Soil & Tillage Research 171 (2017) 42–50

Contents lists available at ScienceDirect

Soil & Tillage Research

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

Biodegradable film mulching improves soil temperature, moisture and seed yield of winter oilseed rape (*Brassica napus* L.)

Xiao-Bo Gu, Yuan-Nong Li*, Ya-Dan Du

College of Water Resources and Architectural Engineering, Key Laboratory of Agricultural Soil and Water Engineering in Arid and Semiarid Areas of Ministry of Education, Northwest A & F University, Yangling, Shaanxi 712100, China

ARTICLE INFO

Keywords:
Biodegradable film
Soil temperature
Soil water storage

ABSTRACT

Biodegradable film has been proven to be a good alternative to conventional polyethylene (PE) film for crops such as maize and cotton, but its suitability for winter oilseed rape (*Brassica napus* L.), one of the most important oilseed crops worldwide, has not been fully investigated. We conducted a three-year field experiment to systematically analyse and compare the effects of conventional PE film mulching (PM), biodegradable film mulching (BM), and no film mulching (CK) on soil temperature, soil water storage, water use efficiency (WUE), root growth, and yield for winter oilseed rape. The effects of increasing soil temperature and soil water storage were similar for BM and PM and were significantly higher than for CK before 150 days after sowing (DAS), but the increases of soil temperature and soil water storage were significantly lower for BM than PM after 150 DAS due to the degradation of the biofilm. The taproots of the rapeseed extended 1.7 cm significantly deeper into the soil for BM than PM, and the mass density of lateral roots in the 20–30 cm soil layer was 18–26 g m^{-3} significantly higher for BM at maturity stage. Evapotranspiration (ET) was significantly higher in BM than PM but still significantly lower than in CK. The average ET in BM was 10.0% higher than in PM and 10.4% lower than in CK. Yield and WUE did not differ significantly between BM and PM. Average yield and WUE in BM were 5.8 and 14.3% lower than in PM and were 38.4 and 54.5% higher than in CK. The seed content of erucic acid and glucosinolate, harmful to human health, was lower in BM than PM, while seed oil, protein, and oleic acid contents did not differ significantly between BM and PM. Biodegradable film is thus recommended as a viable option to the conventional PE film for the production of winter oilseed rape.

1. Introduction

Mulching using plastic film is an important agricultural practice for increasing grain yield and crop productivity by conserving soil humidity and increasing soil temperature in arid, semiarid, and sub-humid areas, especially where irrigation is not available and spring temperatures are low (Espi et al., 2006; Li et al., 2004; Wang et al., 2011). Film mulching has developed rapidly and has been widely used in China since its introduction in 1978 (Dong et al., 2009). The amount of mulching films used in China, mostly low-density polyethylene (PE), increased from 6×10^3 to 1.2×10^6 t from 1982 to 2011, and the mulched area increased from 117.0×10^3 to 197.9×10^6 ha. The negative effects of the PE films, however, became increasing apparent as their use increased.

The main disadvantage of the PE films for mulching is the handling of their wastes (Moreno and Moreno, 2008). Only a small fraction of the PE films is currently recycled due to the expense and time required for recycling. Most of the PE film residues are left on the field or burned uncontrolled by the farmers, producing harmful substances with associated negative consequences to the environment (Briassoulis, 2006; Scarascia-Mugnozza et al., 2004). In addition, the residues can deteriorate the soil structure, become entangled with crop roots, and inhibit the absorption of water and nutrients, thus affecting crop yields and limiting the sustainable development of agriculture (Liu et al., 2008). Dong et al. (2013) reported that cotton yields were 13.5–18.1% and 38.3–45.2% lower at levels of PE film residues of 1000 and 2000 kg ha^{-1}, respectively.

The use of biodegradable film, composed mostly of polysaccharides such as cellulose and starch, may be a promising alternative to retain the advantages and overcome the shortcomings of the conventional PE films (Kijchavengkul et al., 2008). Biodegradable films can be incorporated directly into the soil or into a composting system at the end of the crop season and be biodegraded by soil microorganisms (Moreno and Moreno, 2008). Now, it is a critical stage of study and assessment of biodegradable film, and fortunately some biodegradable films show effects in the production of maize (Zhang et al., 2010), sunflower (Li

* Corresponding author at: No. 23, Weihui Road, Yangling, Shaanxi Province, 712100, China.
E-mail addresses: xiaobo_gu1989@yeah.net (X.-B. Gu), liyuannong@163.com (Y.-N. Li).

http://dx.doi.org/10.1016/j.still.2017.04.008
Received 26 August 2016; Received in revised form 17 April 2017; Accepted 26 April 2017
Available online 03 May 2017
0167-1987/

et al., 2015), and strawberry (Costa et al., 2014). However, a series of challenges has still been faced by the biodegradable film, mainly including improving the quality of biodegradable plastic products, improving the controllability of rupture and degradation, enhancing the ability of increasing soil temperature and preserving soil moisture (Yan et al., 2016). In addition, it is essential to promote the application of biodegradable film on a large-scale. Therefore, studies should be conducted with more crop varieties in more typical areas for the development of biodegradable film mulching technique, the improvement of agricultural production environment, and the sustainable development of agriculture in the world.

Winter oilseed rape is one of the most important oil crops in China and is mainly cultivated in the Yangtze River basin, but the planting area in northwestern China has increased over the years with the recent increase in winter temperatures (Zhang and Wang, 2012). Yields, however, have always been low and unstable due to drought, frost, and poor WUE. Film mulching can increase rapeseed yield by 18.3–95.3% and seed oil content by 0.8–1.0% (Gu et al., 2016), and the area of winter oilseed rape mulched with film has been increasing yearly. Studying the effect of biodegradable film mulching on the production of winter oilseed rape in northwestern China is thus of great importance. So far, however, few studies have evaluated the suitability of biodegradable film for winter oilseed rape (*Brassica napus* L.) (Subrahmaniyan and Zhou, 2008). Moreover, previous studies were mainly focused on comparing the effects of biodegradable and conventional PE films on soil moisture and temperature, crop yield, and water use efficiency (WUE) but not on the related influences on root growth, and the differences of soil temperature and soil water storage before and after the biofilm was degraded. The objectives of this study were thus to (1) assess the effect of biodegradable film on soil temperature, soil water storage (SWS), root growth, seed yield, and WUE, and (2) determine the suitability of biodegradable film to the production of winter oilseed rape.

2. Materials and methods

2.1. Experimental site

A three-year field experiment was conducted from 2012 to 2015 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. The soil of the experimental field was a 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}, available phosphorus content of 24.07 mg kg^{-1}, 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 is about 632 mm with a 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.

The meteorological conditions during the three experimental years are shown in Fig. 1. Mean temperatures followed similar trends in the three years except for February in the 2013–2014 season (much lower) and March in the 2012–2013 season (much higher). Total rainfall during the growing season was 120 mm in 2012–2013, 330 mm in 2013–2014, and 264 mm in 2014–2015, and the mean rainfall during the growing season for 2006–2011 was about 371.6 mm. Rainfall was much higher from March to May in the 2013–2014 (197 mm) and 2014–2015 (179 mm) seasons than in the 2012–2013 season (52 mm). The 2012–2013 growing season was thus severely affected by drought.

2.2. Experimental design

The experiment included three treatments, each with four replicates in a completely randomised design: (1) conventional PE film mulching (PM), (2) biodegradable film mulching (BM), and (3) no film mulching (CK). The plot sizes were 4 × 5 m with a 1-m-wide strip between plots.

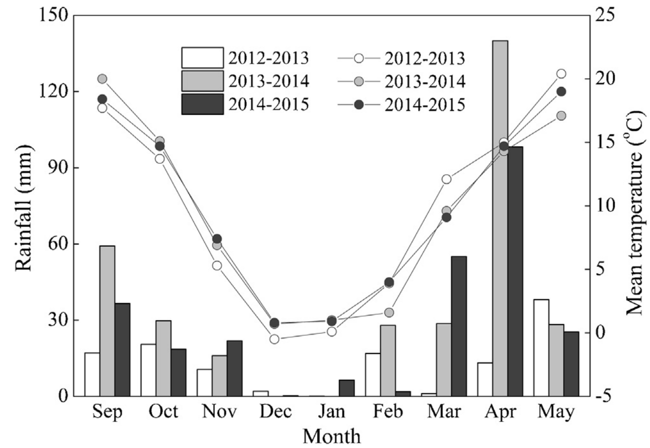

Fig. 1. Monthly total rainfall and monthly mean temperature during the winter oilseed rape growing season in the three experimental years. Rainfall and temperature are represented by columns and lines, respectively.

The cultivation method of ridge-furrow rainwater harvesting was used in this experiment, with a ridge width of 30 cm, a ridge height of 20 cm, and a furrow width of 20 cm. The ridges and furrows were formed after compound fertiliser (N ≥ 20%, P_2O_5 ≥ 20%, and K_2O ≥ 10% at a rate of 600 kg ha^{-1}) had been applied and the field had been ploughed. The ridges were then manually covered with the films one day before sowing. The conventional PE and the biodegradable films were both white, 80 cm wide, and 0.008 mm thick. The biodegradable film was made of corn starch (30%), polycaprolactone (60%), grease (5%), and adjuvants (5%), with an induction period of 120–150 d. Seeds of Shaanyou No. 107 were directly sown by hand in each plot along the middle of the ridges on 15 September 2012, 12 September 2013, and 21 September 2014, and all plants were harvested on 20 May 2013, 22 May 2014, and 23 May 2015, respectively. Seedlings were thinned by hand at the third-leaf stage, and plant density was determined as 120 000 plants ha^{-1} at the five-leaf stage. No additional fertiliser was applied during the growth of the rapeseed. The severe drought in 2012–2013 forced the application of 60 mm of irrigation water to each plot 122 and 202 days after sowing (DAS), respectively. We also added 30 mm of irrigation water to each plot after sowing in 2013–2014 to ensure seedling emergence. The irrigation water was supplied from a pump outlet to the plots using plastic pipes, and a flow meter was used to measure the amount of water applied. Other field production practices such as weed and pest control were conducted to minimise yield loss.

2.3. Measurements and methods

2.3.1. Soil temperature

A set of geothermometers was placed in the middle of a ridge in each plot at depths of 5, 15, and 25 cm. The soil temperatures (n = 4) were recorded every two hours from 08:00 to 18:00 at about 15-day intervals from sowing to harvesting in the three years. The soil temperatures were also measured on bright sunny days before the biodegradable film degraded, i.e., on 8 January 2013 (115 DAS), 11 January 2014 (121 DAS), 19 January 2015 (120 DAS), and after the film had degraded, i.e. 26 April 2013 (223 DAS), 27 April 2014 (227 DAS), and 30 April 2015 (221 DAS).

2.3.2. Soil moisture

Soil moisture to a depth of 200 cm was determined before sowing and after harvesting for calculating the changes in SWS in the soil profiles throughout each growing season. The water content to a depth