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EXPERIMENTAL TRANSMITTANCE OF EVA AND PO FILM MULCHES

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KEYWORDS

transmittance, EVA film, PO film, light intensity.

ABSTRACT

The plastic film materials are a widely used agricultural means of production. Recently, two types of new agricultural film mulches are developed and are used popularly. They are ethylene-vinyl acetate copolymer (EVA) and polyolefin (PO) film mulches. The transmittances of film mulches are related to thermal reservation and plant photosynthesis. We experimentally measure transmittances of several EVA and PO film mulches under different wavelengths. We also find that the transmittances of mulches vary with light intensity change at one wavelength. The variable transmittances for these mulches are also measured in experiments. These data measured can provides help for agricultural production and accurate numerical simulation for the establishment microclimate of plastic greenhouse, even the degradation of plastic films.

INTRODUCTION

In agricultural production, the plastic film mulches are a material used widely. They can be used for thermal insulation, moisturizing, weeding, etc. Among these purposes, thermal insulation is a very important application. There are different ways for thermal insulation. For example, covering the ground with films, the plants grow out of the films, and the films are used to insulate the roots of plant. So soil temperature for the roots can be remained. Of course, the films are also used for establishment of the greenhouse, and in this case the entire plants are in a greenhouse. The off-season vegetables, fruits, etc. can grow inside. Therefrom, the plastic film mulches play an important role in heat retention for crops. As well as, the heat retention has a great relationship with the transmission properties of the plastic films. For visible light, the higher transmittance, the more light is transmitted in and the more heat is preserved. For infrared light, the less transmittance, the more is left behind and the more heat can be retained. But the transmission properties of plastic films are different at different wavelengths. About the transmission of plastic films, a lot of researches have been carried out (Al-Mahdouri et al., 2013; Liang et al., 2020; Njoroge et al., 2014; Lozano et al., 2019; Baloccoa et al., 2018; Adelhafidia et al., 2015; Zhang et al., 2021; Jones et al., 2021; Al-Mahdouri et al., 2014). Njoroge et al. (2014) measured the transmission and reflection coefficients of several PE films and glasses. Their measurement wavelengths are in 700-880 nm range. Lozano et al. (2019) measured the spectra of total transmittance and total absorptance of ultrahigh molecular weight polyethylene (UHMWPE) films and uniaxially-drawn UHMWPE films. They also embedded nanoparticles in plastic films to study the optical, mechanical and thermal properties of the variation films. Baloccoa et al. (2018) also experimentally studied the transmission properties of new low-density polyethylene (LD-PE) films and plastic films after five years of use. Their measurements are made in different wavelength bands, especially the mid-infrared. The relationships between the optical properties of plastic films and their degradation were also investigated (Adelhafidia et al., 2015; Zhang et al., 2021). Because the usage amount of plastic films is very large, its degradation is a big problem that needs to be solved. In their discussion, the degradation is closely related to light absorption and transmission. Characterization of shortwave and longwave properties of several plastic film mulches and their impact on surface energy balance and soil temperature have also been studied (Jones et al., 2021). In their article, the solar thermal performance is closely related to optical properties of plastic film materials. Al-Mahdouri et al. (2014) studied wide-range spectral radiative properties (0.22-25 μm) of silica glass, Polyvinylchloride (PVC) and Low Density Polyethylene (LDPE) materials, and estimated greenhouse temperatures.

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Through the above research, we found that the research about the optical properties of plastic film materials, especially the light transmission, is mainly carried out in different light wavelength bands, such as visible, near-infrared, mid-infrared. However, the light transmission of these plastic film materials is not only related to the wavelength, but also to light intensity. Not only for film materials, but also other optical devices, such as optical lenses, beam splitters, polarizing beam splitters, et al., the light transmission can be affected by light intensity (Huang et al., 2003; Li et al., 2017; Zhan et al., 2017; Sun et al., 2015; Li et al., 2018; Zhang et al., 2019a; Li et al., 2019; Zhang et al., 2019b; Ren et al., 2021). These aforementioned optical devices are even used in quantum research (Huang et al., 2003; Li et al., 2017; Zhan et al., 2017; Sun et al., 2015; Li et al., 2018; Zhang et al., 2019; Li et al., 2019; Zhang et al., 2019), and the changes of transmittance caused by changes of light intensity also have a subtle effect for those experimental results. Light intensity varies from day to day and from season to season, even in different time for one day. So the film transmittance could be usually affected by light intensity. In addition, the degradation of plastic film materials is also related to the light intensity and the microorganism distribution affected by light (Zhang et al., 2021). Thus the transmittance changes with variation of light intensity possess significant research value.

With the technological progress, new types of agricultural films have also been developed. Recently, more and more EVA and PO film mulches have been used in agricultural production and a lot of revenues have been generated. The previous research on light transmission mainly focused on polyethylene (PE) films, Polyvinylchloride (PVC) films etc., and the research on EVA and PO films was basically not carried out. We study the light transmission properties of new EVA and PO films used widely.

In this article, we focus on the light transmittances of new types of EVA and PO film mulches at different wavelengths and also study the transmittance changes with the changes for light intensity. This research not only provides a date basis for the agricultural production about the light transmission of film mulch materials and accurate numerical simulation of microclimate establishment in greenhouse (Ham & Kluitenberg, 1994; Wu et al., 2007; Bonachela et al., 2012; Zhang et al., 2018; Zhang et al., 2020), but also provides a data basis for the degradation of plastic films.

Experiment methods and materials

We take the ballistic transmission method (Baloccoa et al., 2018) to measure the transmittance of light that passes through the plastic films. That is, the ratio of radial transmission along the optical axis of incident light. The diagram is shown in Fig. 1. In order to measure transmittance at different light intensities, a LED light source is used. By adjusting switch, the source can emit light of different intensities. Under different intensities of light source, transmission ratios of the film mulches are measured. For the measurement of incident and transmitted light intensity, a highly sensitive photoelectric detector (PD) is used. With adjusting the wavelength setting, light intensity at several different wavelengths can also be obtained. Thus, the transmittance at different wavelengths can be measured.

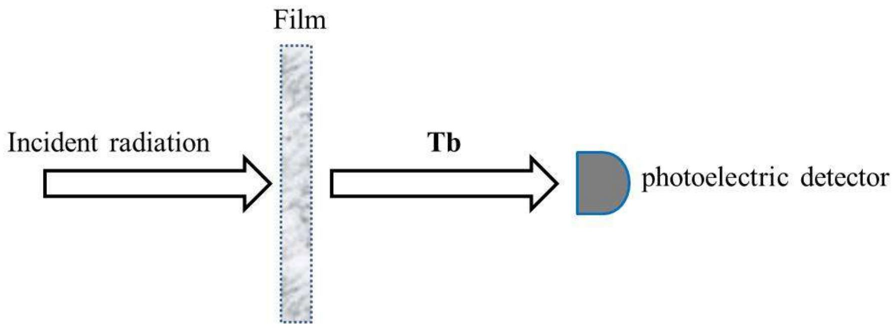


FIGURE. 1 The experimental diagram for transmittance measurement of films. Tb: Ballistic transmittance.

We select two types of plastic film mulches to study their transmittances under different light intensities at different wavelengths. The two types of plastic films are EVA film and PO film, respectively. There are four different specifications for EVA films, and they are 10S, 12S, 14S, 16S, respectively. This means that their thickness is 1.0×10^{-4} meter, 1.2×10^{-4} meter, 1.4×10^{-4} meter, 1.6×10^{-4} meter, respectively. For PO film, there are two different specifications, namely, 10S and 12S. The meaning of specification is the same as EVA film. EVA film is a film produced by casting and extruding EVA raw materials. It is a new generation of green and environmentally friendly materials, and it could be biodegradable and will not cause harm to environment when discarded or burned. EVA film mulches are widely used in establishment of agricultural greenhouses, and they possess excellent thermal insulation effect and also have the function of eliminating fog droplets. Reducing fog droplets in the greenhouse shed, more sunlight can shine on the crops. In agricultural production, it has excellent properties to promote crop growth. The agricultural PO film is also an increasingly popular film mulch material in recent years. It makes the water droplets on mulch inside surface form a water film to flow down evenly, effectively suppressing the fog generation on surface. Compared with EVA film, it lasts longer time to eliminate fog droplets and even lasts for a lifetime. Its aging resistance is also longer, about 2 to 5 years. The two films mentioned above have better light transmission properties than the others films, which are beneficial to light transmission in cloudy or rainy days.

Experimental results analysis and discussion

For EVA films, we selected five different wavelengths and measured their transmittance at these wavelengths. The five wavelengths are 535, 635, 830, 980, 1060 nm, respectively, whose range is from visible light to near-infrared light. Under each wavelength, we vary the light intensity of light source and measure transmittance of the films at different light intensities. Because there are four types of EVA films, we can get the transmittance of different films at one wavelength and plot these data on a graph for contrast.

Figure 2(a) shows transmittance of four EVA films at wavelength 535 nm. We can see that their transmittances are somewhere between 86% and 93%. With increasing light intensity, the transmittances of all four films roughly first increase and then decrease, but this fluctuation is weak. It means that on cloudy days or in morning and dusk, the light shining crops through the films will be affected by light intensity. For the all four films, the transmittances are roughly ordered by their thickness. The 10S film is thinnest and has the highest transmittance. The 16S film is thickest and has the lowest transmittance. The 12S and 14S films are in the middle, and their transmittances are also in the middle. After all, the differences for these film thicknesses are small, and the thickness and the transmittance are only roughly related.

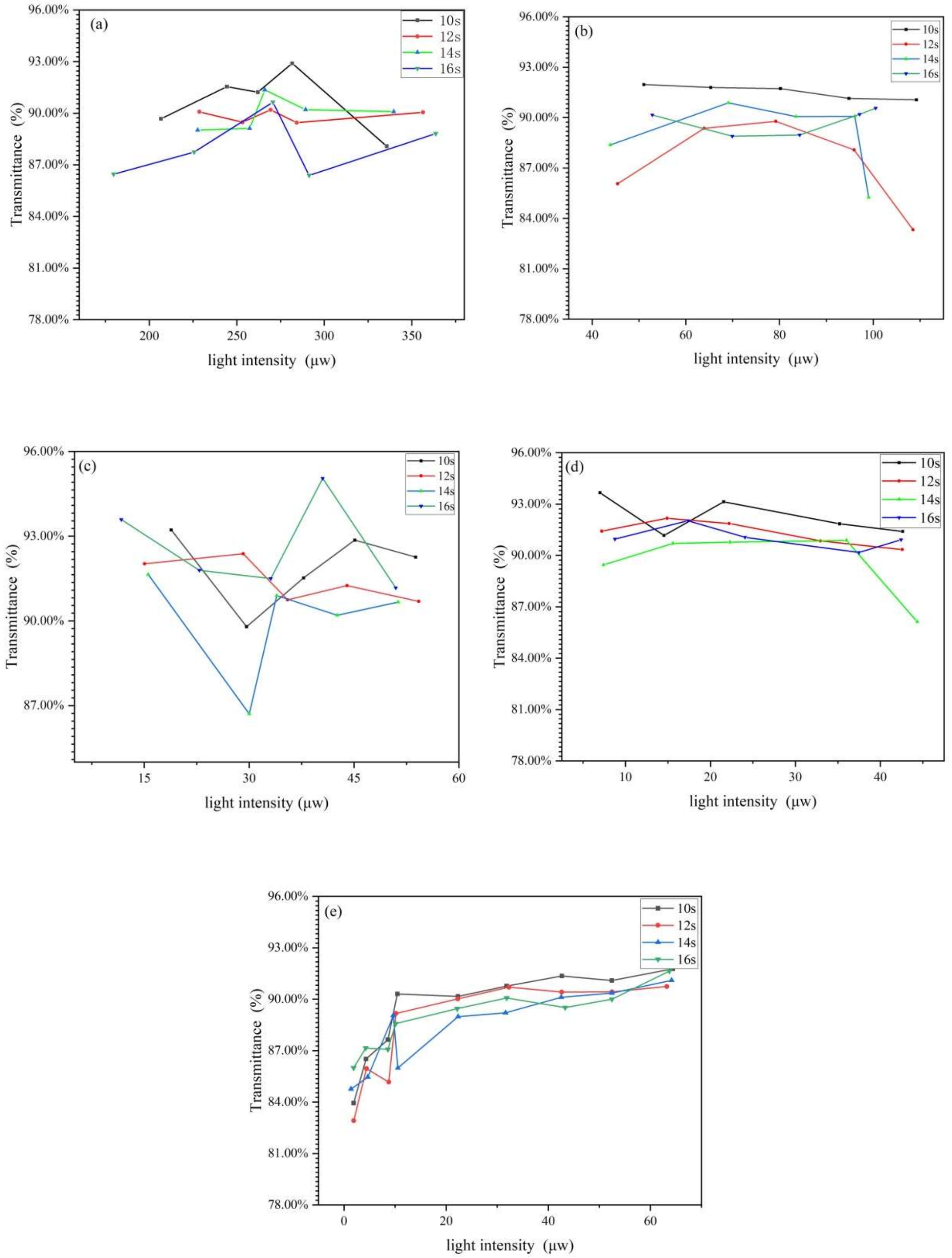


FIGURE 2. The relationships between transmittances and light intensities for several EVA film mulches at different wavelengths. (a): 535nm, (b): 635nm, (c): 830nm, (d): 980nm, (e): 1060nm.

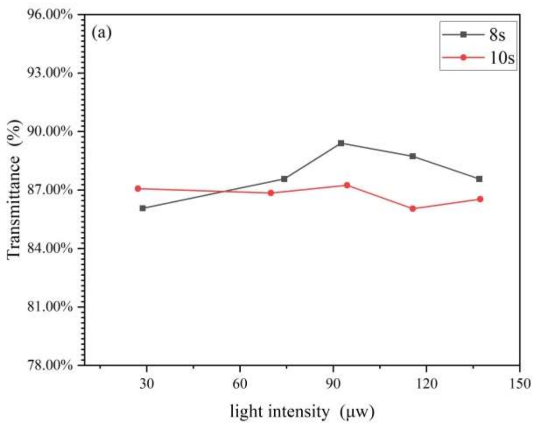
For the wavelength of 635 nm, the relationships between transmittances and light intensities are shown in Fig. 2(b). The variation trend of transmittances as light intensity changes shows its own characteristic at this wavelength. The 12S and 14S film have similar law, both increase first and then decrease. The transmittance of 10S film generally shows a decreasing trend, which is about from 92% to 91%, and 16S film first decrease and then increase. The transmittance of 10S film and 16S film changes slowly with light intensity increase. Their rates of change are only 1 to 2 percentage points. For the four films, it basically shows the thicker films possess lower transmittance and the thinner films have higher transmittance.

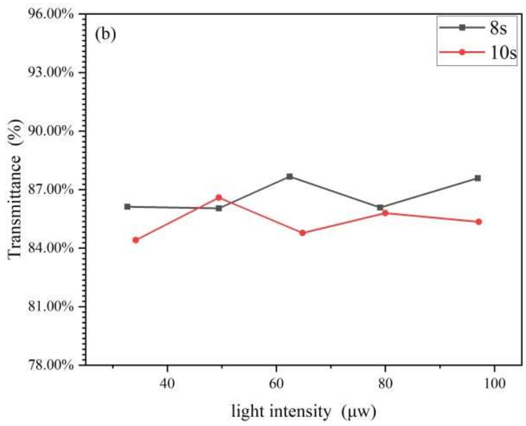
For 830 nm wavelength, the relationships between transmittances and light intensities are exhibited in Fig. 2(c). The change trend of transmittance as a function of light intensity shows fluctuation. The relationships between transmittances and film thicknesses at 830 nm are more complex, which are not as obvious as the rule at other wavelengths. The transmittance of 16S film is relatively high, and the 14S is relatively low. But transmittance of the 10S and 12S is in the middle. Specifically, 16S is about 93%, 10S and 12S are about 91.5%, and 14S is about 90%. It is possible that 830 nm is in the transition stage between visible and infrared, and the rule obeyed by transmittance is different from that of other wavelengths. The overall relationships between transmittances and light intensities are a trend of first decreasing and then increasing.

The relationships between transmittances and light intensities for 980 nm wavelength are displayed in Fig. 2(d). The relationships between transmittances and film thicknesses as a whole show the same rule as other wavelengths. Namely, the thinner film, it has the higher transmittance. The transmittance of 10s film is the highest (about 92%), and the transmittances of 14S and 16S films are lower (about 90% and 91% for 14S and 16S). For the several films except for the 16S, the transmittances generally decrease with the increasing light intensity. But the 16S first increase then decrease.

For 1060 nm wavelength, the relationships between transmittances and light intensities are shown in Fig. 2(e). The 1060 nm is already in infrared band, and for the several films, the transmittances increase gradually with the increasing light intensities. The transmittances are from around 85% in low light intensity to around 91% in high light intensity. For the part of high light intensity, the changes of transmittances begin to level off, and the transmittances approach a certain value subsequently. Similarly, the relationships between transmittances and film thicknesses as a whole still show an inverse correlation. The consistent relationships are shown like the other wavelengths except for 830 nm. For the 1060 nm wavelength, we select a relatively many number of light intensities to measure transmittances, and obtain more data points. We can see that the overall trend is not significantly affected by the number of points. Therefore, for the other wavelengths, we select fewer light intensities to measure, and the data points are also fewer.

For PO films, we selected two types of films to measure their transmittances, which are 8S and 10S films, respectively. Likewise, 8S and 10S indicate that their thicknesses are 0.08mm and 1mm, respectively. The transmittances of these two films at different light intensities are shown in Fig. 3(a)(b)(c)(d)(e). In Fig. 3(a), we can see that the transmittance first increases and then decreases with the changes of whole light intensity at 535 nm wavelength, and the transmittances are between 86% and 89%. The transmittance of the 8S film is substantially higher than that of the 10S film. In Fig. 3(b), at 635 nm wavelength, the transmittances of the two films oscillate with the changes of light intensity, and transmittances of the 8S film are higher than that of the 10S film. The transmittances of 8S film are between 86% and 88%, while the transmittances of 10S film are between 84.5% and 86.5%.





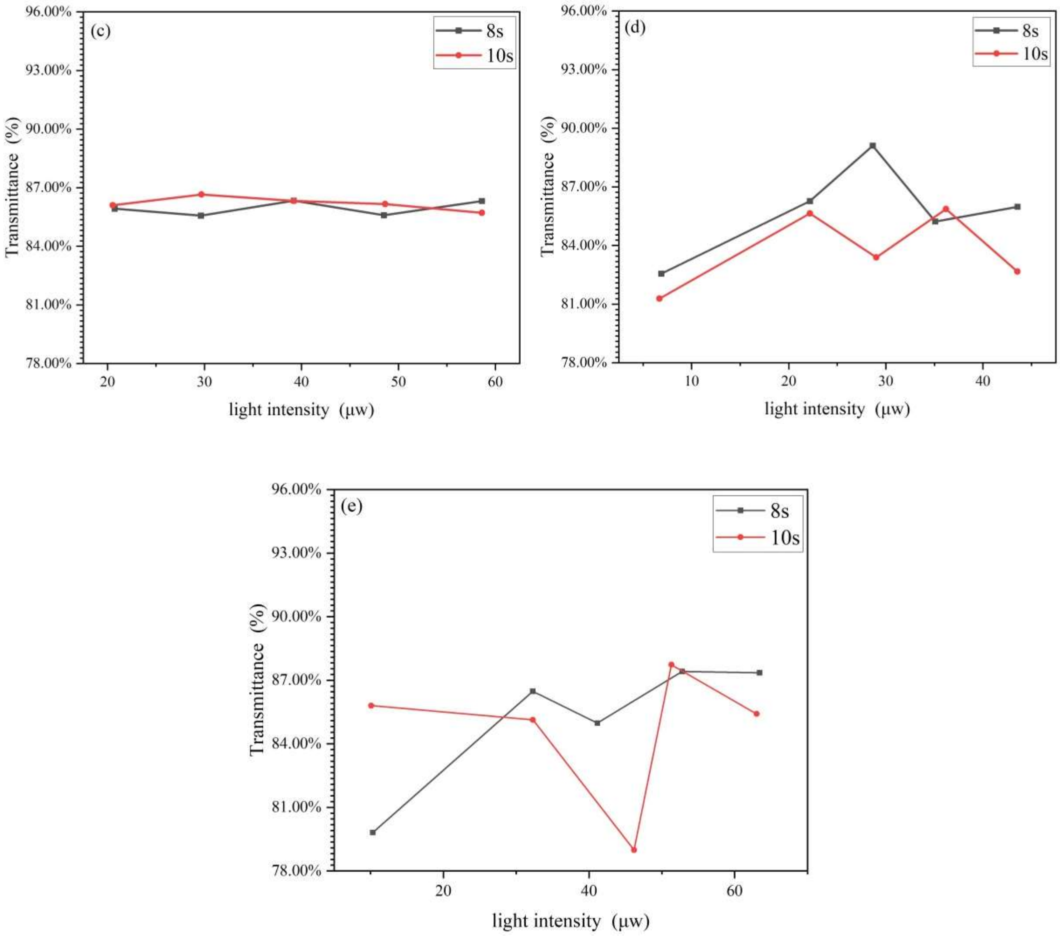


FIGURE 3. The relationships between transmittances and light intensities for two PO film mulches at different wavelengths. (a): 535nm, (b): 635nm, (c): 830nm, (d): 980nm, (e): 1060nm.

In Fig 3(c), again, we can see that the transmittances of 8S film are lower than that of 10S film under 830 nm wavelength. This shows same pattern as the EVA films, which contrary to the situation at several other wavelengths. This may also be because 830 nm is in transition stage of visible light to infrared light. In Fig. 3(d), it is the transmittances of two films at 980 nm. The overall transmittances show a trend of increasing first and then decreasing with light intensity increase. Under relatively low light intensity, the transmittance is relatively low, only 81%, 82% for 10S film and 8S film, respectively. In the part of high light intensity, the transmittances can reach 86% and 89% respectively. The overall transmittances of the 8S film are higher than that of the 10S film. In Fig. 3(e), the transmittances of two films at 1060 nm wavelength are displayed. As light intensity increases, the transmittances of the 8S film increase, but the transmittances of the 10S film have an increasing trend in oscillation. Generally, the transmittance of the 8S film is greater than that of 10S film.

For the two types of EVA and PO mulches, their features of transmittances can be found in the Figure. Under the several wavelengths, the transmittances of EVA film mulches are higher than these of PO mulches. The transmittances of EVA film mulches can reach above 90%, but the PO mulches are generally below 85%. These discrepancies possess different influences for crop growth.

CONCLUSIONS

In this article, we investigate light transmission properties of several agricultural greenhouse mulch materials. There are mainly two types of film mulches, namely EVA film and PO film, which all are the recently popular film mulches and possess excellent performance. The two films have different specifications, and EVA film is 10S, 12S, 14S, 16S, respectively, PO films are 8S and 10S, respectively. We investigated the transmittances of these films related to light intensity at five different wavelengths. Their transmittances each exhibit different properties, and are fluctuation within a range with the changes of light intensity. With the change of film specifications, namely the thickness increase, the two types of films show a uniform same rule under different wavelengths, which is, the thinner the film is, the higher transmittance it has. Only at 830 nm wavelength, it shows a different law, which is the thicker the film is, the higher transmittance it possesses. This may be related to the transition from visible to infrared light at 830 nm. Compared with EVA films, PO films have overall lower transmittance. This may be because the producing materials and preparation methods are different. Through experimental measurement, the transmittances of these films are obtained and exhibited. These researches not only provide light transmission data for agricultural production, but also provide data basis for numerical simulations related thermal maintaining and degradation of plastic film materials that is of great significance.

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