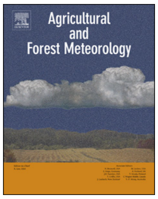
Agricultural and Forest Meteorology 262 (2018) 206–214

Contents lists available at ScienceDirect

Agricultural and Forest Meteorology

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



Ridge-furrow mulching with black plastic film improves maize yield more than white plastic film in dry areas with adequate accumulated temperature

Xiaoliang Qin[a,b], Yüze Li[a], Yunliang Han[a], Yingchun Hu[a], Yajun Li[a], Xiaoxia Wen[a,*], Yuncheng Liao[a,*], Kadambot H.M. Siddique[c]

[a] *College of Agronomy, Northwest A&F University, Yangling, Shaanxi, 712100, China*
[b] *Key Laboratory of Crop Physi-ecology and Tillage Science in Northwestern Loess Plateau, Ministry of Agriculture, Northwest A&F University, Yangling, Shaanxi, 712100, China*
[c] *The UWA Institute of Agriculture and School of Agriculture & Environment, The University of Western Australia, LB 5005, Perth, WA, 6001, Australia*

ARTICLE INFO

Keywords:
Maize
Black film
Loess Plateau
Accumulated temperature
Soil temperature
Yield

ABSTRACT

Ridge-furrow (RF) farming systems with white plastic film have been used extensively for maize (*Zea mays* L.) production in semiarid areas, yet black plastic film has less effect on soil temperature than white plastic film. This study examined whether RF systems with black plastic film perform better than white film in rainfed areas with adequate accumulated temperature. In 2016 and 2017, a field experiment was conducted in the Loess Plateau of China that involved sowing maize under three farming systems: conventional flat planting (CK), ridge-furrow (RF) system with white plastic (WP), and RF with black plastic (BP). The growth period for maize under BP was 5 days longer than under WP and 5 days shorter than CK in two years. The BP treatment produced a significantly higher leaf area index in maize than the CK and WP treatments at 100 and 120 days after sowing (DAS) in two years. Topsoil temperatures in the BP treatment were significantly lower than WP at 20, 80 and 100 DAS in two years. The BP treatment had better soil water content and soil water storage than WP during growth in two years. The BP and WP treatments had similar water use efficiencies, which were 44.98% averaged higher than the CK treatment in two years. The BP treatment produced 11.79% averaged more grain yield than the WP treatment in two years; both treatments produced more grain yield than the CK treatment. The BP treatment produced 55.18% averaged less total weed biomass than the other two treatments at harvest in two years. Net income in the BP treatment was 13.52% averaged higher than the WP treatment, and 18% averaged higher when sprayed. RF with black plastic film can be adopted in maize crops sown in rainfed, arid areas where temperature does not limit crop growth.

1. Introduction

Climate change will have a serious impact on agricultural production (Zhang et al., 2017a), with limited rainfall, seasonal water shortages, and excessive evaporation restricting agricultural development in arid and semiarid areas (Chen et al., 2012; Lian et al., 2007; Ren et al., 2016, 2017; Zhang et al., 2017a, 2017b, 2018). As an important technology for conserving soil moisture, reducing soil evaporation and altering soil temperature, plastic film mulching has been widely applied in Europe (van der Werf, 2010), Africa (Mo et al., 2017), Asia (Jain et al., 2017; Ren et al., 2016; Wang et al., 2016; Zhang et al., 2017a), Central America (Fisher, 1995), North America (Kwabiah, 2004), and other crop production areas around the world. In China, film mulching of crops has exceeded 18 million ha (http://202.127.42.157/moazzys/huafei.aspx).

Ridge-furrow (RF) farming systems have been used extensively for maize (*Zea mays* L.) production in semiarid areas of China (Eldoma et al., 2016; Gan et al., 2013; Li et al., 2001; Zhao et al., 2014). Most of the plastic film mulch used for maize production in China is made from white polyethylene film (Liu et al., 2014a). In recent years, some negative effects of white plastic mulch have been reported for maize, including premature senescence at later growth stages (Bu et al., 2013a) and reduced yield (Steinmetz et al., 2016). In other cereal crops, long-term continuous white film mulching has depleted soil moisture and nutrients in early growth, resulting in water and fertilizer deficiencies in later growth, and subsequently reduced yields in wheat (Li et al., 1999) and sorghum (Zaongo et al., 1997). Premature senescence of crops under white plastic film mulch is a major obstacle to improving

---

* Corresponding authors.

E-mail addresses: wenxiaoxia6811@163.com (X. Wen), yunchengliao@163.com, yunchengliao@nwsuaf.edu.cn (Y. Liao).

https://doi.org/10.1016/j.agrformet.2018.07.018
Received 18 March 2018; Received in revised form 6 July 2018; Accepted 16 July 2018
0168-1923/

yields (Bu et al., 2013a).

Removing the white film mulch at later growth stages can increase maize yields (Bu et al., 2013a), but also increases labor costs. Using straw mulch is another option, but the water conservation effect is much less than plastic mulch (Min et al., 2011). Black plastic film is less likely to increase soil temperatures than white plastic film—due to its low light permeability and low pass-through of radiant heat (Loughrin and Kasperbauer, 2002; Moreno and Moreno, 2008). Studies have shown that black plastic film can reduce soil temperatures and the mineralization rate of soil nutrients (Loughrin and Kasperbauer, 2002; Moreno and Moreno, 2008) and control weeds (Anikwe et al., 2007; Ricotta and Masiunas, 1991) better than white plastic film. Black plastic film has produced higher maize yields than white plastic film (Eldoma et al., 2016; Mo et al., 2017), but the reverse has also been observed (Mbah et al., 2010) as well as no difference between the two colored films (Mo et al., 2017). Currently, the area of maize sown under black plastic film is much lower than white plastic film in China. Research was needed to explore the differences between black and white plastic film on yield.

The Weibei plateau as a typical area in the Loess Plateau, with an adequate accumulated temperature, that is also the most suitable area for maize production in China (He and Zhou, 2012). In this study, we hypothesized that an RF system with black plastic film will delay premature senescence and increase yield more than white plastic film mulch in this area. The objectives of this study were to 1) evaluate the effects of RF with black and white plastic film on soil moisture dynamics, weeds, soil temperature, crop growth, water use efficiency (WUE) and yield, and 2) compare the economic benefits of each planting system.

2. Materials and methods

2.1. Study site

A maize (*Zea mays* L.) field experiment was conducted in the growing seasons of 2016 and 2017 at the Changwu Experimental Station located on the Loess Plateau, Shannxi, China (35°14′ N, 107°42′ E). The site is located in the dry farming zone with a typical, semiarid climate that relies on rainfall, being 580 mm mean annual precipitation, 2230 h annual sunshine duration, 484 kJ cm^{-2} total radiation, 171 d frost-free period, and 70 m to groundwater, 9.1 °C annual temperature, 19.4 °C average air temperature in July and September. ≥ 10 °C mean annual accumulated temperature is 3029 °C. In 2016 and 2017, ≥ 10 °C mean annual accumulated temperature were 3905.98 °C and 3722.78 °C, respectively; and the corresponding maize growing seasons were 3005.2 °C and 2734.8 °C, respectively. The soil type is black loessial with the top 20 cm consisting of 11.56 g kg^{-1} organic matter, 46.66 mg kg^{-1} available nitrogen, 16.94 mg kg^{-1} available phosphorus, and 122.35 mg kg^{-1} available potassium. Climate data for the two growing seasons are shown in Fig. 1.

2.2. Experimental design

The experimental plots were arranged in a randomized block design with three blocks. There were three treatments (Fig. 2): i. conventional flat planting (CK), ii. ridge-furrow farming (RF) system with white plastic (WP, 0.008 mm thick, 40% transmittance), and iii. RF system with black plastic (BP, 0.008 mm thick, 2% transmittance). Each treatment was repeated three times at a planting density of 82,500 plants ha^{-1}. The land was manually furrowed and ridged. Each plot was 32 m^2 (8 m × 4 m). For the second growing season, the residual plastic film from the previous year was removed, and new film applied before sowing. Maize variety Xianyu335 was sown on 20 April 2016 and harvested on 25 September 2016 for the first growing season and sown on 21 April 2017 and harvested on 28 September 2017 for the second growing season. Compound fertilizer was spread to supply 225 kg N ha^{-1} and 120 kg P ha^{-1} before the plastic film was laid; all of the P and N fertilizer was applied at a depth of 20 cm. No irrigation and herbicides were applied during the growing period of maize.

2.3. Determination of major parameters

2.3.1. Phenology of maize

Plant growth was monitored in each plot; the dates for the V2 (two-leaf), V6 (six-leaf), V12 (12-leaf), R1 (silking), and R6 (physiological maturity) stages were recorded when 50% of the plants in each plot had reached that stage, as per the standardized maize development stage system (Ritchie et al., 1992).

2.3.2. Plant height, leaf area index and shoot dry matter

Five plants were sampled for plant height and leaf area index (LAI) at 20, 40, 60, 80, 100, and 120 DAS. LAI was represented by the ratio of leaf area (LA) of each plant to the average land area occupied; in this study, the ratio was 0.12 m^2 $plant^{-1}$. Leaf length and width were measured with a measuring tape, and LA calculated using Eq. (1).

$$LA = L \times W \times 0.75 \tag{1}$$

where L is the average length (cm) of all leaves from the selected plants, W is the average width (cm) of all leaves from the selected plants, and 0.75 is the correction factor for maize leaf area (Mo et al., 2017).

For shoot dry matter estimation, five plants were randomly selected from each plot at 20, 40, 60, 80, 100, 120, and 140 DAS. The aboveground parts were cut from the roots using a sharp billhook. The samples were oven dried at 80 °C for 24 h then weighed and averaged to obtain dry weight per plant (Lian et al., 2016).

2.3.3. Soil temperature, soil water content and soil water storage

Soil temperatures were recorded at 8:00 h, 14:00 h and 20:00 h at 20, 40, 60, 80, 100, 120, and 140 DAS in soil depths of 5 cm and 15 cm using a set of digital thermometers (Shenyang Huashengchang Mechanical and Electrical Equipment co., LTD, Shenyang, China). The mean daily temperature was calculated using three daily readings.

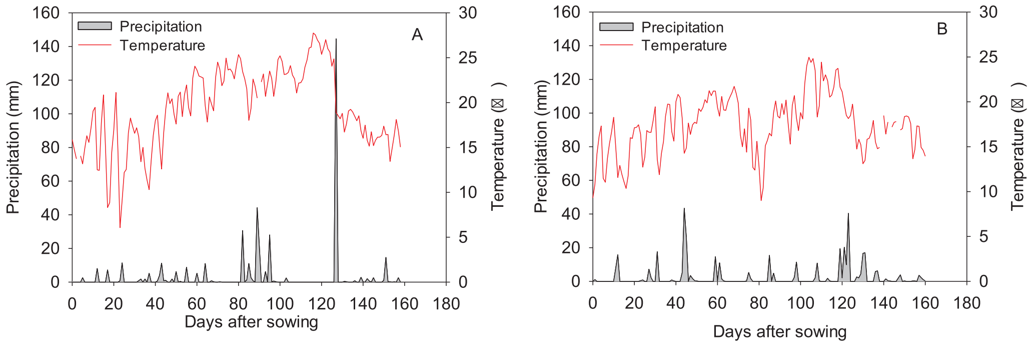


Fig. 1. Daily average temperatures (°C) and rainfall (mm) at the experimental site in the (A) 2016 and (B) 2017 maize growing seasons.