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RESEARCH PAPER

Characteristics of Growth and Development of Winter Wheat Under Zero Tillage in North China Plain

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Abstract: To evaluate the growth and development of winter wheat under zero-tillage treatment in the North China Plain, an experiment using a winter wheat (*Triticum aestivum* L.) cultivar Kenong 9204, with 3 tillage treatments, including conventional tillage with stubble incorporation (CT), rotary tillage with residue returning (RT), and zero tillage with stubble direct drilling (ZT), was conducted in the Luancheng Ecological Experimental Station of the Chinese Academy of Sciences during the 2004–2006 growing seasons. For keeping a similar rate of seedling emergence in all treatments, the seeding rate was increased from 165.0 kg ha^{-1} (in CT and RT treatments) to 262.5 kg ha^{-1} in ZT treatment. In addition to the characteristics of growth and development of wheat, the plough layer temperature and soil water content were also measured. The basic seedling and tillers in the 3 treatments ranked significantly as ZT < RT < CT ($P \leq 0.05$), but the percentage of seed-setting tillers in the ZT treatment was higher than that in the CT treatment. The number of basic seedlings in ZT was lower than that in CT by 28.9% and 11.7% in the 2004–2005 and 2005–2006 growing seasons, and lower than that in RT by 11.7% and 10.0%，respectively. The plant height, leaf area index, dry weight of wheat shoot, and grain yield were the lowest in the ZT treatment because of deficient population. In the ZT treatment, the maximum leaf area indices were 2.9 and 6.0, respectively, in both growing seasons. The grain yield of ZT reduced by 30.1% and 27.2% compared with that of CT and decreased by 15.3% and 25.2% when compared with that of RT, in the 2 growing seasons, respectively. In the ZT treatment, the water content in 0–30 cm soil layer was significantly higher ($P < 0.05$) than that in the CT treatment during the whole growing period. The topsoil temperature was the lowest in the ZT treatment from seedling to revival stages, indicating that ZT had a “lower temperature effect”, which delayed the emergence and revival of seedlings and reduced the tillering rate in the winter wheat. The time of seedling emergence and revival in ZT was 1–3 and 4–5 d later than that in CT and RT, respectively.

Keywords: zero tillage; winter wheat; growth and development; North China Plain

Food production in the North China Plain contributes about 15% of the whole production of China [1]. This has been a major commodity grain production region. However, the agricultural ecosystem of the North China Plain is facing a number of environmental problems that threaten the system stability and sustainability, such as, water resource shortage and crop residue management [2]. New techniques are needed to solve these problems. Zero tillage (ZT) can alleviate and solve these problems in the North China Plain agroecosystem. At present, ZT has been used widely throughout the world for its advantages of soil, water, and labor conservation [3–10]. Many studies have been conducted on the effects of soil, water, and crop growth under ZT, but only a few have been carried out in the multicropping system. In the North China Plain, studies have often focused on ZT for maize (*Zea mays* L.). Compared to maize, the studies on winter wheat, under ZT, are few and the results are not consistent because of different experimental conditions.

It was reported that the average yield of winter wheat of ZT was higher than that of the conventional tillage in Zhangqiu County, Shandong Province [11]. It was proved that ZT of winter wheat had a good performance in Hebei Province [11]. Liu et al. [5] showed that the highest total yield was observed in ZT plus 100% straw mulch treatment in the wheat–maize double cropping system in Hebei Province.

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However, high soil resistance and poor soil aeration were found in ZT. These factors affected the root growth of winter wheat and limited the absorption of water and nutrients, which made the wheat seedlings weak [12]. Some studies pointed out that the lower soil temperature in ZT affected the early growth of winter wheat by delaying seedling revival and eventually decreased grain yield [13–15].

Tillage practices changed the physical, chemical, and biological properties of soil and affect the growth of winter wheat. Li et al. [16] concluded that the reasons for the decreasing emergency rate for winter wheat in the ZT system were residue hinders, seed rotting, too shallow or too deep seedings, and insufficient soil moisture. However, some investigators considered that “low temperature effects” in ZT greatly influenced wheat growth. The objective of this experiment was to compare the effects on winter wheat emergency, growth, soil temperature, and moisture in the 3 tillage systems Based on this study, some supplementary measures for ZT were suggested, which would benefit the extension of ZT in the North China Plain.

1 Materials and methods

1.1 Experimental site

In 2001, this study was initiated at the Luancheng Ecological Experimental Station of the Chinese Academy of Science (37°50' N, 114°40' E). The experiment station is located in the middle-south of the Hebei Province in North China, which is was the typical region of the Taihang Mountain plain. The climate of this region belonged to the semi-humid temperate zone. The average precipitation is 494 mm and distributed unevenly in a year. The rainfall of the 2004–2006 growing seasons is given in Table 1. The soil was a gray-brown, light loam soil. The average bulk density of the topsoil was 1.39 g cm^{-3}. The chemical properties of the soil are shown in Table 2.

1.2 Experiment design

The experiments consisted of conventional tillage (CT), rotary tillage (RT), and ZT treatments. Each treatment was replicated thrice. In the CT treatment, the total maize stalk was crushed and remained on the soil surface, and fertilizer was spread over the fields; next, the soil was tilled once to a depth of 5 cm with the rotary tillage machine, to make the residue and chemical fertilizer distribute evenly and plowed 20 cm deep once, using moldboard plowing. In the RT treatments, the total maize stalk was crushed and left on the soil surface, and fertilizer was spread over the fields; followed by the soil being tilled twice to a depth 10 cm, with the rotary tillage machine. In the ZT treatment, the maize stalk was maintained standing in the field after harvest, and the stalk crush, fertilizer, and seeding was completed once with a ZT planter; ridges and furrows were formed on the soil surface after seeding and the seeds of the wheat cultivar Kenong 9204 were planted in the furrows.

At planting, urine and MAP ($NH_4H_2PO_4$) were applied at a rate of 188 and 300 kg ha^{-1}, respectively. At the revival stage, urine was added at a rate of 300 kg ha^{-1}. Irrigation was adjusted according to the rain (Table 3). The seeding rate was 165 kg ha^{-1} for CT and RT. Considering that the sowing quality was not good for the ZT treatment, the seed rate was increased to 262.5 kg ha^{-1}.

Table 1 Monthly rainfall during 2004–2006 growing seasons of whiter wheat (mm)

Growing season	October	November	December	January	February	March	April	May	June
2004–2005	4.2	6.2	11.4	0.5	8.0	0.0	10.6	63.3	10.0
2005–2006	2.2	0.0	0.3	1.5	0.4	0.0	10.5	79.1	28.7

Data are from the Luancheng Ecological Experimental Station of the Chinese Academy of Sciences.

Table 2 Chemical properties of tested soil

Soil layer (cm)	Total N (%)	Alkali-hydrolysable N (mg kg^{-1})	Available K (mg kg^{-1})	Available P (mg kg^{-1})	Organic matter (%)
0–10	0.074	37.95	115	62.90	1.28
10–20	0.064	30.58	90	39.62	1.24
20–30	0.045	27.99	65	23.32	0.99

Data are from Luancheng Ecological Experimental Station of the Chinese Academy of Sciences.

Table 3 Irrigation management during 2004–2006 growing seasons (mm)

Growing season	Seeding	Overwintering	Revival	Jointing	Heading	Flowering	Filling
2004–2005	37.5	60.0	0	60.0	0	0	0
2005–2006	0	60.0	60.0	52.5	22.5	15.0	45.0