Soil & Tillage Research 153 (2015) 137–144

Contents lists available at ScienceDirect

Soil & Tillage Research

journal homepage: www.elsevier.com/locate/still

Effect of controlled traffic system on machine fuel saving in annual two crops region in North China Plain

Hao Chen*, Yali Yang

College of Automotive Engineering, Shanghai University of Engineering Science, Shanghai 201620, China

ARTICLE INFO

Article history:
Received 5 November 2014
Received in revised form 21 May 2015
Accepted 2 June 2015

Keywords:
Controlled traffic
Small and medium machinery
Traction
Fuel consumption
Crop yield

ABSTRACT

Energy saving was one of the main benefits of controlled traffic system. Research on the energy conservation mechanism of controlled traffic system with medium and small scale agricultural machinery was conducted in the North China Plain, to quantify the energy benefits of controlled traffic system. Two treatments were included: zero tillage with controlled traffic (NTCN) and zero tillage with random traffic (NT). Results showed that controlled traffic system can increase soil compaction in traffic lane and reduce soil compaction in crop zone. Controlled traffic system can reduced machinery field working force significantly through lower tire rolling resistance from relatively harder permanent track, and lower tine opener working resistance from softer soil in crop zone. Compared with NT, NTCN reduced traction force by 14.6%, 13.3% and 13.3% at subsoiling, wheat and maize no-till planting. Consequently, fuel consumption was reduced in all machine operation in controlled traffic system. Compared with NT, two years total fuel consumption in NTCN was significantly reduced by 19.79 L/ha (23.7%). Besides, controlled traffic increased total annual yield and WUE by compensating yield loss in winter wheat through the yield benefit in summer maize, even though 30% of the field was occupied by the permanent traffic lanes. Although these results were preliminary, it was indicated that controlled traffic system was fuel saving system in small and medium machinery condition in North China Plain.

1. Introduction

As the main agricultural production base, the North China Plain, which includes the provinces of Hebei, Henan, Shandong, Beijing and Tianjin, has about 18 million hectares of farmland (18.3% of the national total) and represents 20% of total food production in China (Sun et al., 2007). The main cropping system in the North China Plain is annual double crop, summer maize and winter wheat. Conservation tillage showed significantly higher performance in both soil conservation and crop yield in the region (He et al., 2009). Over 1 million hectares of farmland are now under conservation tillage in arid and semiarid regions of northern China (Li et al., 2011).

This region is characterized by high mechanization index (6–10 kW/hm^2), mostly medium and small scale machinery, which is far above the national average. Random traffic caused 60% of the ground area being trafficked by wheel using minimum tillage systems and 100% for zero tillage system (Kingwell and Fuchsbichler, 2011). Wheel traffic increased soil strength and the draft requirement of subsequent tillage and operations, nearly 50% of energy was implemented for soil loosen (Burt et al., 1994). Due to the high level on agricultural mechanization, serious soil compaction had been observed in previous studies on conservation tillage in annual double crop region in North China Plain (He et al., 2011). As an intensified machinery operation region with medium and small scale machinery, many passes were included in the field operation. The steadily growing soil compaction resulted in higher fuel consumption, which significantly restraint the benefits of conservation tillage system in North China Plain (Li et al., 2011).

Controlled traffic system is a valuable system to solve soil compaction issue, in which crop areas and traffic lanes are permanently separated to provide optimal conditions for crop growth (not trafficked) and traction (compacted) (Gasso et al., 2013). The penalties of wheel traffic compaction and benefits of controlled traffic have been demonstrated by a number of researchers, including Chamen et al. (1992), Hamza and Anderson, (2005), Tullberg et al. (2007), Tullberg (2010) and Li et al. (2009). Among all the benefits, energy saving was one of the main purpose for controlled traffic system. Cooper et al. (1969) reported an indirect energy economy due to less need for deep tillage in controlled traffic system. Campbell et al., (1986) reported 14% reduction on barley planting energy consumption in controlled

* Corresponding author. Tel.: +8613585901312.
E-mail address: pschenhao@163.com (H. Chen).

http://dx.doi.org/10.1016/j.still.2015.06.001
0167-1987/

traffic system. Williford (1980) pointed out that energy increase for subsequent tillage after soil compaction nearly equaled to the energy consumed in soil compaction induced by tires. Tullberg (2000) demonstrated that controlled traffic reduced draft by more than 30%, and increase operation efficiency.

In northern China, series researches have been conducted in controlled traffic system, under medium and small scale agricultural machinery condition, mainly focusing on soil improvement and water conservation, and crop performance (Chen et al., 2008; Wang et al., 2009; Bai et al., 2009), and illustrated that controlled traffic system is a valuable system for soil and water conservation for sustainable development of agriculture in northern China.

However, application of controlled traffic system was restricted due to the lack of energy saving mechanism under small and medium machinery condition. There was no systematic research on the energy saving mechanism of controlled traffic system. Only a few researches were conducted for preliminary study. Huang et al. (2007) reported significant reduction on tine opener working resistance in controlled traffic system in North China Plain. Li et al. (2000) and Chen et al. (2010) observed significant lower machine rolling resistance in controlled traffic system, which resulted in obvious fuel saving during field operation. He et al. (2012) reported controlled traffic system reduced total fuel consumption significantly in the arid northwest China, compared with traditional tillage system. The lack of quantified data on energy saving, especially in farm level practice, was one of the obstructions for the promotion of controlled traffic system in this region.

The objective of this work was to investigate the energy saving mechanism of controlled traffic system with medium and small scale agricultural machinery in the North China Plain, to further quantify the benefits of controlled traffic system and promote its application.

2. Materials and methods

2.1. Site

Experiments were conducted at Daxing (39°7′N, 116°4′E) district, Beijing, from 2004 to 2007. Daxing lies in south Beijing in a semi-humid region 45 m above sea level. Average annual temperature is 11.9 °C with 186 frost-free days. Average annual rainfall is 526 mm, in which more than 70% occurs during June–September. Double cropping system with winter wheat and summer maize is the main cropping system practiced in this region. Summer maize is seeded in early June and harvested in the middle of September. Winter wheat is then seeded in early October and harvested in the following June.

Soil is defined as silt loam according to the USDA texture classification system, which is low in organic matter (<1%) and slightly alkaline (pH 7.7). Soil in this region is generally described as porous and homogenous to considerable depth with limited variance across fields.

2.2. Experiment design

At the beginning of the experiment in 2004, the entire field was plowed to a depth of 40 cm to mix soil thoroughly and provided uniform soil condition in each experimental plot. The plot was 9 m wide and 90 m long. The experimental design was a random block with 4 replications. Two treatments were used: zero tillage with controlled traffic (NTCN) and zero tillage with random traffic (NT). Both treatments consisted of zero tillage with full residue retention for both wheat and maize.

NTCN: winter wheat was no-till planted at early October. Three times of irrigation were applied in late November, next March and middle May. Winter wheat was harvested at early June. Then, summer maize was no-till planted at middle June, and harvested at late September. Before winter wheat planting, the maize residue was chopped. All residues were return to the filed. All traffic was controlled to the permanent wheel track.

NT: winter wheat and summer maize was growing following the same procedure as NTCN. The only difference was that the traffic was not controlled. Random traffic was applied in the field.

The layout of the crop and permanent traffic lanes in controlled traffic treatment NTCN was shown in Fig. 1, designed according to the characteristics of the local tractors and harvesters. Seven rows of winter wheat and two rows of summer maize were planted in 1.5 m beds. The width of each wheel track was 0.45 m, occupying 30% of the ground area. In NT treatment, there was no permanent track lane. Wheat and maize were uniformly planted in each plot, 20 cm and 75 cm, respectively. The plot was 9 m wide and 90 m long. The experimental design was a random block with 4 replications.

Winter wheat was Jingdong-6 at a seeding rate of 120 kg/ha, and summer maize was Jingyu-13 at a seeding rate of 37.5 kg/ha, both of which were the most widely used varieties in the region. Urea ($CO[NH_2]_2$), $(NH_4)_2HPO_4$ and KCl (K_2O content: 60%) were applied to provide 95 kg N/ha, 75 kg P/ha and 40 kg K/ha as the basal N, P, K fertilizer at planting time. An additional 50 kg N/ha was applied at first-node stage for winter wheat. Summer maize sowing density was seven plants per m^2 and a complete fertilizer ($N–P_2O_5–K_2O$) was applied at the rate of 85 kg N/ha, 45 kg P/ha, and 40 kg K/ha at planting. Roundup (glyphosate, 10%) was used for weed control during summer maize growing season.

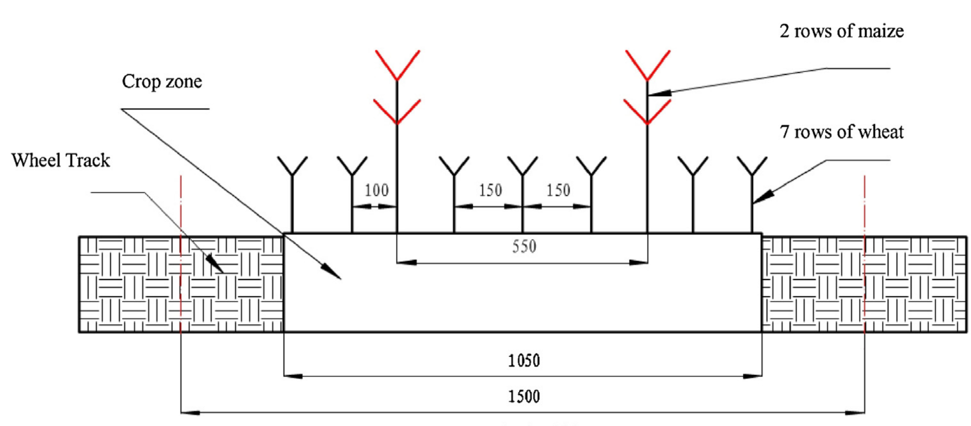

Fig. 1. Traffic lanes and crop row layout for winter wheat and summer maize on NT treatment (units: mm).