

## Effect of Ridge Tillage on Grain Quality and Dough Properties of Spring Wheat in the Northeast China

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### Abstract

### Original Research Article

Ridge tillage could change soil temperature and water patterns compared to conventional tillage, thus improve growth of plant root and absorption of mineral nutrient, which was available to enhance grain yield and quality. Ridge tillage was conducted on quality of spring wheat, field experiments in two successive years. Three cultivars of spring wheat (Longmai 26, Longfumai 16, Kehan 16) were sown equally with 15-20 cm distance in crown of ridge formation with 70 cm width × 20 cm height, and were entirely harvested and determined grain quality, as well tested flour and dough properties after milling. The results showed that ridge tillage decreased soil temperature of 0-5 cm depth compared to conventional tillage at mid-tillering stage and blooming period of spring wheat by 3.6 °C and 1.4 °C, respectively, as well narrowed the temperature gap between 5 cm depth and 25 cm depth. Moreover, ridge tillage enhanced the activity of soil urease and acid phosphatase of 0-5 cm depth by 31.6 % and 16.5 %, respectively. In 2016, ridge tillage increased significantly protein content of grain and flour, sedimentation value and gluten content of flour by 17.2 %, 50.0 %, and 38.1%, respectively. In spite of slight increase was found for these parameters in 2017, the efficacy of ridge tillage was not obvious. In addition, ridge tillage improved markedly doughy rheological parameters, including water absorption, doughy formation, stability, and extensibility in 2016, and showed significant increase of doughy stability, extension energy and extension resistance in 2017. Ridge tillage adjusted soil environment of rhizosphere, furthermore improved grain quality and end-product properties of spring wheat in Northeast China.

**Keywords:** Ridge tillage End-use quality Soil temperature Soil enzyme activity.

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## INTRODUCTION

Ridge tillage (RT) is the term for any cropping system in which plants are grown on soil formed into raised beds or ridges [1]. RT provided a better water and temperature condition for crop emergence and growth [2, 3]. In addition, ridge operation also adjusted heat and water balance of soil [4, 2, 5], and improved the poor condition caused mouldboard ploughing system for C and N mineralization [16].

RT generated a favourable soil conditions to the plant growth by transforming microtopography. The advantage of RT in wheat not only appeared positive effects on root growth by lower bulk density of soil [7, 8], but also increased grain yield and quality [9, 10] compared with conventional tillage (flat cultivation, CT). It was reported that RT increased maize and sorghum yield by 14 %-106 % and 6%-59 % respectively compared to CT [11]. Hao demonstrated RT could improve the flour-milling rate of wheat grain and milling quality by 3.3 %-6.4 %, and improved grain yield by 9.0 %-14.6 %, but did not affect significantly

on end-product quality, such as grain protein content, water absorption rate of flour and dough development time [9]. Wang *et al.* demonstrated the effect of RT on dough properties were connected with genotype of wheat cultivar, and there was different efficacy on gluten content, sedimentation value and dough stability time [10]. It is well-known that end-product quality and dough properties depended on protein content and quality of grain, more over protein content of grain was related markedly to supplying ability of soil nitrogen nutrition and rhizosphere environment [12-14].

RT increased net radiation absorption by enlarging undulating surface, and improved soil temperature and influenced water balance [4]. RT has higher temperature and moderate desiccation [2, 5], which stimulated nitrogen mineralisation of soil and nitrogen assimilation of wheat plant [15]. In addition, RT increased amino acids content of post-floral growth, and enhanced the activity of nitrite reductase of leaf, and promoted the transportation of nitrogen from leaf to grain [15]. Abundant available nitrogen nutrition at grain-filling stage reduced higher flour protein content,

total high-molecular weight-GS content, and end-use quality [14]. Two field trials were conducted by comparing RT with CT in spring wheat to evaluate soil properties in RT, and the effect of RT on quality of grain and dough properties.

## MATERIALS AND METHODS

### Study site

The study was conducted from 2016 to 2017 at Mishan, Heilongjiang Prince, China (45°63'N; 131°80'E). The agrotype was meadow albic bleached soil. The mean annual air temperature and precipitation were 3.5 °C and 566.2 mm from January to December, respectively. It is a moderately well-drained loamy soil with a deep profile that is considered highly suitable for crop production. The average organic matter content in the tillage layer (0-20 cm) was about 38.2 g kg<sup>-1</sup> and the available N, P and K were about 160.7 mg kg<sup>-1</sup>, 44.4 mg kg<sup>-1</sup> and 110.7 mg kg<sup>-1</sup>, respectively. Soil pH value around 6.

### Experimental design

Prior to spring wheat, soybean (*Glycine max*) was grown as a single-season crop before winter (October 11, 2016 and October 7, 2017, respectively). Soybean was harvested by soybean combine harvester, and straw of soybean plant was chopped and thrown above ground, thus remnant and stubble of plant were cut short and mixed with soil by rotary tillage stubble cleaner, then crop materials were either pressed to the ground with rollers. The ridge systems were established by three-row spreader with plough, and adjoined plots of untreated with RT (CK) on October 23, 2016 and October 21, 2017, respectively. Meanwhile, mixture chemical fertilizer with 120 kg ha<sup>-1</sup> (N: 46 kg ha<sup>-1</sup>; P<sub>2</sub>O<sub>5</sub>: 50 kg ha<sup>-1</sup>; K<sub>2</sub>O: 24 kg ha<sup>-1</sup>) was applied in soil with 18-20 cm deep. The height of ridges was 15 cm, and distance of centre line between ridges was 90 cm, and the width of ridge was 70 cm. The length of each plot in this trial was 10 m, included 4 ridges. The layout of the experiment was a split plot design, and cultivation formation as main factor, while cultivar as sub-factor.

The experimental wheat cultivars consisted of Longmai 26 (LM26), Kehan 16 (KH16), and Longfumai 16 (LFM16), which were conventional spring wheat at local experimental location. KH16 was medium gluten content genotype, and LM26 and LFM16 were high gluten content genotype, which contained protein of 14.8 %, 16.4 %, 16.1 %, respectively, as well were registered (in China). Three cultivars were sown in 2017, but only LM26 was sown in 2016.

Conventional tillage was conducted with a sowing machine for experimental plots (eight-row), while ridge tillage was formed with an eight-row sowing machine with two ridges (specially made for this study). There were four rows of seed in ridge, and were parallel arranged according to internal distance

with 15 cm, 20 cm, and 15 cm, respectively. The weight of seed for sowing was 230 g per plot. Meanwhile, mixture chemical fertilizer with 60 kg ha<sup>-1</sup> (N: 23 kg ha<sup>-1</sup>; P<sub>2</sub>O<sub>5</sub>: 25 kg ha<sup>-1</sup>; K<sub>2</sub>O: 12 kg ha<sup>-1</sup>) was applied in soil 1-2 cm under seed with sowing.

### Samplings and measurements

#### Soil temperature

Soil temperature was measured with mercury thermometer in 2017. Thermometers were installed after sowing in 5 cm, 10 cm, 15 cm, 20 cm, and 25 cm depth, respectively in representative plot. Daily means temperature was investigated in 2017 at mid-tillering stage and blooming period, respectively. Thermometer data were recorded at 8:00, 14:00, 16:00 and 18:00, respectively.

At blooming period, various layer of soil sample were punched by pocket earth drill from soil surface to 20 cm depth. Soil subsample were mixed entirely in 5 cm thick layer and signed with 0-5 cm, 5-10 cm, 10-15 cm, 15-20 cm, respectively. Each soil subsample was pretreated and determined urease activity [16] and acid phosphatase activity [17].

#### Determination of product quality parameters

Grain was harvested during the last week of July in both seasons (2016 and 2017). The whole plot was harvested by manual cutting and threshed by a thresher (5TDS-200, Hongxinglong Machine Making Factory, China). The grain of each plot was cleaned individually, thus air dried and stored.

The parameters of grain quality were performed as follow: weight (using HGT-1000, Orient Weighing Apparatus Factory, and China), protein content and sedimentation (using Infratec™ 1241 Grain Analyzer, Foss, Switzerland).

The wheat grain was moistened at the relative humidity of 15 % for 18 h and was ground by a Brabender Quadrumat Junior mill (Duisburg, Germany) with a 335 µm sieve for experimental flour.

The protein content of flour was determined by near-infrared reflectance spectroscopy on a 14 % (w/w) moisture basis (NIR-Systems, Perten, Sweden), and the falling number was conducted by FN-1500 (Falling Number Apparatus, Perten, Sweden). Wet and dry gluten content were determined according to AACC38-12 standard method by GQAS-2020 (Gluten Quality Analysis System, Perten, Sweden)

#### Investigation of rheological dough parameters

Farinograph parameters were determined according to the GB/T 14614-2006 (RACI, 2006) with a Farinograph (Brabender-AT, Duisburg, Germany) fitted with a 50 g stainless steel mixing bowl using the constant flour weight procedure (50.00 g flour with 14.0 g/100 g moisture). Extensograph parameters were

determined according to the GB/T 14615-2006 (RACI, 2006) with a Extensograph (Brabender-E, Duisburg, Germany). Optimal water absorption for the Farinograph analyses was determined iteratively with different amounts of water. The following Farinograph parameters were recorded: water absorption, dough development time, dough stability, and dough elasticity. The following Extensograph parameters were recorded: maximum resistance, extensibility, extension area and ratio.

### Data analysis

All the data of quality parameters collected were statistically analyzed using ANOVA to test the difference in grain quality, flour quality and rheological dough parameters among different treatments. The F-test indicated statistical significance at  $P < 0.05$ , mean comparisons were made by the least significant difference method.

## RESULTS AND ANALYSIS

### Soil chemical and physical properties

Soil temperature gradually reduced in the range of 0 to 25 cm depth, and surface soil has higher temperature than deep soil (Figure 2). At mid-tillering stage of wheat, the temperature difference (the difference of temperature between 25 cm and 5 cm depth) of RT was only 4.8 °C, while CT was 9.7 °C. RT decreased soil temperature by 2.3-3.6 °C in the range of 0 to 10 cm depth compared with CT, and was similar to CT in the range of 15 to 20 cm depth, while increased it by 1.3 °C in 25 cm depth (Figure 2). However, the soil temperature of RT was slightly lower than that of CT at blooming period of wheat in all layers, and RT lowered temperature by 0.1-1.4 °C compared with CT (Figure 2). The temperature difference of RT was still maintained 4.1 °C, while the temperature difference of CT was shrunk 5.4 °C.

In the soil surface (0-5 cm) and 15-20 cm depth, RT increased activity of soil urease compared to CT by 31.6 % and 22.0 %, respectively (Figure 3). However, activity of urease of RT was similar to CT in the range of 5 to 15 cm. Moreover, CT has most high activity of urease in the range of 10 to 15 cm depth, while RT in 0-5 cm depth (Figure 3).

Activity of soil acid phosphatase decreased with soil depth (Figure 4). RT increased activity of soil acid phosphatase compared to CT by 1.5 %-33.5 %, respectively the soil surface (0-5 cm) and deep layout (15-20 cm).

### Grain quality

RT slightly increased the grain protein content by 0.3%-0.8 % compared with CT in 2017 according to overall results of grain quality, whereas RT significantly increased the grain protein content by 2.3 % in 2016 (Table 1). In addition, RT also enhanced drastically the grain sedimentation value by 3.5 (LM

26) and 5.9 (LFM 16) compared with CT in 2017, respectively, and significant increase of 15.2 was showed on sedimentation value in 2016 (Table 1). There was no significant difference in grain weight for KH16 and LFM16, however, ridge tillage has increased markedly by 16 g L<sup>-1</sup> and 23 g L<sup>-1</sup> on grain weight for LM26 in 2017 and 2016, respectively (Table 1).

### Flour quality

The similar profile of grain protein content was appeared in flour protein content, which was increased slightly by 0.2%~0.7 % in 2017, and increased signally by 2.7 % in 2016 (Table 2). As well, the wet gluten content of flour between cultivation treatments was not different significantly in 2017, while RT increased it compared to CT by 7.9 % in 2016. On the contrary, there was no significant difference for the flour falling number in two consecutive years (Table 2).

### Dough Properties

RT increased significantly water absorption and dough formation time compared with CT in 2016 by 2.6% and 0.9 min, respectively, whereas increased slightly that of in 2017. The dough stability in RT was enhanced distinctly by 2.1 min and 1.5 min in 2016 and 2017 respectively. Similarly, RT also improved dough elasticity compared with CT by 35.4 BU in 2016, 13 BU in 2017, respectively (Table 3). In addition, RT improved noticeably end-produce properties of dough including extensibility, extension area and resistance in 2017, while only increased extensibility in terms of statistical evaluation in 2016 (Table 4).

## DISCUSSION

Spike differentiation and blooming were two necessary stages for wheat growth, honoured as two turning points for the formation of grain yield and quality. RT increased continuously soil pores, and resulted in abundant soil air [18], thus reduced bulk density of soil [19]. Soil porosity influenced the hydrology and thermal status of agricultural soils [2, 20]. Soil temperature in the range of 0 to 5 cm depth of RT was reduced by 3.6 °C compared with CT due to variation of heat exchange between surface soil and air (Figure 2). As power to drive spike differentiation process [21], lower temperature delayed and prolonged it [21, 22], on account of tillering node was located at 3-4 cm deep of soil surface. It was reported that yield volume was often higher when the prophase of spike differentiation was slower, for example spikelets per spike and TKW [23, 22], so increase of protein content of grain was available.

The activity of urease and acid phosphatase increased in loose soil [24], and a ridge scheme with highest inorganic nitrogen contents and available phosphorous was observed in the crown [19]. In this study, activity of urease and acid phosphatase of RT in the range of 0 to 5 cm depth were increased by 31.6 % and 16.5 % compared to CT, respectively. Therefore,

RT provide abundant resource of available nitrogen and phosphorous for the grain protein synthesis, and promoted increase of grain protein content.

In 2017, the grain protein content of RT was increased slightly by 1.2%-4.8 % (Table 1), but not reached significant on statistic valuation, and three tested cultivators had similar appearance in this study. However, RT increased markedly not only grain protein content by 17.8 %, but also flour protein content by 50.0 % in 2016. So RT had better efficacy on increasing grain protein content in the case of not conducive to nitrogen metabolism (LM26 has only protein content of 13.4 % for CT in 2016), while no obvious performance was showed under opposite condition (LM26 has high protein content of 17.1 % for CT in 2017). It was also proved from variation of test weight and sedimentation value of grain (Table 1). In addition, decomposition of crop residue and weeds, and other hydrolysis of organic matter in different air temperature and moisture appeared large regional and inter-annual difference.

There was significant difference of ridge efficacy between cultivars. RT influenced obviously the allocation and accumulation of carbohydrate (photosynthetic products) for medium gluten content genotype (KH16), while affected significantly nitrogen assimilation and protein synthesis for high gluten content genotype. Similar phenomenon was observed in study of Wang *et al.* [10] and Li *et al.* [25]. RT increased significantly gluten content and sedimentation value for Yannong19, but not influenced dough stability, while opposite efficacy for Jimai19 [10]. RT decreased significantly the canopy temperature for the multi-spike cultivars, while not influenced it for the large-spike cultivars [25]. The possible reason was that various genotype cultivars had different ability of nitrogen utilization efficiency and allocation of photosynthetic products. In the previous study, the grain protein content of LM26 was increased with increasing fertilization application, while the grain weight of KH16 was increased at same fertilization level [26]. Namely, LM26 has superior nitrogen utilization efficiency compared to KH16.

For the same cultivar (LM26), RT influenced continuously doughy stability and extension in 2016 and 2017, while affected doughy formation in 2016 (low level of protein content), as well affected processing characteristics in 2017 (high level of protein content). Flour water absorption and doughy formation time were also inferior when protein content was lower [27]. RT can increase grain protein content, so water absorption ability was improved, and doughy formation time was increased. When grain protein content was superior, RT improved simultaneously production of protein and starch. Adhesive strength between gluten protein and starch granule was strengthened [28], so flour sedimentation value and extension resistance of dough were improved. On account of limitation of

experimental condition and test cost, only one cultivator was determined with flour farinograph and doughy extensograph characteristics. Various genotypes should were assayed for evaluation of effect of RT on end-use quality of wheat grain in the following research.

## CONCLUSION

Ridge tillage (RT) decreased the temperature of surface soil (0-10 cm), and increased the temperature of deep soil (20-25 cm), furthermore shrunk the gap of temperature between cropping soil layers at mid-tillering stage of spring wheat. Meanwhile, ridge system decreased slightly the temperature of cultivated soil (0-25 cm) at blooming period, and promoted the activity of soil urease and acid phosphatase. RT improved the nitrogen metabolism of wheat plant due to response of rhizosphere environment to ridge system. Consequently, RT improved the sedimentation of grain, stability and extensibility of dough. When grain protein content was relatively low level, RT increased markedly protein content and test weight of grain, furthermore increased significantly wet gluten and water absorption content of flour, moreover improved formation time of dough.

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