Field Crops Research 209 (2017) 58–64

Contents lists available at ScienceDirect

Field Crops Research

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

Reserving winter snow for the relief of spring drought by film mulching in northeast China

Hongchang Jia[a,b,1], Yong Zhang[a,c,1], Shiyan Tian[a,1], Reza Mohammad Emon[a,1], Xingyong Yang[c], Hongrui Yan[b], Tingting Wu[a], Wencheng Lu[b,*], Kadambot H.M. Siddique[d], Tianfu Han[a,*]

[a] Institute of Crop Science, the Chinese Academy of Agricultural Sciences, Beijing 100081, China
[b] Heihe Branch of Heilongjiang Academy of Agricultural Sciences, Heihe 164300, Heilongjiang Province, China
[c] Keshan Branch of Heilongjiang Academy of Agricultural Sciences, Keshan 160000, Heilongjiang Province, China
[d] The UWA Institute of Agriculture, The University of Western Australia, M082, LB 5005, Perth, WA 6001, Australia

ARTICLE INFO

Keywords:
Spring drought
Film mulching
Winter snowfall
Northeast China
Potato

ABSTRACT

Drought is a widespread problem in crop growing areas and a threat to food security worldwide. Mulching has become an important practice for maintaining soil moisture, reducing weed growth, mitigating soil erosion and improving soil temperatures in arid and semiarid areas. In northeast China, winter snow is heavy and spring drought frequently occurs, partially due to the loss of melted snow water by evaporation in spring. As such, this study assessed the use of plastic mulching in potato crops to minimize drought by accumulating and reserving water from winter snowfall. In field experiments conducted at two locations in the Heilongjiang Province, China (Keshan in 2011 and 2013, Heihe in 2011 and 2012), black and colorless transparent films were used as mulch during the thickest snow from late winter to early spring. The effects of plastic mulching on soil moisture content and temperature at various soil depths and its influence on potato growth and yield were evaluated. The results showed that film mulching increased the temperature and moisture content of the plow layer (0–10 cm). Black film retained more solid snow than colorless film. The black and colorless films advanced potato emergence by 7 and 14 days, respectively, compared with the control; higher temperatures under the colorless film resulted in earlier emergence than under the black film. The colorless and black film mulching increased soil water contents by 2.5 and 1.5 percentage points, respectively, compared with the control. Average tuber yield over the three-year study at both sites increased by 68.6% and 110.9% with black and colorless film, respectively, with yield increases more apparent in the year with spring drought. The effect of film mulching on yield mainly depended on differences in soil water content between mulching treatments and the control. Snow conserved by winter film mulching supplied water to the plow layer. Our results revealed that film mulching in winter significantly increases soil moisture content, ensures good stand establishment, and effectively solves a severe problem with spring drought in northeast China.

1. Introduction

Snow cover is the layer of snow covering the ground in winter. Snow develops from a complex set of variables that includes moisture content and temperature. Snow is an important source of fresh water. One-third of the total snow covering area in China occurs in northeast China in the Liaoning, Jilin and Heilongjiang Provinces and the eastern part of Inner Mongolia (Chen and Li, 2011). Snow cover in northeast China ranges from 25 to 50 cm depth, which equates to heavy rain periods (Sun et al., 2006). Making use of this snow would improve soil moisture. However, when the snow starts to melt, the soil beneath is frozen, making it difficult for the water to penetrate (Yang et al., 2012). During the middle and last stages of snow melting, water seepage into the soil can saturate the soil, causing runoff (Yang et al., 2008). Thus, most of the snow melt is wasted. Moreover, spring in northeast China is dry and windy, so soil moisture loss is a serious concern (Wei, 2006). Even with heavy snowfalls in winter, the surface soil or plow layer can be short of water when crop planting begins (Zou et al., 2008).

Ground covers including plastic film mulch are an effective way to conserve water (Dang et al., 2007; Mahmood et al., 2002; Qian et al., 1997; Yang et al., 1997; Yi et al., 2007; Yuan and Wang, 2008). Film mulching plays an important role in conserving water, increasing

* Corresponding authors.
E-mail addresses: tianfuhan@hotmail.com, hantianfu@caas.cn (T. Han).
[1] Hongchang Jia, Yong Zhang, Shiyan Tian and Reza Mohammad Emon contributed equally to this work.

http://dx.doi.org/10.1016/j.fcr.2017.04.011
Received 22 February 2017; Received in revised form 17 April 2017; Accepted 18 April 2017
0378-4290/

temperature, controlling weeds, disease and insects, early harvesting, and increasing yields (Csizinszky et al., 1995; Lamont, 1993; Pan et al., 2002; Qin et al., 2011; Wang et al., 2011). Film mulching increases the temperature of the surface soil layer distributes soil moisture, increases topsoil water content and enhances soil water infiltration, thereby relieving water stress to some degree (Chakraborty et al., 2008; Díaz-Pérez and Batal, 2002; Gan et al., 2013; Hu et al., 2014; Li et al., 2004; Liakatas et al., 1986; Liu et al., 2016; Pan et al., 2002; Zhao et al., 2012). Mulching could save irrigation water and reduce evapotranspiration (Wang et al., 2009a). Compared to non-mulched crops, the yields of crops under film mulching have increased by 50–100% in drought years or at cold sites, by 30–90% in average-rainfall years or at warmer sites, and by 10–40% in wetter-than-normal years and at milder temperatures (Gan et al., 2013; Wang et al., 2016).

Film mulching is widely used in China, especially in cold, long-winter regions, for vegetables, maize (*Zea mays* L.), cotton (*Gossypium hirsutum* L.), potato (*Solanum tuberosum* L.), wheat (*Triticum aestivum* L.) and rice (*Oryza sativa* L.) (Gao, 2009; Li et al., 2004; Qin et al., 2014; Wang et al., 2009b, 2011, 2013; Xia et al., 1997; Yang et al., 2009). However, with the dry springs in northeast China, soil water contents are low when the temperature is appropriate for planting (Wei, 2006). Furthermore, even when film is applied, it cannot relieve drought conditions due to the short supply of water. Applying the film before the snow melts may conserve the water, enabling it to seep into the soil as the frozen soil thaws (Xia, 2001). This method should allow the water to move in a natural state for effective spring planting and to relieve spring drought.

Earlier film mulching can improve the soil environment, which is good for crop emergence (Wang et al., 2011). Film mulching in autumn can result in higher water contents the following spring (Yu and Jin, 2012; Zou et al., 2008). The studies mentioned above mainly considered the effects of film mulching applied to crops after planting but rarely focused on the effects of mulching applied before sowing, especially those related to winter snow, soil moisture, temperature and crop yield.

Different-colored films can have different effects (Ham et al., 1993). Colorless film raises the soil temperature but does not constrict weed growth, while dark-colored film is less able to raise temperatures but constricts weed growth (Inada, 1973). Films that allow light or infrared rays to pass through them can combine the temperature-increasing characteristic of colorless film and the weed-control characteristic of dark-colored film (Lamont, 2005). Black film is better for saving water than colorless film (Han et al., 2012).

To evaluate the effects of mulching on crop growth and yield, and to determine the optimum cover material for maintaining snow water and the best time to apply film mulch, this study used different-colored plastic sheeting as a closed covering before snow melt and compared the differences in soil moisture and temperature changes. This study provides a foundation for using retained winter snow water for drought relief during spring in north China.

2. Materials and methods

2.1. Experimental sites

Field experiments were conducted at the Heihe (latitude 50°15′N, longitude 127°27′E, altitude 168.5 m) in 2011 and 2012 and the Keshan (latitude 48°3′N, longitude 125°53′E, altitude 230 m) in 2011 and 2013branches of the Heilongjiang Academy of Agricultural Sciences.

Heihe city is located in a cold temperate zone with a continental monsoon climate, annual average temperature of 0.4 °C, effective accumulated temperature of 2200 day-degree, and average annual precipitation of 521.9 mm (Pan, 2010). Keshan County is located in a temperate zone with a continental monsoon climate, annual average temperature of about 2.4 °C, effective accumulated temperature of 2400 day-degree, and annual precipitation of 520.1 mm (Kang et al., 2009). The temporal distribution of precipitation in Heihe and Keshan varies considerably. Rainfall is mostly concentrated in June, July and August in both sites. Precipitation in spring is only 10–20% of annual precipitation. The temperature in spring (March–May) rises fast with dry winds, and is prone to drought. Briefly, Heihe is located in a light spring drought area, while Keshan County is located in a heavy spring drought area (Wang et al., 2005).

The soil at the Heihe experimental site is a dark-brown earth and the previous stubble was corn. The soil type at Keshan is a leaching Chernozem and the previous crop was soybean. The soils at both sites were plowed in autumn and ridged with 60 cm between ridges. After ridging, any soybean or corn stubble on the surface was removed, to preserve the film and not affect the test results.

2.2. Materials

Potato (*Solanum tuberosum* L.) cultivar 'Kexin21' was used as a test crop. This variety was released by the Keshan branch of the Heilongjiang Academy of Agricultural Sciences. Kexin21 takes approximately 70 days from emergence to maturity symptoms on leaves. It can be planted in different ecological regions in the Heilongjiang Province, is anti-PVY (potato virus Y) and PLRV (potato leafroll virus), and has medium resistance to potato late blight (Wang et al., 2009b).

2.3. Experimental design

The experiment consisted of three treatments: (1) colorless film mulch, (2) black film mulch, and (3) no film (control). Each treatment covered an area of snow 3.6 m × 6 m (Table 1); the film, which fully covered the field surface (Fig. 1), was applied to the plot during winter and removed after the emergence of potato. The experimental design used random groups, and the treatments were replicated three times. Field views of the treatments in winter are shown in Fig. 2.

2.4. Sowing and management

The colorless (transparent) and black films were applied in early March before snow melt in Heihe and Keshan. In Heihe, the tubers were sown on 21 April in both 2011 and 2012. In Keshan, the sowing dates were 21 April in 2011 and 14 May in 2013. The tubers were placed 25 cm apart within the rows in each plot. The field management was the same as that in local farmer fields.

2.5. Survey and measurements

Following film application, the soil temperature was measured every three days. Soil temperature at depth (0, 5, 10, 15, 20 and 25 cm) was measured four times a day (6:00, 12:00, 14:00 and 18:00) on measuring days at the Keshan site and three times a day (8:30, 12:00 and 18:00) on measuring days at the Heihe site until the potatoes were planted. When the control surface snow dispersed, soil moisture at 5, 10, 15, 20, 25 and 30 cm depth was measured at 12:00 every three days. The measured soil samples were drilled from various layer depths using a soil drill. After measuring the wet weight, samples were placed into a digital display drying box (Type DHG202A-0, Huahong

Table 1
Treatments and plot area of the film mulching experiments in potato fields.

No.	Treatment	Description of treatment
1	Control (no film)	No film, potatoes sown in spring
2	Colorless film	Colorless film applied in winter and removed after potato emergence in spring
3	Black film	Black film applied in winter and removed after potato emergence in spring