Effects of Lignin-based Fully Biodegradable Plastic Film on Growth and Yield of Lettuce in the Open Field

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Abstract [**Objectives**] This study was conducted to investigate the effects of lignin-based fully biodegradable plastic film on the growth and quality of lettuce under open-field cultivation conditions. [**Methods**] In this experiment, compared with bare soil, a polyethylene plastic film (PE) treatment and two lignin-based fully biodegradable plastic film treatments (LBF-0.01 and LBF-0.008) with different thicknesses were set to study the effects on the growth and quality of lettuce. [**Results**] During autumn cultivation in Shanghai, the thermal insulation performance and yield-increasing effect of the two degradable plastic films were consistent with those of PE film, and effectively met lettuce growth requirements, but treatment LBF-0.01was better than treatment LBF-0.008. Moreover, lignin-based fully biodegradable plastic film could significantly increase the contents of Vc, soluble sugar and carotenoids in lettuce, and treatment LBF-0.008 showed the best effect. It could be seen that under the experimental conditions, the two kinds of lignin-based biodegradable plastic films with different thicknesses could be applied to the cultivation of lettuce in the open field in Shanghai in autumn, and LBF-0.01 had the best effect of increasing temperature and increasing yield, while LBF-0.008 had the best effect of improving quality. [**Conclusions**] This study provides theoretical basis and technical support for the further application of lignin-based fully biodegradable plastic film.

Key words Fully biodegradable plastic film; Lignin; Lettuce; Growth; Quality

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Plastic film mulching can significantly improve the utilization efficiency of agricultural production resources such as light, heat, water and nutrients by changing the material and energy exchange between the earth's surface and the environment, thus achieving important functions such as increasing temperature and preserving moisture, reducing soil and nutrient loss, protecting seedlings, and inhibiting weeds. It is an important agronomic measure in the process of agricultural production[1]. At present, the main components of mulching film used in production are polyethylene (PE) and other materials. Due to their ultrathin structural characteristics, polyethylene agricultural mulching film is difficult to be recycled after being laid in farmland, and it is difficult to be completely degraded even after thousands of years. Residual mulching film will be further broken and decomposed into microplastics, which will lead to the deterioration of soil environment and enter the food chain, threatening human health[2-3]. In view of this, using a kind of new biodegradable film that has the same warming, moisture retention, insect prevention, and weed control effects as PE plastic film to replace traditional polyethylene film is considered one of the feasible solutions to solve plastic pollution.

Lignin, as the second largest plant resource after cellulose, can be obtained directly from pulp with low cost. Lignin is a natural amorphous aromatic polymer, which can be combined with other polymer materials to prepare lignin-based mulching film. Lignin can be completely degraded and transformed into organic matter in nature, thus providing a stable source of organic matter for the sustainable development of agriculture[4]. Lignin can also darken the color of composite films, help regulate light intensity, and play a key role in thermal insulation[5]. Moreover, lignin has high ultraviolet resistance, and thus can prolong the service life of films and prevent some diseases, pests and weeds[6]. Lignin can also be used as a controlled release carrier of medium and trace fertilizers and a synergist of nitrogen/phosphorus fertilizers, thus improving the utilization rate of fertilizers[7]. In view of the low cost and environmental friendliness of lignin materials, its application in degradable plastic films has attracted wide attention.

In this study, lettuce, the main leafy vegetable in China was selected as the research material, and the thermal insulation effect of lignin-based fully biodegradable plastic film with different thicknesses and its effects on the growth and quality of lettuce in open fields were investigated, so as to find out its application effects in lettuce planting. We hope that this study will provide both theoretical frameworks and practical implementation strategies for sustainable plasticulture development.

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Hong WANG (1979 -), female, P. R. China, PhD, devoted to research about application of biodegradable mulch in agricultural production.

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Materials and Methods

Experimental materials and experimental design

The experiment was carried out in the open field of Shanghai Hangyu Agricultural Development Co., Ltd. (41° 47′ 46″ N, 119°19′03″ E) from October 2024 to November 2024. The tested

mulching films were as follows: polyethylene mulching film (PE, with a thickness of 0.02 mm), which was purchased in the market, and fully biodegradable mulching film 1 (LBF-0.01, with a thickness of 0.01 mm) and fully biodegradable mulching film 2 (LBF-0.008, with a thickness of 0.008 mm), both with a width of 1.5 m. The two kinds of fully biodegradable mulching films differed in thickness, but their main components were both lignin. They were independently developed and produced by Shanghai Changfa New Materials Co., Ltd. The variety of lettuce tested was Spanish lettuce.

Four treatments were set in the experiment, namely bare soil, polyethylene film (PE), fully biodegradable film 1 (LBF-0.01) and fully biodegradable film 2 (LBF-0.008). The experiment adopted a single factor randomized block design, with three replicates for each treatment. Each plot had an area of 30 m^2. Two weeks before lettuce planting, 30 000 kg/hm^2 of organic fertilizer and 600 kg/hm^2 of Kingenta compound fertilizer (15-15-15) were applied. Films were spread on the borders 3 d before planting. The plant and row spacing was 25 cm × 26 cm, and about 112 500 lettuce plants were planted per hectare of land. The field management measures for various treatments were consistent during the experiment.

Test items

Determination of soil temperature: From 5 d after lettuce planting, the temperature at a soil depth of 10 cm was recorded regularly every day with a geothermal meter for each treatment.

The yield of lettuce was measured when it was harvested, and 1 m^2 was randomly selected from each treatment to measure the total yield, which was measured in three replicates and converted to yield per plant.

Determination method of physiological indexes: The functional leaves of lettuce were taken to determine the physiological indexes of lettuce. Chlorophyll and carotenoid contents were determined by 95% ethanol extraction. Vc content was determined by 2,6-dichlorophenol indophenol titration. Soluble protein was determined by Coomassie brilliant blue staining. The specific operations were carried out according to the methods of Cao *et al.* [8]. The contents of soluble sugar and nitrate nitrogen were determined by kits, which were purchased from Suzhou Comin Biotechnology Co., Ltd.

Data processing

EXCEL2021 was employed for data processing. Origin2021 was used for drawing pictures. The new multiple range test in SPSS software was used for multiple comparisons ($P<0.05$).

Results and Analysis

Effects of different treatments on soil temperature

As shown in Fig. 1, under the experimental conditions, compared with bare soil, plastic film mulching could increase soil temperature. During the lettuce planting period, the soil temperature of the PE treatment was slightly higher than those of the two fully biodegradable plastic film treatments, but the differences were not significant. It could be seen that LBF-0.01 and LBF-0.008 had good warming effect.

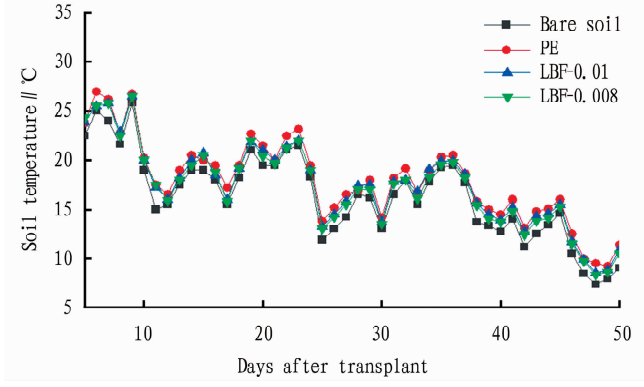

Fig. 1 Changes of soil temperature at 10 cm under different treatments

Effects of different treatments on chlorophyll content and yield of lettuce

The effects of different treatments on chlorophyll content of lettuce are shown in Fig. 2. The contents of chlorophyll a and chlorophyll b in lettuce could be significantly increased after mulching. In specific, the content of chlorophyll a increased by 31.09%, 16.98% and 10.51% in the PE treatment, LBF-0.01 treatment and LBF-0.008 treatment, respectively, and the content of chlorophyll b increased by 29.51%, 32.4% and 25.21%, respectively.

The effects of different treatments on lettuce yield are shown in Fig. 3. The yields per plant of the three plastic film mulching treatments were significantly higher than that of the treatment free of plastic film mulching. The yield increase rate was the highest in the PE film mulching treatment, at 78.79%. The yield per plant of lettuce increased by 66.08% and 40.52% respectively in the two fully degradable plastic film treatments LBF-0.01 and LBF-0.008. The above results showed that mulching with plastic film could significantly promote the growth of lettuce. Among various treatments, PE mulching had the best yield-increasing effect, followed by LBF-0.01 and LBF-0.008 treatments.

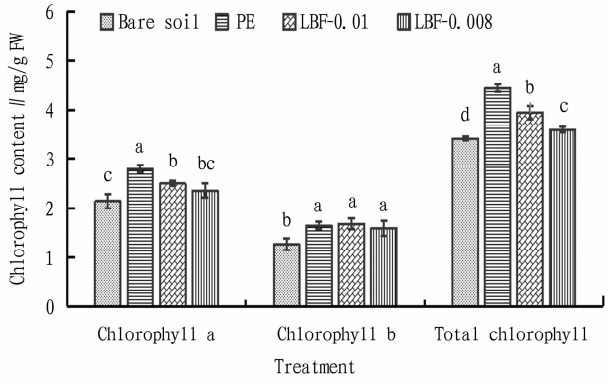

Fig. 2 Effects of different film mulching methods on chlorophyll content of lettuce

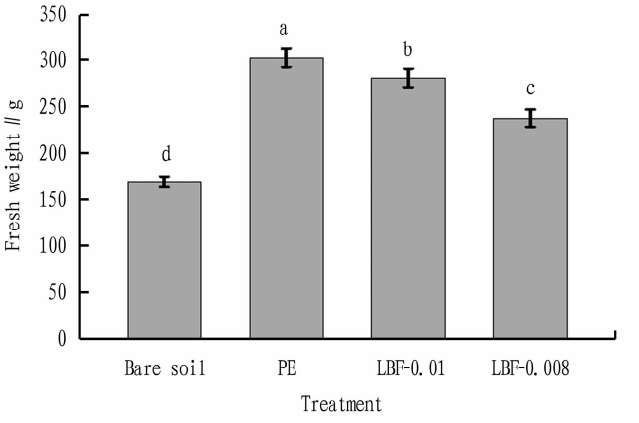

Fig. 3 Effects of different film mulching methods on the weight of lettuce per plant

Effects of different treatments on the quality of lettuce

As shown in Fig. 4, the quality of lettuce was significantly improved by plastic film mulching. Compared with the treatment of bare soil, different film mulching treatments significantly increased the contents of Vc, soluble sugar and carotenoids in lettuce. The quality of lettuce was the best under LBF-0.008 treatment, and the contents of the three substances increased by 44.58%, 34.17% and 347.14% respectively. The values in treatment LBF-0.01 taking the second place increased by 32.96%, 25.44% and 256.63%, respectively. In addition, treatments LBF-0.01 and LBF-0.008 also significantly reduced the content of nitrate nitrogen in lettuce, and the values were 34.68% and 59.23% lower than that of the bare soil treatment, respectively. The above results showed that lignin-based fully biodegradable plastic film could significantly improve the quality of lettuce.

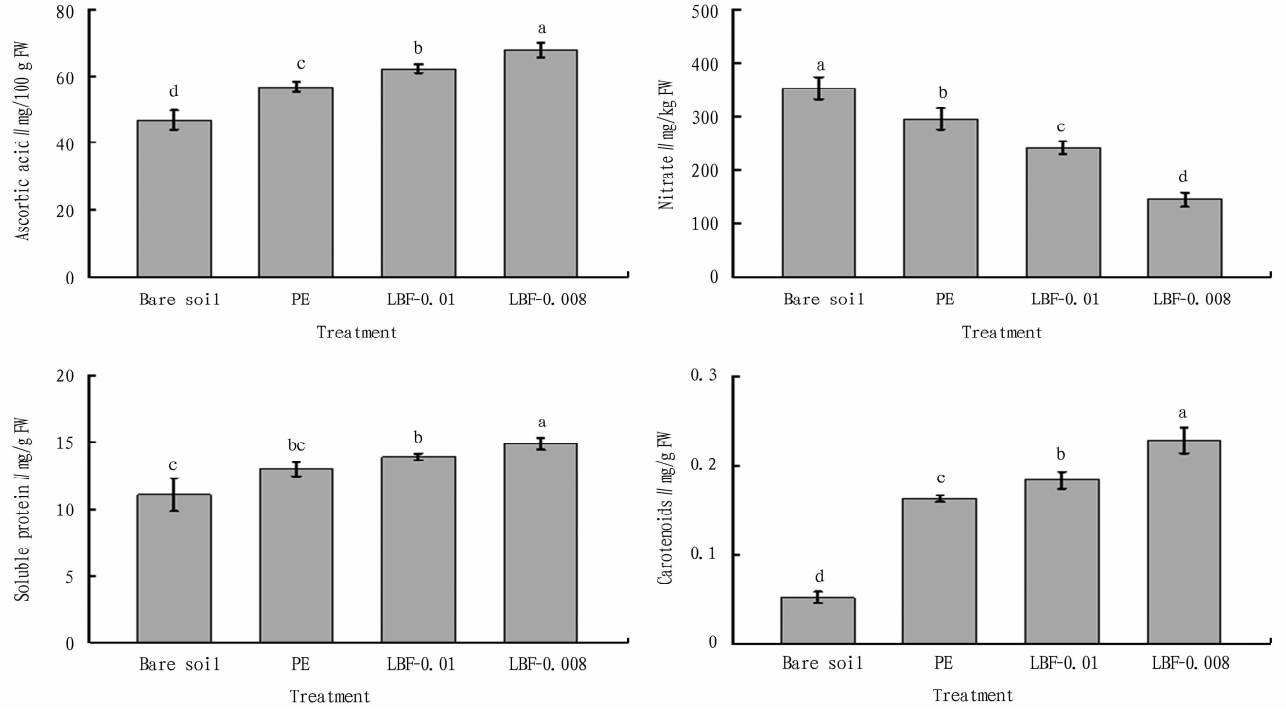

Fig. 4 Effects of different film mulching methods on lettuce quality

Conclusions and Discussion

The results of this study showed that compared with the treatment of bare soil , the PE treatment and lignin-based fully biodegradable plastic film could increase soil temperature and increase lettuce yield. The results of this study are consistent with those of previous studies in Chinese chive[9], strawberry[10], tomato[11] and other fruits and vegetables. The different effects of the three kinds of plastic films might be caused by their different thicknesses and different chemical components[12].

In addition, lignin-based fully biodegradable plastic film could significantly increase the contents of nutrients including Vc, soluble sugar and carotenoids. It might be due to the fact that compared with PE film (with a thickness of 0.02 mm), the thicknesses of the two kinds of fully degradable plastic films tested decreased, which led to the increase in the evaporation of soil and the decrease in water content of plants, and caused slight stress on plant growth, resulting in the increase in the synthesis of defensive substances such as Vc, soluble sugar and carotenoids in plants[13]. It might also be related to the fact that lignin is the synergist of soil fertilizers, and the utilization rate of fertilizers was improved after lignin was added to plastic film[14].

The experimental results demonstrate that lignin-based fully biodegradable films exhibit superior thermal regulation and dual-functional benefits in both yield enhancement and quality improvement under the specified cultivation conditions. Therefore, this advantage can be fully utilized in agricultural production to reduce the cost of using biodegradable plastic film. In summary, lignin-based fully biodegradable film has a good effect on the growth and quality synthesis of lettuce, demonstrating high application prospects and promotion value.

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of pretilachlor on the growth of rice seedlings in a suitable dosage range, but the dosage should be strictly controlled. Ten days after application, the plant height of treatment 8 showed a better alleviation rate of 21.72%, and the fresh weight of treatment 9 exhibited a better alleviation rate of 31.04%. Fifteen days after application, a better alleviating effect of plant height was observed in treatment 6, and a better alleviating effect of fresh weight was found in treatment 8, with an alleviation rate of 22.39%. In this study, it was found that the extract of Phellodendri Chinensis Cortex could alleviate the increase of POD activity in rice leaves caused by pretilachlor. Meanwhile, it was found that the extract of Phellodendri Chinensis Cortex promoted the expression of CAT in rice seedlings, thus significantly increasing its activity and alleviating the toxicity of pretilachlor to rice (reflected in the slight increase in plant height and fresh weight).

Previous studies have shown that the extracts of Rhizoma Chuanxiong[12], Radix Zanthoxyli[13], Rhizoma et Radix Notopterygii[14] and other Chinese herbal medicines can effectively alleviate the phytotoxicity of amide herbicides such as metolachlor and acetochlor to rice, which shows that plant-derived safeners have great application prospects. At present, one of the problems existing in the application of plant-derived safeners is that the dosage is relatively large compared with chemical synthesis safeners. Therefore, in future research, the preparation research of plant-derived safeners and how to reduce the dosage of plant-derived safeners will become key problems to be solved urgently.

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