Photo-Selective Plastic Film for Mulch

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The clear and black sheets of polyethylene (PE) film are widely used for mulch.

Under the mulch with clear film, soil temperature rises high in the daytime, but weeds grow thick; on the contrary, black film mulch restricts the growth of weeds but does not raise soil temperature.

To promote the growth and development of crop plants by increasing soil temperature, the mulching film which is effective to raise soil temperature and to control weed growth is necessary. The herbicidal film spread with herbicides already has been contrived to meet this demand[6].

Many kinds of colored plastic films have also been tested for this purpose; especially, the effect of green film on the transmission of insolation, soil temperature and weed growth has been studied by many investigators[1),7),10)].

But the studies on green film mulch hitherto reported that green film is less effective than clear film to raise soil temperature and also less effective than black film to control weed growth.

The author has conducted studies on the necessary conditions which are vital to satisfy the demand to raise soil temperature as high as the clear film mulch and to control weed growth as well as the black film, from the standpoint of the photo-selectivity of film[2].

Soil Temperature and spectral transmissibility of plastic film

1) Increase of soil temperature under solar radiation

The wavelength extent of the solar radiation which is attainable to the earth surface is limited mostly from 0.3 to 4 μ. Consequently, the wavelength of light, which is transmissible through the mulch film and raise the soil temperature under the film in the daytime naturally resides in this extent.

Fig. 1 shows the spectral distribution of

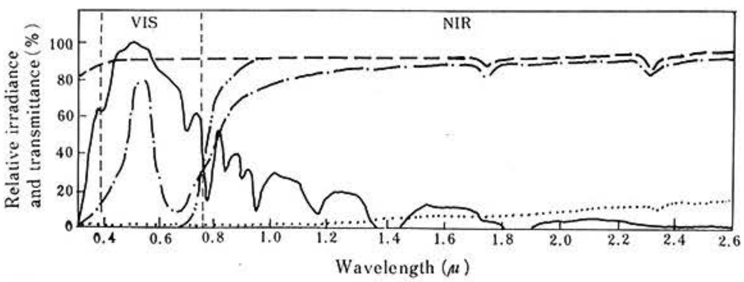

Fig. 1. Spectral curves of solar radiation and film transmission in wavelength shorter than 2.6μ

——— Solar radiation at sea level[5]   — — — Clear film
— • — Green film   ········ Black film
— ·· — Visible-opaque, near infrared-transparent film

solar radiation and spectral transmission curve of PE films.

Transmitted energy can be calculated from the product of irradiance and transmittance of each wavelength.

Clear film is very effective to increase soil temperature because it can transmit about 90 per cent of the whole solar radiation while black film cannot make high soil temperature on account of the fact that it is almost opaque to the light of visible region except that of near infrared region.

Grayish and translucent dark green films transmit from 10 to 20 per cent of the visible region and from 20 to 70 per cent of the near infrared region[2].

night and consequently soil temperature drops.

A black body heated to 10–30°C shows a spectral radiation curve which possesses a peak at the site of about 10 μ and more than one-half of the whole energy of this black body exists in the extent from 7 to 15 μ. The transmissibility of film at this range of wavelength, therefore, affects the maintainance of soil temperature at night[9].

As for the temperature conserving property of film, as it is shown in Fig. 2, polyvinyl chloride (PVC) film which is less transmissive for the radiation of this range of wavelength, is superior to the PE film which is transmissive for about 80 per cent of the radiation of this range[3),8]

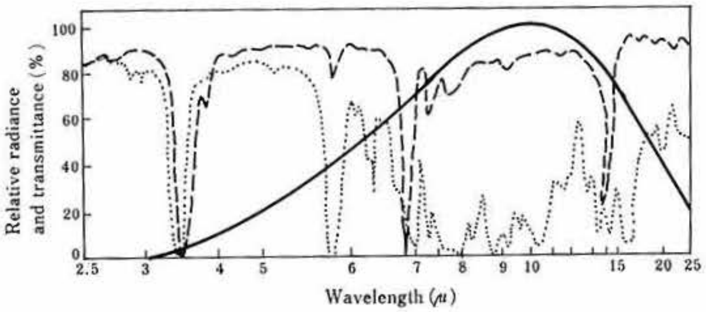

Fig. 2. Spectral curves of heat radiation from a black body film transmission in infrared region
——— Heat radiation from black body of 15°C
– – – PE film of 0.1 mm thickness
········ PVC film of 0.1 mm thickness

Transparent colored film, though it shows an absorption band in the visible region, reveals high transmission as much as the clear film in the region of more than about 0.8 μ wavelength irrespective of the kinds and concentration of pigment[4].

Accordingly, as for the increase of soil temperature, the transparent colored films stand between clear and black films and are considered to be more effective than the black and translucent colored films.

2) Decrease of soil temperature during night

The soil heated by solar radiation in the daytime radiates heat into the atmosphere at

Consequently, clear PVC film is effective to maintain high soil temperature through day and night and that PE film is also available during the season when heating is not needed at night.

The films and other covering materials which are opaque to the visible and infared regions are effective to restrict the rise of temperature in the daytime and the descent at night.

Weed control and spectral transmissibility of plastic film

Light promotes the germination of many species of weeds and light is indispensable for the photosynthesis and photomorphogenesis of plant. The reason the growth of weeds is restricted under the black film mulch which hardly transmits visible light is due to this fact. But the black film which is almost opaque to the visible and near infrared regions is unfavorable to raise soil temperature.

The film which was made by mixing deep blue, red and other pigments is opaque to visible region and is transparent to near infrared region; this film may be nearly as effective as the clear film to raise soil temperature.

To increase the soil temperature more effectively, it is necessary in addition to the near infrared transparency to perceive the existence of a transmissing band which is most effective to control the weed growth among the visible range.

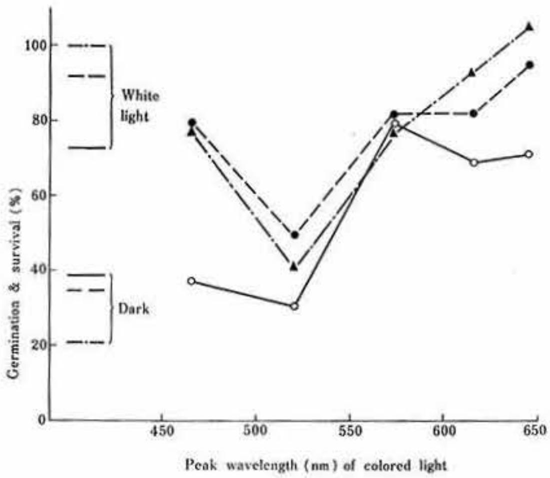

Fig. 3. Spectral dependence of the germination and growth of weeds
——— Germination ——— Survival
········ Dry weight of survived plants [% of White (W) light]. Each value was expressed as the average of 6 kinds of weed (*Echinochloa crus-galli, var. oryzicola, Cyperus difformis, Cyperus serotinus, Digilaria adscendens, Poa annua* and *Portulace oleracea*). Survival test was done by the irradiation treatment for 10 days using the seedlings grown under W light. The irradiance at plant level was 1.3 $mW\,cm^{-2}$ including W light and daylength was 15 hr.

The wavelength dependence of the germination and growth of weed was examined with colored fluorescent lamps.

Fig. 3 shows the results; judging from the means value of six weed species, it may be concluded that blue (peak, 465 mm) and green (peak, 520 mm) lights were most restrictive to germination and the survival percentage as well as the dry weight of seedlings were the least, respectively, under the green light.

It is presumed, therefore, that the green region is the most effective spectral band of visible light to restrict the growth of weed and that the film which transmits the green and near infrared regions is effective to raise soil temperature and to control weed growth.

Effect of transparent deep green film

According to the results described above, the test material of PE film which transmits the green and near infrared regions (in other words, which absorbs blue and red regions) was compared with clear of black film on the effects of raising soil temperature and controlling weed growth.

Fig. 1 shows the spectral transmission curves of these films and Table 1 indicates their solar radiation transmission.

Table 1. Solar radiation transmission of films

Film	Visible radiation	Total radiation
Clear	93	92
Green	40	56
Black	2	7

Measurements were made at 1:45 p.m. and 3:06 p.m. on April 24, 1970 (fine day) at horizontal position

1) Soil temperature

Soil temperature was measured on the 1×1 m mulched surface. As to the soil temperature at the point of 5 cm underground during the five days from the beginning of mulch, the temperature under green film was slightly higher than that of the clear one but afterward the latter came to the top reversely. On the other hand, the temperatures at the point of 10 cm in depth were nearly the same between them.

Table 2 shows the mean values of daily maximum soil temperature on fine cloudy and rainy days respectively and there is no difference between clear and green films.

Table 2. Maximum soil temperatures under film mulches

Depth (cm)	Film	Average of 6 fine days	Average of 6 cloudy and rainy days
5	Clear	33.4	24.6
〃	Green	33.5	24.6
〃	Black	31.1	23.4
〃	None	24.9	21.3
10	Clear	26.9	20.9
〃	Green	26.9	20.9
〃	Black	24.7	20.0
〃	None	20.4	18.6

Observations were made from April 23 to May 8, 1970. Average of 3 replications was indicated

It is reported by a practical experiment that the soil temperature under the green film mulch possessing the same spectral property was always higher than that of clear film[7].

It is impossible solely from the standpoint of transmission of solar radiation to clarify the cause of the green film not being inferior to the clear film to raise soil temperature.

Following the results of many experiments and observations conducted to clarify this cause, it was found that the newly applied green film, colored material as it is, can stand comparison at least while it is fresh with the clear film on the effect to increase soil temperature owing to the decidedly less deposition of dew drops on the inside surface of the mulching film[2].

Being exposed to the direct rays of the sun, the green film temperature rises rapidly, absorbing the light energy after sunrise and the heat rising above the dew point evaporates and causes the disappearance of the numerous dew drops deposited on the inside surface of the film. On the contrary, the clear film temperature does not rise so rapidly because it hardly absorbs the light energy and the dew drops do not disappear instantly. Therefore, the solar radiation is reflected by the dew drops and the effect to raise soil temperature may be reduced.

2) Weed control

The growth of three species of weeds seeded in boxes which were covered with film was observed comparatively under the natural condition of light.

The results in Table 3 disclose that the effect of green film to control weed growth differs by the species of weeds and that green film is more effective than clear film though it is less effective compared with black film.

Table 3. Effect of covering films on the growth of weeds

Film	*Digitaria adscendens*		*Portulaca oleracea*		*Cyperus serotinus*	
	No. of plant	Total D. W.	No. of plant	Total D. W.	No. of plant	Total D. W.
Clear	100	100	100	100	100	100
Green	95	49	52	10	95	33
Black	8	1	19		32	1

The experiment was made with plastic boxes. Seeds were sowed on May 26 and the examination was made 20 days after sowing. Average of 3 replications was indicated

The effect of green film may be practically realized because a better weeding result was reported by the field test with the green film which has nearly the same transmission curve as that described above[1),7)].

The weeding effect of green film increases according to the decreased transmission of blue and red lights, so the pale green film effect is not big.

The visible opaque and infared transparent film may be available to restrict completely the growth of weeds though this is less effective in raising the soil temperature than the green film. (Fig. 1)

References

1) Aimi, R.: The effect of green-light on the growth of plants: Application to weed-suppression mulch by green plastic film. Extrait du compte rendu 4e Colloque International des Plastiques en Agriculture (1970).
2) Inada, K. & Yamaki, M.: Studies on the colored plastic film for mulching. *Proc. Crop. Sci. Soc. Japan*, **40**, 132–140 (1971).
3) Inada, K.: Transmission characteristics of clear plastic films for crop protection. *Environ. Control in Biol.*, **8**, 111–118 (1971).
4) Inada, K.: Transmission characteristics of colored plastic films. *Environ. Control in Biol.*, **9**, 120–123 (1971).
5) Kondratyev, K. Ya.: Radiation in the Atmosphere. Academic Press. New York and London (1969).
6) Nakayama, K., Koiwa, T. & Noguchi, K.: Studies on the contrivance and utility of herbicidal film. *Proc. Crop. Soc. Japan*, **37**, 645–649 (1968).
7) Miwa, S., Takeuchi, E. & Konaka, N.: Effects of green polyethylene film mulching on the weed control and the growth and yield of crop plants. *Proc. Crop. Sci. Soc. Japan*, **39**, Extra issue 2, 99–100, Abstracts and data of papers presented at the 150th meeting of the society (1970).
8) Takahashi, K.: Temperature conditions under tunnels covered with EVA (Ethylen vinyl acetate copolymer) film. *J. Agr. Metorol. Tokyo*, **24**, 193–197 (1969).
9) Trickett, E. S. & Goulden, J. D. S.: The radiation transmission and heat conserving properties of glass and some plastic films. *J. Agr. Eng. Res.*, **3**, 281–287 (1958).
10) Waggoner, P. E., Miller, P. M. & DeRoo, H. C.: Plastic mulching principles and benefits. *Connecticut Experiment Station, Bull.*, **634**, 5–44 (1960).