling or ploughing farmland input, and other inputs include pesticide, seed and manual input. Among them, fertilizer diammonium was 3.1yuan/kg, urea was 2.2 yuan/kg, potash fertilizer was 5.2 yuan/kg, deep-plowing was 675yuan/hm^2, ploughing was 525 yuan/hm^2, and the corn prices in 2009 and 2010 were 1.42 and 1.48 yuan/kg, respectively. In the same column, lowercase letters represent a significant difference in 5% of the statistical test.

The results of two-year experiments showed that among the 9 combinations of fertilization and tillage, the net income of the treatment of deep plowing with balanced fertilization was the highest, with an average of 5104.1 yuan/hm^2, followed by the treatment of balanced fertilization and no-tillage, and the average net income was 4914.3 yuan/hm^2, the last was that of conventional fertilization and deep-plowing treatment, and the average net income was 4705.1 yuan/hm^2.

Tillage measures had no significant effect on soil bulk density before sowing, but had significant effect on soil bulk density after harvest. The soil bulk density of no-tillage was higher than that of traditional tillage and the soil bulk density was significantly increased. Ploughing could keep the soil bulk density maintain at a low level. The effect of water storage and soil moisture conservation of no-tillage and deep-plowing tillage treatments was better than that of ploughing treatments. The deep -plowing treatment showed better water storage capacity and high water use efficiency, and the combination of balanced fertilization and deep -plowing tillage was beneficial to increase income and yield of spring maize in Weibei Arid Highland, which is a suitable planting mode of spring maize conservation tillage in Weibei dry plateau.

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