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Continuous ridges with film mulching improve soil water content, root growth, seed yield and water use efficiency of winter oilseed rape

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ABSTRACT

Limited water resources and low water use efficiency (WUE) have limited the increase in yield of winter oilseed rape (*Brassica napus* L.) in northwestern China for a long time. In order to determine an optimal cultivation method for increasing seed yield and improving WUE, field experiments were conducted to study the effects of various ridge-furrow and film-mulching planting patterns on soil water content, root distribution, seed yield, and WUE for three growing seasons from 2012 to 2015. Winter oilseed rape was planted in four patterns: flat planting without film mulching (CK), flat planting with film mulching (M1), ridge-furrow planting with film mulching on both ridges and furrows (M2), and ridge-furrow planting with film mulching on continuous ridges (M3). The results showed that M3 was the best at increasing soil water storage to a depth of 1.0 m after rain or irrigation and at maintaining much higher soil water content in the 0–0.3 m soil layer at the late growth stage. M3 produced the shortest taproots, but the largest taproot diameter and dry weight at both the seedling and pod-filling stages in all the three growing seasons. M3 also induced significantly more lateral-root proliferation in the 0–0.1 and 0.1–0.2 m soil layers without much reduction of lateral-root mass density in the 0.2–0.3 m layer in comparison to M1 and M2. Seed yield and WUE were the highest and evapotranspiration (ET) was the lowest in M3 in all the three growing seasons. Average seed yield was 70.0, 41.1, and 15.0% higher and average ET was 23.6, 14.3, and 9.4% lower in M3 than in CK, M1, and M2, respectively, thus improving WUE by 121.9, 64.5, and 26.8%, respectively. These results suggested that M3 was the best mulching and planting treatment for improving soil water storage, root growth, seed yield, and WUE. M3 may thus be the optimal mulching and planting pattern for the cultivation of winter oilseed rape in arid and semiarid areas.

1. Introduction

Oilseed rape (*Brassica napus* L.) is used to produce a kind of important edible oil for human consumption and it is also a promising biodiesel crop (Zhang et al., 2012). Rapeseed yield has rapidly improved in recent decades by the use of swede rape (*B. napus* L.) instead of turnip rape (*Brassica rapa* L.), by the introduction of high-yielding cultivars, and by improving the agronomic practices. Higher oilseed rape production, however, will still be required due to the increasing demand for edible oil and fuel from the expanding population and to the limited arable land worldwide (Rondanini et al., 2012).

Oilseed rape is one of the most important oil crops in China, with about 7.5 million hectares cultivated and 14.4 million tonnes of seeds produced in 2013 (FAOSTAT, 2015). Winter oilseed rape in China is mainly cultivated in the Yangtze River basin, but with rising winter temperatures in northern China in recent years, cultivation has expanded northward and westward, and the planting area of winter oilseed rape in northwestern China has increased year by year (Yin et al., 2010; Zhang and Wang, 2012). Yields, however, have always been low and unstable due to drought, frost, and poor water use efficiency (WUE) (Jing and Dong, 2004).

Film mulching is an important agricultural technique for increasing soil water content and temperature (Gan et al., 2013). Ridge-furrow planting pattern is also a widely used practice for conserving soil water in crop production (Li et al., 2007). A new pattern of crop cultivation, the ridge-furrow film-mulching (RFM) planting pattern, has been recently developed by combining plastic-film mulching with ridge-furrow planting (Gan et al., 2013; Li and Gong, 2002; Li et al., 2001). RFM, especially the plastic-film fully mulched

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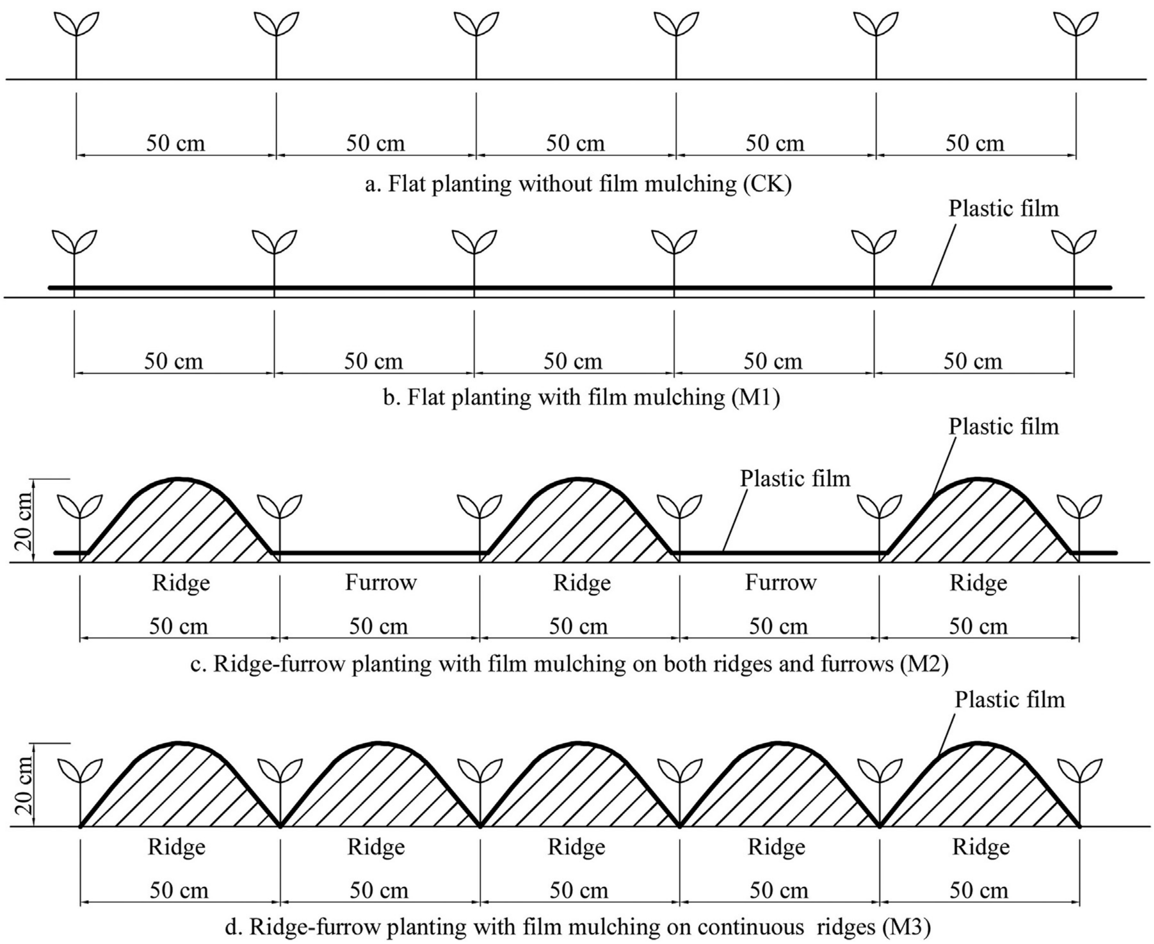

Fig. 1. Schematic diagrams of the planting patterns in the three growing seasons.

ridge-furrow (FMRF) system, can effectively improve soil water content and increase topsoil temperature (Gan et al., 2013; Liu et al., 2014). The hydrophobic nature and impermeability of the plastic film, allows any rainwater falling onto the ridges of a FMRM system to flow along the slope and then to infiltrate into the furrow soils through seepage holes in the film. FMRF also reduces the evaporation of soil water, weed competition, and soil erosion and compaction, because the entire soil surface is covered (Clark et al., 2003). Productivity has been significantly improved in the temperature and rainfall limited regions of northern China from the alleviation of the hydrothermal limitations by the FMRF system (Liu et al., 2009; Zhou et al., 2009).

The RFM systems have become a well-evolved technique for maize (Gao et al., 2014; Wang et al., 2009; Zhou et al., 2015), wheat (Chen et al., 2015; Zhang et al., 2007), and potato (Qin et al., 2014; Zhao et al., 2014) production in sub-humid, semi-arid, and arid regions, especially where irrigation is not available and spring temperatures are low (Hou et al., 2010; Zhang et al., 2011a,b). Qin et al. (2014) found that RFM systems increased potato yield by 46.0–86.8%, significantly decreased evapotranspiration at the early and late growth stages, and improved WUE by 40.3–83.9%. Maize yield in a full film-mulching system was increased by 81.0–92.0% due to higher soil water content to a depth of 1.6 m (Gao et al., 2014), and the WUE was improved by 26.6–57.3% in comparison to flat planting without mulching (Zhou et al., 2015). The WUE of mulched ridge and furrow planting with wheat was increased by 14.9% compared to conventional flat planting (Zhang et al., 2007). Previous studies, however, have focused mainly on maize, potato, and wheat crops, and little is known about the effects of film mulching and planting pattern on soil water content, root growth, yield, and WUE of winter oilseed rape, a globally important oil crop. The objectives of this study were thus to (1) determine the effects of ridge-furrow and film-mulching planting patterns on the distribution of soil water and root growth of winter oilseed rape, and (2) elucidate an appropriate cultivation method for winter oilseed rape to maximise WUE and seed yield under film-mulching patterns.

2. Materials and methods

2.1. Experimental site

Three-year field experiments were conducted at the Key Laboratory of Agricultural Soil and Water Engineering in Arid and Semiarid Areas of the Ministry of Education (34°18′N, 108°24′E; 521 m a.s.l.), Northwest A&F University, Yangling, Shaanxi, China, from 2012 to 2015. The soil of the experimental field was a medium loam with a field capacity of 24.0%, dry bulk density of 1.40 g cm^{-3}, organic matter content of 13.36 g kg^{-1}, total nitrogen (N) content of 0.96 g kg^{-1}, nitrate N content of 73.01 mg kg^{-1}, rapidly available phosphorus content of 24.07 mg kg^{-1}, rapidly available potassium content of 135.73 mg kg^{-1}, and a pH of 8.13 in the topsoil (0–0.2 m). The annual precipitation of the study area is about 632 mm, with pan evaporation of 1500 mm, mean temperature of 12.9 °C, mean sunshine duration of 2163.8 h, and a frost-free period of more than 210 d. The water table is more than 8 m deep.