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Straw strips mulch on furrows improves water use efficiency and yield of potato in a rainfed semiarid area

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ABSTRACT

Potato (*Solanum tuberosum* L.) production in semiarid regions is always constrained by water availability. This study was to evaluate the effects of straw strips mulch to potato growth, yield and economic benefits. The field experiment was conducted in northwest China in 2016 and 2017, including four treatments: (1), alternating narrow and wide ridges both mulched by black polyethylene film (PM); (2) alternating large ridges and small furrows with maize straw strips mulched only on the furrows (RS); (3) alternating the strips mulched with maize straw and bare plots with no ridges (PS); (4) traditional flat planting without mulching (CK). Results indicated that mulched treatments significantly ($P < 0.05$) increased tuber yield and WUE of potato compared with CK. The magnitude of yield in mulched treatments increase were 36.9–61.2% in 2016 and 38.7–45.5% in 2017, respectively, compared with CK. PM and RS treatments produced the highest tuber yield and enhanced water use efficiency by up to 74.8%, compared with CK. Soil water storage (0–2 m depth) was 21.5–39.9 mm in 2016 and 16.7–41.2 mm in 2017, respectively, greater in the mulched treatments, which significantly ($P < 0.05$) reduced evapotranspiration from sowing to seedling stages, compared with CK. Greater water availability was associated with greater biomass accumulation in above- and below-ground components, and plant height gain, during the growing season. PM significantly ($P < 0.05$) increased soil temperature (5–25 cm depth), which advanced the duration whole growth period by 6 days on average. RS and PM treatments experienced lower soil temperature (5–25 cm depth), which prolonged the duration whole growth period by 10 days on average, and increased the mass and percentage of Grade 1 tubers and the commodity rate ($P < 0.05$). As straw strips mulch application has lower input and labor costs than plastic film mulch, it produced the greatest economic benefits during this study, and it should be considered as an environmentally-friendly alternative to plastic film mulch for potato production in semiarid areas.

1. Introduction

Potato (*Solanum tuberosum* L.) is one of the main food crops traditionally planted in the semiarid region of northwest China, where accounting for 36% of China's total potato acreage (Li et al., 2018b). However, potato yields are frequently limited by water scarcity and suboptimal field management strategies in this region (Gan et al., 2013). To alleviate these issues, many management strategies had been made and tested to improve rainwater use efficiency in semiarid regions over last 30 years. In these efforts, a high- and stable-yielding in-situ rainwater harvesting technique, namely ridge-furrow mulch system (RFMS), has been developed and widely applied to crop yields in semiarid regions, especially smallholders farmers occupied the dominate position (Mo et al., 2017; Liu et al., 2009).

The RFMS consists of film mulch and alternating ridge-furrow units. It is generally built along with the contours on sloping lands, where the film mulch mainly used to prevent soil evaporation and the ridge-furrow units are usually used to rainwater harvesting (Zhou et al., 2009; Hu et al., 2014; Gan et al., 2013). The RFMS has been proved to be beneficial both directly and indirectly to crop growth, such as optimizing soil hydrothermal environment (Liang et al., 2018; Li et al., 2013; Jay et al., 1993; Zhao et al., 2014), increasing water use efficiency (Qin et al., 2014; Hu et al., 2014; Li et al., 2018b), promoting full release and efficient use of soil rapidly available nutrients (Jeffrey and

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Kong, 2012), and the smallholder farmer obtaining relatively high economic benefits (Zhao et al., 2014; Mo et al., 2017).

However, straw mulching is a convenient mulching method and more environmentally friendly than plastic film mulching in regions where straw resources are locally available (Tang et al., 2015). Because the long-term plastic film mulch has a huge negative impact, such as leading to excessive soil water and nutrients consumption of crops (Wang et al., 2009; Zhang et al., 2008; Hou et al., 2010), causing deterioration of soil structure, entanglement of crop roots, inhibition of nutrients and water absorption, thus affecting root development, reducing crop yields and restraining the sustainable development of agriculture (Liu et al., 2014; Gu et al., 2017). In addition, for potato, if the high temperature-humidity stress coexist which induced severe late blight under the ridge-furrow plastic-mulch system (Gansu Economic Daily, 2013).

Straw mulch have been widespread in potato production in semiarid region of China. Straw mulch can conserve soil moisture by decreasing soil temperature (Yan et al., 2018), increasing infiltration during heavy rains (Rahma et al., 2017), reducing soil evaporation, restraining runoff, improving the environment of crop growth (Kashif et al., 2006; Zhang et al., 2013; Jiménez et al., 2017). However, traditional full straw mulch practice often lead to a significant decrease in soil temperature, and hence making the wheat (Bonfil et al., 1999; Li et al., 1999; Asefa et al., 2004), maize (Lu et al., 2015) and other thermophilic crops seriously reduce production due to the shortage of accumulated temperature. Some studies have shown that the soil moisture of full straw mulch increase gradually with the increase of straw dosage, but the soil temperature is opposite, and it also make tillage difficult (Chen et al., 2013; Zhang et al., 2008), especially in potato production there are serious mechanical obstacles caused by straw at sowing and harvesting stages. Therefore, it is urgently necessary to develop some new straw mulch measures to coordinate the solution of the contradiction between water conservation and cooling under full straw mulch, and at the same time, it is suitable for mechanized tillage in this area. Therefore, over the last few years, our team designed a new straw mulch with system with reference to typical ridge-furrow plastic-mulch system (Gan et al., 2013), namely straw strips mulch system (SSMS), is to use crop straw or by-products for local soil surface mulch. The SSMS consists of two critical components: straw strips mulch and alternating crop planting strips (non-mulch) (Fig. 1b, c). Previous research by our team had shown that the SSMS significantly improved winter wheat yields compared with traditional-flat planting without mulch and plastic film mulch (Wang et al., 2017). In addition, the acceptance extent by small farmer is another key factor, because any agricultural system is expected to be cost-effective and it should be easy to operate.

In the present study, two-year field experiments were performed in 2016 and 2017 on the semiarid rain-fed agriculture region of northwest China. The objectives were to: 1) assess the effects of straw strips mulching and plastic film mulching practices on potato growth, water use efficiency and tuber yield, 2) to evaluate the influences of different mulching cultivation patterns on soil temperature and soil water storage and 3) to determine an appropriate mulching cultivation patterns for the maximum yield and economic benefits of rain-fed potato in the semiarid region.

2. Materials and methods

2.1. Description of the experiment site

The field experiment was established in 2016 and 2017 at Tongwei Modern Dryland Circular Farming Experiment Station, Dingxi City, Gansu Province, China (35°11′N, 105°19′E; altitude 1740 m). The study site is characterized as typical semiarid rain-fed agricultural region with one harvesting per year and belongs to the Loess Plateau. According to local meteorological date, annual mean temperature is 7.2 ℃, annual mean sunshine hours are 2092 h and the frost-free period was 155 days, annual mean precipitation is 390.6 mm (250–550 mm), which occurs mostly from June to September, whereas annual mean soil evaporation was 1500 mm. The highest values of mean monthly temperature and precipitation were recorded in July and August, respectively, according to average level over last 40 years (1975–2015). Dryland potato was generally sown in late April to early May and harvested from late August through mid-October. The soil type at the experimental site is classified as loess soil according to the USDA texture classification system (Soil Survey Staff, 1998), with an average bulk density is 1.25 g cm^{-3} in the 0–200 cm soil layer. Field water holding capacity and permanent wilting point of the upper 200 cm layer in 6.9% and 24.8%, respectively, according to the date of the station. Soil properties

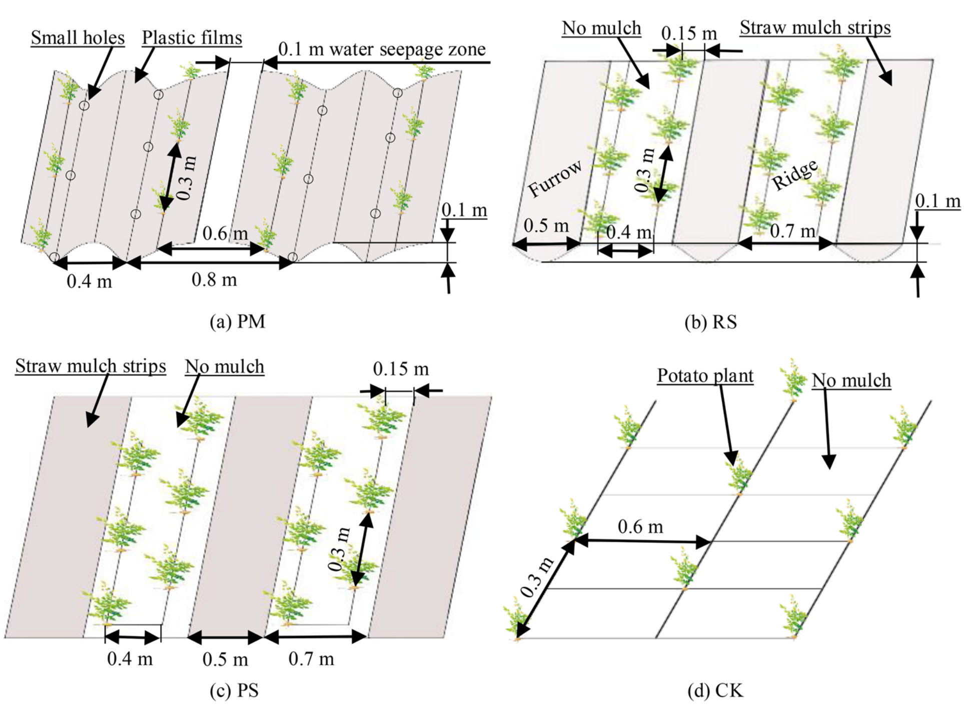

Fig. 1. Cultivation practice is for potato production established experimental field plots in Tongwei, Gansu Province, China. These were (a) alternating narrow and wide ridges both mulched by black polyethylene film (PM); (b) alternating large ridges and small furrows with maize straw strips mulched only on furrows (RS); (c) alternating the strips mulched with maize straw and bare plots with no ridges (PS). (d) traditional flat planting without mulching (CK).