Influence of different tillage methods on growth characteristics and maize yield after straw returning

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Abstract: In order to study the influence of different tillage methods on production process and growth characteristics of Anhui summer maize of double cropping system after total returning of wheat straw, a comparative analysis was made to analyze and compare four tillage methods in this paper. Through comparative analysis on treatment of preceding wheat straw, maize seeding and harvesting, the indexes of pulverization rate, straw scattering in homogeneity, anti-blockage and crop characteristics were applied to show the production process and growth characteristics of summer maize. Study results showed that, under tillage method A (wheat combine harvester fixed with pulverize and no-till planting of maize), pulverization of preceding wheat straw had significant scattering effects with good performance in anti-blockage; maize grew well at early stage and its yield was improved during harvesting period. The plant height increased by 4.9%; stem diameter increased by 11.75% and yield increased by 7.63% on average.

Keywords: total returning of wheat straw, tillage methods, summer maize, growth characteristics

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1 Introduction

Mechanized total returning of wheat straw can fully utilize straw and increase organic matters in soil, thus improve soil structure by loosening soil, increase porosity, reduce soil bulk density, and increase yield by improving the activity of microorganism and growth of root system. Besides, it can avoid environmental pollution caused by straw burning and benefit the development of ecological agriculture and environment-friendly agriculture. Therefore, the technology of straw returning as an important technology in environment-friendly agriculture is one of the new and key technologies promoted and implemented by Chinese government (Dalal et al., 1986; Zhao et al., 2003; Hu, 2000; Li et al., 2014; Li et al., 2015; Pan et al., 2013).

Compared with tedious traditional methods of crop harvesting including moving away straw, turning up soil and seeding of next season, straw returning can simplify farming stages and save time and cost. Straw returning can also increase the soil surface straw and reduce the evenness of soil surface. The changes in traditional farming will bring about changes in soil condition, seeding method, growth status and yield. Wang pointed out that straw returning effectively increased water-soluble organic carbon (WSOC) in soil by 23%-68% and soil microbial biomass carbon (MBC) by 21%-40% (Wang et al., 2013); the study of Zhao showed that deep ploughing + straw returning can increase soil respiration rate of winter wheat and summer maize by 41.9% and 21%, and can increase dry matter accumulation and improve the growth of root system (Zhao et al., 2014); the study of Yang pointed out that straw returning significantly increased the enzymatic activity of unease and sucrose (Yang et al., 2013). The experts above studied the advantages of straw returning and its influence on growth characteristics of next season crops; however, there are no in-depth discussions on the systematic influence of different mechanized tillage methods on growth

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characteristics and yield.

In this paper, through analysis of different tillage methods and crop yield under total returning of wheat straw in Anhui, an easy, applicable and cost-saving tillage method for total returning of wheat straw was found out, with the aim to provide reference to the mechanized planting model in the wheat-maize rotation system.

2 Materials and method

2.1 Information of test fields

The test was carried out in a 50 mu test field of Anhui Agricultural University in Xiaoxinji Village, Mengcheng county, Anhui province in 2015 and 2016. Mengcheng county is located in the south of the Huanghuaihai Plain, in warm temperate zone and has a semi-humid monsoon climate. It is a region mainly affected by tropic oceanic air mass and polar continental air mass, with temperate and humid climate and four distinctive seasons. The annual average temperature here is 14.7°C, the average temperature in January the coldest month is –0.1°C; the average temperature in July the hottest month is 27.5°C. The area is affected by distinctive alternations of monsoon, with frequent south wind in the summer and north wind in the winter. The mean annual precipitation there is 822 mm; rainfall frequently occurs from June to August; frost-free season lasts for 216 days, annual sunshine hours are 1400-2200 h. The climate is very suitable for growing wheat and corn. The soil in the experiment was Shajiang Black Soil. The soil status after total returning of straw of double crops for two consecutive years is shown in Table 1.

Table 1 Physicochemical properties of soil under different treatment methods

No.	Treatment method	Soil depth, cm	PH	Organic matters, g/kg	Available K, mg/kg	Available P, mg/kg	Total N, g/kg
The first year	Total returning of straw	0-10	6.5	22.69	166	30.22	1.34
		10-20	6.0	19.51	138	16.42	1.45
The second year	Total returning of straw	0-10	7.2	23.71	218	32.44	1.64
		10-20	5.9	20.32	194	18.59	1.23

2.2 Test conditions

The variety "Wanmai 52" were planted on October 1, 2014 and October 10, 2015 (10 kg per mu), and "Jinqiu 963" were planted on June 14, 2015 and June 16, 2016 respectively (5000 seedlings per mu). The maize straw of the two years was pulverized and returned to field by a tractor suspended with a pulverizer. In order to ensure the reliability of the comparative test, the same method was used in middle stage of field management of wheat and maize.

2.3 Test design

Four plots A, B, C, D with equal areas (Figure 2) were selected from the test field (10 mu=6666.7m^2) for four tillage methods in terms of machine in wheat harvesting, treatment method of wheat straw, use of maize seeder, and method of maize harvesting, as is shown in Figure 1.

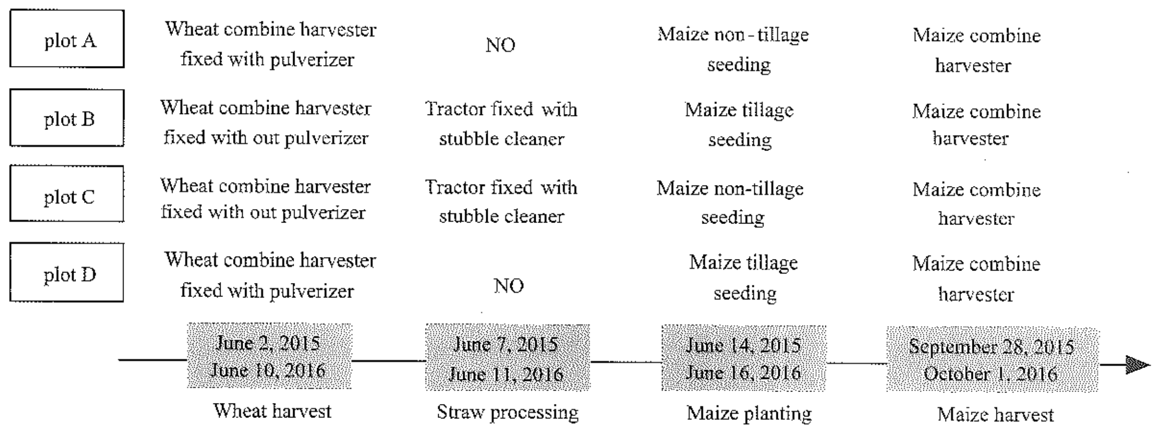

Figure 1 Test design of different tillage methods

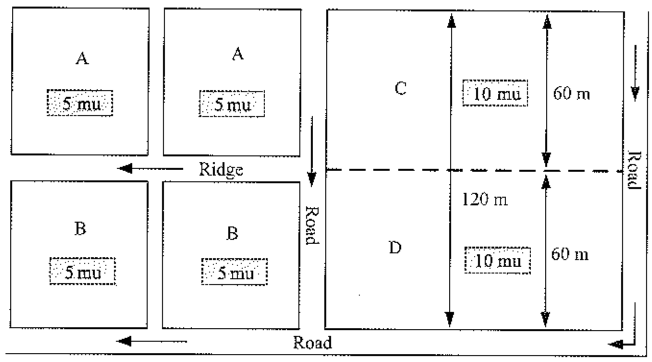

Figure 2 Division of test fields

2.4 Evaluation indexes

In order to scientifically and precisely analyze the differences in working efficiency, growth status of maize, maize yield and tillage economy under different tillage methods, based on the testing indexes of working quality for agricultural machinery formulated by China Agricultural Machinery Testing Center,and according to GB/T 24675.6-2009, *Conservation tillage machinery - smashed straw machine,* -the requirements (GB/T 24675.6-2009, 2009),the indexes of straw pulverization rate, straw scattering in homogeneity, anti-blockage, growth properties of crops and maize yield were selected to comprehensively evaluate different tillage methods in total returning of straw.

2.4.1 Wheat straw pulverization rate and straw scattering in homogeneity

In the four plots of A, B, C, D, a 1m×1m metal frame was used to choose five sampling points, and 20 samples were obtained in all. All straw on ground surface in the range of metal frame of each sampling point was weighed, M (kg); then straw longer than 10 cm after pulverization was chosen and the weight of the straw m (kg), was obtained, and

(1) Straw pulverization rate is: $\eta=(1-\frac{m}{M})\times 100\%$;

where, η is pulverization rate; m is mass of straw longer than 10 cm, kg; M is total straw mass in sampling area, kg.

(2) Straw scattering in homogeneity is

$$F_b=\frac{1}{\overline{M}}\sqrt{\frac{\sum_{i=1}^{5}(M_{zi}-\overline{M})^2}{5}}\times 100\%;$$

where, $\overline{M}$ is the average straw mass in each sampling point of test area, kg; M_{zi} is the total straw mass of sampling point i, kg; F_b is straw scattering in homogeneity, %.

2.4.2 Anti-blockage of seeder

According to property detection and literature of non-tillage seeders by China Agricultural Machinery Testing Center (Sidhu et al., 2007; Luo et al., 2006; Wang et al., 2002), the degrees of blockage within 60 cm of working distance were categorized. The status of straw congestion that hinders machine operation is serious blockage; the status of straw congestion that doesn't need to stop machine is common blockage; the status of straw congestion that can allow automatic flowing between furrow openers is slight blockage; without the status of straw congestion and smooth operation is no blockage.

2.4.3 Determination of plant characters

An analysis was made on plant height and stem diameter of maize seedlings (three-leaf stage) and (ten-leaf stage) under different tillage methods. The 100 maize seedlings were selected randomly in the four plots A, B, C and D to test their plant height and stem diameter. The maximum distance from soil surface to the top leaf in natural hanging status of the maize seedlings is plant height H, cm. The average diameter of maize stem measured on the ground surface by vernier caliper is stem diameter B, mm.

2.4.4 Yield measuring

Two days before maize harvesting, five continuous rows of 3 m long maize seedlings were randomly selected from plots A, B, C and D for ear plucking, threshing and weighing. Some kernels were selected in the samples and put in a drying box at 105°C for drying until the mass became stable. Then the maize yield was calculated based on 14% moisture content.

3 Test results

3.1 Wheat straw pulverization rate and scattering in homogeneity

Then pulverization and scattering status of wheat straw were measured on the plots under the four tillage methods, and the test data are shown in Table 2.

3.2 Anti-blockage test

The seeder walked at a constant speed at first high-speed gear. The stubble height was 20 cm; straw coverage rate was higher than 50% and even reached 90% in some area; the straw qualification rate after pulverization was above 85%; straw mulching quantity was 1.05 kg/m^2. The seeder walked on the field with straw moisture content <15% back and forth for three times. The data of seeder are shown in Table 3.

3.3 Characters of maize plants

The influences of different tillage methods on plant height and stem diameter of maize seedlings (three-leaf stage) and (ten-leaf stage) are shown in Table 4.

3.4 Maize yield measurement

From September 28, 2015 to October 1, 2016, the maize in the test field were harvested and the number of maize seedlings and maize yield were measured, maize yields under different tillage methods were obtained, as is shown in Table 5.

Table 2 Test data of unqualified pulverization

Tillage methods	Mass	Test data in 2015			Test data in 2016		
		Mean value, kg	Pulverization rate, %	Straw scattering inhomogeneity, %	Mean value, kg	Pulverization rate, %	Straw scattering inhomogeneity, %
Method A	M (kg)	0.400±0.03	0.884	0.122	0.424±0.05	0.901	0.120
	m (kg)	0.046±0.02			0.042±0.01		
Method B	M (kg)	0.384±0.06	0.881	0.110	0.414±0.08	0.884	0.105
	m (kg)	0.044±0.03			0.048±0.02		
Method C	M (kg)	0.357±0.03	0.847	0.094	0.248±0.03	0.885	0.086
	m (kg)	0.055±0.07			0.029±0.02		
Method D	M (kg)	0.430±0.08	0.876	0.115	0.237±0.09	0.824	0.105
	m (kg)	0.050±0.02			0.042±0.01		

Table 3 Records of anti-blockage of seeder

Tillage methods (maize seeding)	Test data in 2015			Test data in 2016		
	1st test	2nd test	3rd test	1st test	2nd test	3rd test
A	No blockage	No blockage	No blockage	A slight blockage	No blockage	No blockage
B	Two slight blockages	A slight blockage	No blockage	A slight blockage	A slight blockage	A serious blockage
C	A slight blockage	No blockage	A slight blockage	No blockage	Three slight blockages	A slight blockage
D	A serious blockage	No blockage	Two slight blockages	A slight blockage	A slight blockage	Two slight blockages

Table 4 Plant height and stem diameter of maize seedlings under different tillage methodsin 2015 and 2016

Tillage methods	(Three-leaf stage, 2015)		(Ten-leaf stage, 2015)		(Three-leaf stage, 2016)		(Three-leafstage, 2016)	
	Plant height/cm	Stem diameter/cm	Plant height/cm	Stem diameter/cm	Plant height/cm	Stem diameter/cm	Plant height/cm	Stem diameter/cm
A	23.08±0.12	0.63±0.05	64.58±0.10	2.72±0.06	24.38±0.22	0.79±0.01	64.50±0.14	2.88±0.03
B	22.75±0.18	0.60±0.03	61.64±0.15	2.15±0.07	22.95±0.17	0.64±0.02	62.84±0.25	2.35±0.06
C	22.65±0.11	0.68±0.01	63.08±0.09	2.36±0.04	23.20±0.15	0.69±0.01	63.42±0.16	2.42±0.04
D	21.36±0.09	0.59±0.05	60.26±0.15	2.12±0.03	21.64±0.17	0.60±0.03	59.76±0.25	2.16±0.05

Table 5 Maize yield under different tillage methods

Tillage methods	Maize yield measured in 2015			Maize yield measured in 2016		
	Number of maize seedlings in one test area on average	Maize yield in one test area on average, kg	Yield per mu on average, kg (2015)	Number of maize seedlings in one test area on average	Maize yield in one test area on average, kg	Yield per mu on average, kg (2016)
A	54.4±0.30	8.55±0.16	791.67	57.4±0.36	8.66±0.25	801.54
B	57.0±0.44	7.72±0.21	715.00	57.2±0.43	7.64±0.21	707.66
C	56.2±0.57	8.30±0.32	768.89	56.8±0.65	8.39±0.34	776.42
D	54.8±0.43	8.21±0.15	760.19	54.4±0.36	8.19±0.20	758.50

4 Analysis and discussion

Based on test data of the two years, a comparative analysis was made on mechanized working status, maize characters and maize yield under different tillage methods.

4.1 Analysis on pulverization of preceding wheat straw stalks

Wheat straw pulverization rate and straw scattering inhomogeneity under different tillage methods are shown in Figures 3 and 4.

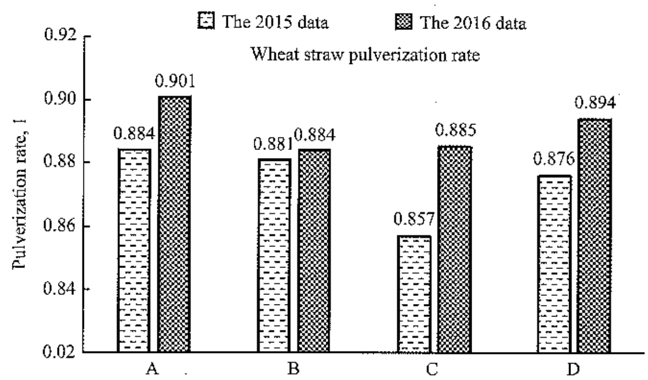

Figure 3 Status of preceding wheat straw pulverization under different tillage methods

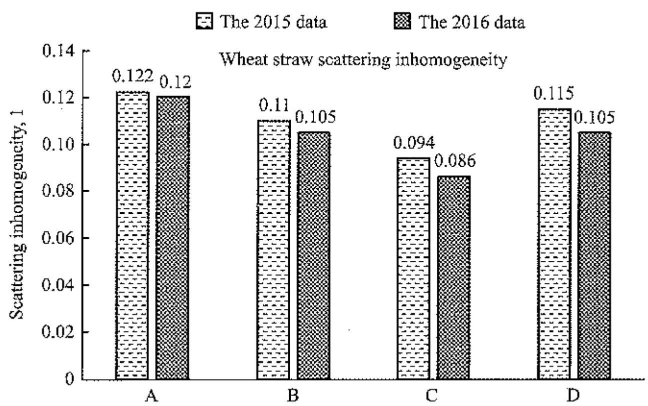

Figure 4 Scattering status of pulverized preceding wheat straw under different tillage methods

The two-year experiment data showed that, under tillage methods A and D, the wheat straw pulverization rate and straw scattering inhomogeneity were better than that under tillage methods B and C, and pulverization rate of wheat straw was increased by 12.3%, straw scattering homogeneity increased by 19.65%.showing that, combine harvester fixed with pulverizer could achieve obvious wheat straw pulverization effects, meanwhile, it can reduce utilization of the machine and thus alleviate machine compaction on soil.

4.2 Anti-blockage analysis

During seeding, the smooth functioning of the seeder can affect the working efficiency as well as seeding quality. Therefore, the two years of test data showed that, compared with tillage method C and method D, the working performance of the maize seeder was improved under method A and method B respectively. The result further verified the conclusion that the pulverization effects of preceding wheat straw were better under tillage methods A and D. Second, compared with method D and method B, the seeder had better performance in anti-blockage under methods A and C, showing good seeding effects for the non-tillage seeder under the same treatment conditions of the preceding wheat straw.

4.3 Analysis on plant height and stem diameter of maize

Test data analysis showed that, the seedlings grew well before the ten-leaf stage under method A, and plant height increased by 3.13% compared with method B, 2.14% compared with method C, and 8.91% compared with method D on average; the stem diameter increased by 10.37% compared with method B, 4.76% compared with method C and 15.22% compared with method D on average, as is shown in Figures 5 and 6. The possible reason might be the high pulverization rate and good straw scattering homogeneity of wheat straw under method A, besides, soil moisture were well preserved and no blockage occurred in seeding. The smooth seeding process resulted in good growth of maize seedlings.

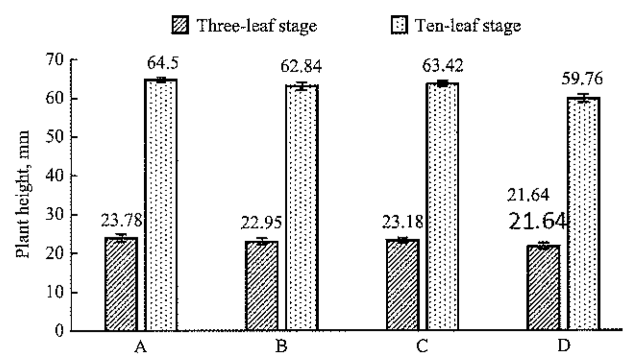

Figure 5 Statistics of maize plant height under different tillage methods

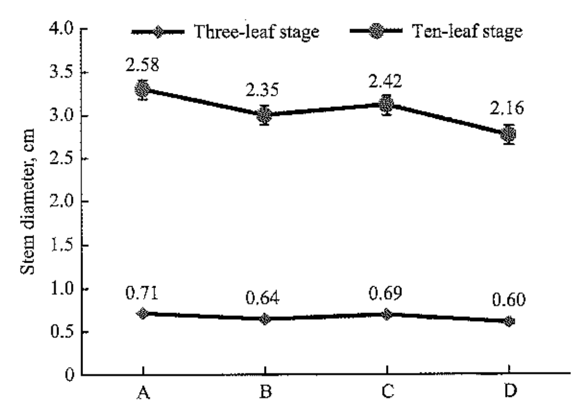

Figure 6 Statistics of maize stem diameter under different tillage methods

4.4 Maize yield analysis

The maize yield under tillage method A increased by 11.99% compared with tillage method B, and increased by 3.10% and 4.91% compared with tillage methods C and D respectively. Under the same field management method, different tillage methods may have different impacts on maize yield. High maize yield can be achieved under tillage method A, one reason is the good growth status of maize seedlings at early stage, and the other reason might be the straw treatment method and seeding method. High straw treatment quality can achieve good decomposition effects and increase nutritional elements in the soil. No blockage occurrence during seeding also ensured the basic number of seedlings per mu and achieved high yield.

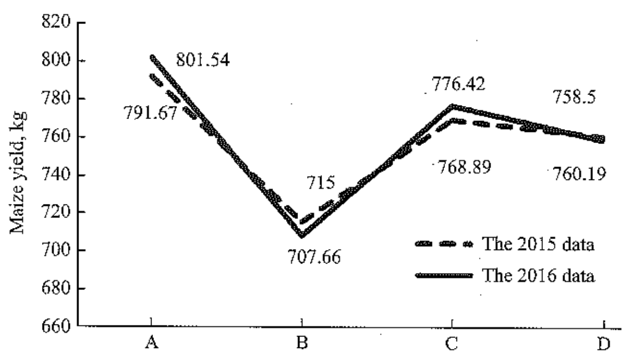

Figure 7 Statistics of maize yield under different tillage methods

5 Conclusions

1) Tests showed that, under tillage methods A and D, combine harvester fixed with pulverizer had better straw returning effects than combine harvester without pulverizer and tractor suspended with stubble cleaner under tillage methods B and C, and pulverization rate of wheat straw was increased by 12.3%, straw scattering homogeneity increased by 19.65%.

2) Tests showed that after total returning of preceding wheat straw, the seedlings grew well before the ten-leaf stage under method A, and plant height increased by 3.13% compared with method B, 2.14% compared with method C, and 8.91% compared with method Don average; the stem diameter increased by 10.37% compared with method B, 4.76% compared with method C and 15.22% compared with method Donaverage. It was consistent with the conclusions of Zhu et al. (2013) that, under the condition of total returning of preceding wheat straw, the growth of maize seedlings was obviously better than that of maize seedlings without wheat straw returning and returning to field for the second time.

3) Tests also showed that after total returning of preceding wheat straw, the maize yield under tillage method A increased by 11.99% compared with tillage method B; increased by 3.10% compared with tillage method C and increased by 4.91% compared with tillage method D.

4) Taking into consideration the indexes such as treatment effects of preceding wheat straw, anti-blockage in seeding, plant characteristics at seedling stage and maize yield, the test data of two consecutive years showed that, in the wheat and maize planting area in Anhui province, the tillage method A (harvesting wheat by applying combine harvester fixed with pulverizer + maize non-tillage seeder + combine harvesting of maize) had better performances after total returning of preceding wheat straw.

Acknowledgements

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