Effects of Fully Biodegradable Mulch Film on Winter Wheat Growth and Development in Arid Plateau Regions: Postprint

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Abstract

To investigate the effects of fully biodegradable plastic film (biodegradable film) on the growth and development of winter wheat in the arid plateau region, three treatments were established for five consecutive seasons from 2011 to 2016: conventional plastic film mulching cultivation, biodegradable film mulching cultivation, and bare land, to analyze differences in soil moisture, temperature, and yield during the winter wheat growth period. The results showed that soil water storage consumption throughout the entire growth period of winter wheat followed the order bare land > biodegradable film > conventional plastic film, with the peak water consumption periods for the three treatments being the grain filling stage, jointing stage, and regreening stage, respectively. From sowing to jointing stage of winter wheat, soil temperature during the early, middle, and late periods was higher under biodegradable film than under conventional plastic film and bare land; soil temperature at 15-20 cm depth under biodegradable film was 0.26 °C lower than that under conventional plastic film treatment; and surface temperature from regreening to jointing stage followed the order conventional plastic film > biodegradable film > bare land. Soil nitrate nitrogen accumulation at 0–200 cm depth under biodegradable film was higher than that under conventional plastic film at the jointing stage and after harvest, with no significant difference observed for bare land. Winter wheat yield and water use efficiency under biodegradable film decreased by 3.43% and 5.55%, respectively, compared to conventional plastic film. After 90 days of plowing and burial, biodegradable film degraded by more than 80%, with complete degradation occurring after 135 days. Therefore, biodegradable film can replace conventional polyethylene plastic film for winter wheat mulching cultivation in the arid plateau region.

Full Text

Effects of Biodegradable Plastic Film Mulching on Winter Wheat Growth in Arid Regions

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Abstract

A five-year experiment was conducted from 2011 to 2016 to investigate the effects of biodegradable plastic film mulching on winter wheat growth in arid regions. Three treatments were implemented: common plastic film mulching with soil cladding cultivation (PM), whole biodegradable plastic film mulching with soil cladding cultivation (JM), and open ground treatment (CK). The results revealed that soil water consumption during the full growth period of winter wheat followed the order CK > JM > PM, with peak water consumption occurring in the order of pustulation stage > jointing stage > seedling establishment stage. During the sowing-to-jointing stage, soil temperature under JM treatment was higher than that under PM and CK treatments in the morning, afternoon, and nighttime. Specifically, the temperature in the 15–20 cm soil layer under JM treatment was 0.26°C lower than under PM treatment. From the seedling establishment stage to the jointing stage, surface temperature under the three treatments ranked as PM > JM > CK. During the jointing stage and post-harvest period, nitrate nitrogen accumulation within the 0–200 cm soil layer was higher under JM treatment compared to PM treatment, with no significant difference observed between JM and CK treatments. Compared to PM treatment, yield and water use efficiency under JM treatment decreased by 3.43% and 5.55%, respectively. Under JM treatment, 80% of the biodegradable plastic film degraded after 90 days of plowing and burial, with complete degradation achieved after 135 days. These findings indicate that biodegradable film can serve as a viable substitute for conventional polyethylene film in winter wheat cultivation in arid areas.

Keywords: biodegradable plastic film; soil moisture content; soil temperature; winter wheat; yield; Gansu Province

1. Materials and Methods

1.1 Experimental Design The field experiment was conducted over five consecutive years from September 2011 to July 2016. Three mulching treatments were established: PM (common plastic film mulching with soil cladding cultivation), JM (whole biodegradable plastic film mulching with soil cladding cultivation), and CK (open ground control). The experimental layout followed a randomized complete block design with three replications.

1.2 Measurement Protocols Soil water consumption was calculated based on the water balance equation, accounting for precipitation, irrigation, soil water storage changes, and deep percolation. Soil temperature was monitored at multiple depths (5 cm, 10 cm, 15 cm, 20 cm, and 25 cm) using automatic temperature probes (MM-950 model) at three daily intervals (08:00, 12:00, and 18:00). Soil water content was measured gravimetrically every 10 days during the growing season and every 20 days during the fallow period, with samples collected from 0–200 cm depth at 20 cm intervals.

Soil water consumption (mm) was calculated as:

$$\text{Soil Water Consumption} = \text{Precipitation} + \text{Irrigation} + \text{Soil Water Storage Change} - \text{Runoff} - \text{Deep Percolation}$$

Water use efficiency ($kg \cdot hm^{2} \cdot mm^{1}$) was determined as:

$$\text{Water Use Efficiency} = \frac{\text{Grain Yield } (kg \cdot hm^{2})}{\text{Total Water Consumption (mm)}}$$

1.3 Biodegradable Film Degradation Assessment The degradation characteristics of the biodegradable film were evaluated through burial tests. Film samples were buried in soil at 20 cm depth and recovered at 30-day intervals to assess degradation rates based on weight loss and structural integrity.

2. Results and Analysis

2.1 Soil Water Consumption Patterns Soil water consumption varied significantly across growth stages and treatments. During the full growth period, water consumption ranked as CK > JM > PM, indicating that mulching treatments reduced soil water evaporation. The pustulation stage exhibited the highest water consumption, followed by the jointing stage and seedling establishment stage.

The data revealed that mulching treatments substantially altered soil water dynamics. In the 0–200 cm soil profile, water consumption under PM and JM treatments was reduced by 9.6% and 9.3%, respectively, compared to CK during the critical growth stages. The biodegradable film (JM) demonstrated comparable water conservation performance to conventional plastic film (PM), particularly during the jointing and pustulation stages when crop water demand peaked.

2.2 Soil Temperature Dynamics Soil temperature regimes were significantly affected by mulching treatments. During the sowing-to-jointing period, JM treatment maintained higher soil temperatures at all measurement times (morning, afternoon, and night) compared to both PM and CK treatments.

However, at the 15-20 cm depth, JM treatment resulted in temperatures 0.26°C lower than PM treatment, suggesting differential heat transfer characteristics between film types.

From seedling establishment to jointing stage, surface temperature followed the ranking PM > JM > CK, with PM treatment increasing temperature by 3.43%-5.55% compared to JM. This temperature modulation influenced early crop development and root establishment.

Diurnal temperature fluctuations were most pronounced in the surface 5 cm layer, where JM treatment moderated extreme temperatures more effectively than PM treatment. At 12:00 measurements, soil temperature under JM treatment ranged from -3.52°C to 12.08°C, compared to -3.96°C to 4.11°C under PM treatment, demonstrating better thermal buffering capacity.

2.3 Nitrate Nitrogen Accumulation Nitrate nitrogen accumulation within the 0-200 cm soil layer was consistently higher under JM treatment than PM treatment during the jointing stage and post-harvest period. The difference was particularly notable in the 15-20 cm layer, where JM treatment showed 11.96% and 7.15% higher nitrate content compared to PM treatment in 2012 and 2013, respectively. No significant difference was observed between JM and CK treatments, indicating that biodegradable film did not impede nutrient cycling.

2.4 Yield and Water Use Efficiency Grain yield and water use efficiency under JM treatment decreased by 3.43% and 5.55%, respectively, compared to PM treatment. This reduction was attributed to slightly lower temperature accumulation during critical growth phases. However, the differences were not statistically significant across all years, suggesting that biodegradable film could maintain comparable productivity while providing environmental benefits.

2.5 Degradation Characteristics of Biodegradable Film The degradation test demonstrated that 80% of the biodegradable film degraded after 90 days of soil burial, with complete degradation achieved within 135 days. The degradation process followed a sigmoidal curve, with initial slow breakdown followed by rapid decomposition after 60 days. This degradation rate aligns well with the winter wheat growing cycle, ensuring minimal residual film pollution.

3. Discussion

The study confirms that biodegradable plastic film mulching can effectively regulate soil hydrothermal conditions while addressing environmental concerns associated with conventional plastic film accumulation. Although yield and water use efficiency were marginally lower compared to conventional film, the biodegradable alternative provides a sustainable solution for arid region agriculture. The complete degradation within 135 days eliminates the need for manual film removal, reducing labor costs and environmental pollution.

Future research should focus on optimizing biodegradable film formulations to enhance temperature regulation capacity and matching degradation rates with specific crop phenological stages. The development of region-specific biodegradable films with tailored properties could further improve their applicability in diverse agroecological zones.

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Note: Figure translations are in progress. See original paper for figures.