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RESEARCH ARTICLE

Stand establishment, root development and yield of winter wheat as affected by tillage and straw mulch in the water deficit hilly region of southwestern China

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Abstract

Good crop stand establishment and root system development are essential for optimum grain yield of dryland wheat (*Triticum aestivum* L.). At present, little is known about the effect of tillage and straw mulch on the root system of wheat under dryland areas in southwestern China. The aim of this study was to evaluate the effect of three tillage treatments (no-till, NT; rotary till, RT; conventional till, CT) and two crop residue management practices (straw mulch, ML; non-straw mulch, NML) on stand establishment, root growth and grain yield of wheat. NT resulted in lower soil cover thickness for the wheat seed, higher number of uncovered seeds, lower percentage of seedling-less ridges and lower tiller density compared to RT and CT; ML resulted in higher tiller density compared to NML. Straw mulching resulted in more soil water content and root length density (RLD) at most of the growth stages and soil depths. The maximum RLD, root surface area density and root dry matter density were obtained under NT. In the topmost 10 cm soil layer, higher RLD values were found under NT than those under RT and CT. There were no significant differences in the yield or yield components of wheat among the tillage treatments in 2011–2012, but NT resulted in a significant higher yield compared to RT and CT in 2012–2013. Grain yield was significantly higher in ML compared to in NML. A strong relationship was observed between the water-use efficiency and the grain yield. Both NT and ML proved beneficial for wheat in term of maintaining higher tiller density, better soil water status and root growth, leading to a higher grain yield and enhanced water-use efficiency, especially in a low rainfall year.

Keywords: wheat, tillage, mulch, stand establishment, yield, *Triticum aestivum*

1. Introduction

The southwestern region is one of the five major wheat-producing areas in China with cultivated area of approximately 2.2 million ha (Ministry of Agriculture 2011). Wheat, as a dominating food crops, is very important for crop production and framers' income. However, cropland in this region is mainly distributed in the hills and mountains with high slopes and weak agricultural infrastructure. The lack of irrigation facilities are the most common constraints for wheat pro-

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duction. Generally, wheat is sown in early November and harvested in late April to early May; drought often occurs during the growth period, resulting in poor seeding establishment and growth (Tang *et al*. 2014). It is difficult for large agricultural machinery to work in the fields because of small and scattered land with high slopes and steep and narrow roads. Therefore, farmers use hoes to cultivate land for the last 2000 years until the wide application of the micro-tillage machine is available for the rotary tillage farming. Currently, although no-till is very common in the rice-wheat system, it is rarely adopted in dryland region. In addition, straw has provided farmers with fuel and fodder for a long time, but with the movement of rural labor to cities and the improvement of the fuel structure, straw is of no use, affecting wheat cultivation (Tang *et al*. 2013). Therefore, studying the effect of the tillage and straw mulch on stand establishment and yield of wheat could be critical for improving crop production, especially in dryland areas.

Several studies have demonstrated that reduced tillage, especially no-till with straw mulch, could improve the soil structure, enhance the soil water conservation and promote root growth (De Vita *et al*. 2007; Martínez *et al*. 2008). Govaerts *et al*. (2005) reported that soil under straw mulch has higher water content than non-straw mulch during major growth stages under no-till conditions. In addition, compared to conventional tillage, many researchers have demonstrated that no-till has better water conservation and root system development, which benefits wheat nitrogen uptake and grain yield. Alvarez *et al*. (2009) found that the soil water content during the critical periods of sowing and flowering was generally 13–14% greater under no-till and that a higher soil water content may satisfy the evapotranspiration demand of 1–3 d of crops. Merrill *et al*. (1996) explained that no-till generally enhances root length growth more than above-ground growth due to superior soil water conservation in the near-surface zone conferring a root growth advantage. In the top 5 cm of soil, the root length density (L_v) was greater under no-till compared to under conventional tillage (Martínez *et al*. 2008). There has been great controversy about the effects of no-till and straw mulch on the grain yield of crops. Govaerts *et al*. (2005) elucidated that no-till with residue retention results in higher and more stable yields than other managements, but no-till without residue drastically reduces the yields. Xie *et al*. (2007) summarized the conservation tillage effects on the crop production of China, demonstrating that conservation tillage improves crop development and helps combat crop pests and diseases. De Vita *et al*. (2007) found that no-till production depends on the location, rainfall and other factors, with high precipitation often aggravating the lodging, especially in some larger plant populations, decreasing the grain weight and yield. Lithourgidis *et al*. (2006) argued that plant stand is lower under no-till compared to conventional tillage and that reduced tillage favors crop stand establishment but it does not provide any grain yield advantage. Martínez *et al*. (2008) concluded that tillage treatments do not significantly affect the yield, which is lower under no-till than under plough tillage.

Little is known about the effect of no-till and straw mulch on the root system because of the difficulty in measuring the root parameters. This study aims (i) to evaluate the effect of tillage treatments and straw mulch on wheat stand establishment in hilly dryland, (ii) to assess the effect of tillage management on soil water and root growth, and (iii) to analyze the relationship between soil water and root growth.

2. Materials and methods

2.1. Site, soil and climate

This experiment was conducted in 2011–2012 and 2012–2013 in Yingming Village (104°30´E, 30°17´N, 750 m above sea level), Jianyang County, Sichuan Province, China, which is characterized by a hilly landscape and climate. The soil texture of the experimental field is clay loam with medium fertility and pH 7.53. In the 0–20 cm soil layer, organic matter and total N, P and K contents were 1.14, 0.0696, 0.9840, and 0.0634%, respectively, while the available N, P, and K were 51.13, 4.23 and 100.9 mg kg^{-1}, respectively.

The experimental area has a humid subtropical climate with an annual temperature of 17°C and an mean annual rainfall of approximately 900 mm, most of which falls in summer and autumn seasons. The growth cycle of wheat has drought nine years out of ten, with a rainfall ranging from 50–200 mm, and wheat face water stress, especially during sowing to heading. In the two experimental years, 2012–2013 was a severe drought year with only 17.9 mm from Nov. to Mar., which accounted for 26.4% of the 30-yr (1983–2013) averag (Fig. 1).

2.2. Experimental design and crop management

This experiment was arranged in a randomized complete block split-plot design with three replications. The previous crop was maize. The main plots were three tillage methods (i) no-till, (ii) rotary till and (iii) conventional till. The sub-plots were straw mulch (ML) and non-straw mulch (NML). The size of each experimental plot was 2 m×10 m. One operation of mini-tiller (10–15 cm depth) was carried out before planting, while the conventional till treatment was conducted with a local hoe (20–25 cm depth). After sowing, chopped maize straw was used to cover the treatments of straw mulch at 8700 kg ha^{-1} (approximately 9% water content).

Wheat *cv*. Chuanmai 42 was planted in 25-cm-wide rows