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Optical properties of plastic mulches affects weed populations

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Abstract

The effect of plastic mulch on soil temperature, mulch surface temperature and the radiation balance is determined primarily by the optical properties of the material. Mulches may transmit, absorb, or reflect a portion of the incident radiation at each wavelength. The mulches decrease light transmission and prevent development of most weed species. Laboratory and field experiments were conducted to measure optical properties of different plastic mulches and evaluated owing to its light transmission in terms of weed infestation during the year 2017 and 2018. The unused plastic mulches were silver-on-black, black and transparent. On average, 83.01%, 57.28% and 43.61% light in the 400 to 1100 nm range was transmitted through the transparent, black and silver-on-black plastic mulches, respectively. After 120 days of field exposure (used) different plastic mulches on average 85.36%, 42.65% and 34.93% light in the 400 to 1100 nm range was transmitted through the transparent, black and silver-on-black plastic mulches, respectively. Different plastic mulches were evaluated owing to its light transmission in terms of weed infestation and results revealed that weed infestation was observed highest in transparent plastic mulch and negligible in silver-black plastic mulch. Highest weed density and total weed biomass 152.33 No./m² and 129.19 g/m², respectively were observed in transparent plastic mulch, whereas total absence of weeds were observed in black plastic mulch.

Keywords: Optical properties, plastic mulch, wavelength, weed infestation

1. Introduction

Plastic mulch to modify soil temperature, conserve water, control weeds, and alter other microclimatalogical characteristics of the field depends on the optical properties (reflectivity, absorbitivity or transmittancy) of a particular material in relation to incoming solar radiation (Decoteau *et al.*, 1988; Ham *et al.*, 1993; Kasperbauer and Hunt, 1998; Tarara, 2000) [4, 6, 10, 14]. Vegetable growers routinely use the same plastic mulch to grow more than one crop (Hanna, 2000a & 2000b) [7, 8]. Double cropping reduces grower expenses for mulch and drip irrigation equipment while also reducing the amount of plastic waste (Hanna 2000a, 2000b; Mugalla *et al.*, 1996; Waterer, 2000) [7, 8, 12, 15]. The success of double cropping is highly dependent on the quality of the plastic before planting the second crop. At least 50% to 60% of the soil must remain covered to provide adequate weed suppression and soil warming (Jones and Chapman, 1968; Maelzer, 1986) [9, 11]. However, the physical, optical, and thermal properties of a film change with field exposure, and even when a film remains sufficiently intact, a lengthy field exposure may affect its ability to warm the soil and block or transmit light (Brandenberger and Wiedenfeld, 1997; Brault *et al.*, 2002) [1, 2].

Film color may affect therefore effective weed seed germination, growth, and development under the plastic (Brault *et al.*, 2002; Ham *et al.*, 1993; Paterson, 1998) [2, 6, 13]. Knowing the spectral transmittance of colored films may help in understanding their weed suppressive effect (Brault *et al.*, 2002; Paterson, 1998) [2, 13]. Such information would help predict weed infestations and assist growers in selecting the appropriate film for their growing conditions. This study was therefore conducted to measure optical properties of plastic mulches, evaluate weed populations under each plastic mulch type, and determine if light transmission could be used as an indicator for potential weed populations in the field.

2. Materials and Methods

2.1. Location and layout of field plot

The experiment was conducted in the field and laboratory. The plastic mulches were silver-on-black, black and transparent. All plastic mulches were 120 cm wide and 30 micron thickness.

Laboratory experiment: The analyses were conducted on new plastic mulches and on used mulches after about 120 days of field exposure. The total (specular and diffuse) reflectance and transmittance of the plastic mulches before and after use were measured in the range from 400 to 1100 nm, with Spectroradiometer (UV-2700i and FTIR-8400S) of Shimadzu in the Department of Physics laboratory, SRT University Nanded (Decoteau *et al.*, 1988; Ham *et al.*, 1993; Brault *et al.*, 2002) ^[4, 6, 2]. Light transmission was determined by the percentage transmission through one layer of plastic compared with the blank scan. (Brault *et al.*, 2002) ^[2].

Field experiment: The field experiment was conducted during February to May in 2 years 2017 & 2018 at Research Farm of AICRP on Irrigation Water Management, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani. Parbhani is situated in the Marathwada region of Maharashtra state at 19°16' N Latitude and 76°47' E Longitudes and at altitude of 409 meters above the mean sea level. The field experiment was laid out in split plot design, in which three irrigation levels were assigned to main plots and four mulch treatment to sub plots. Thus, the experiment consisted of total 12 treatment combinations which were replicated thrice. All sub plot treatments were randomized in each main plot treatment.

3. Results and Discussion

3.1 Light transmission on used and unused plastic mulches

The analysis of samples of unused and used three plastic mulches after 120 days of field exposure was performed with respect to light transmission. Light transmission in wavelength band of 400 to 1100 nm range was measured using spectroradiometer. The observations on light transmission with all plastic mulches are presented in Table 1, Figure 1 and Figure 2.

Data presented in Table 1 indicated that among unused plastic mulches, transparent plastic mulch transmitted the highest amount of light in photosynthetically active wavelength band and total wavelength band 83.01 and 78.16% respectively followed by that in black plastic mulch 57.28 and 49.30% respectively. Lowest light transmission was observed in

silver-black mulch and was to the tune of 43.61 and 35.84% respectively on photosynthetically active wavelength band and Total wave length band.

Table 1: Light transmission through unused and used plastic mulches 2017

Types of plastic mulch	Light transmission (%)			
	Unused plastic mulch		Used plastic mulch	
	PAR	Total	PAR	Total
Transparent	83.01	78.16	87.91	85.36
Black	57.28	49.30	50.02	42.65
Silver-black	43.61	35.84	41.82	34.93

Total wave lengths = 400 to 1100 nm

Photosynthetically active radiation (PAR) = 400 to 700 nm.

Similarly among used plastic mulches, transparent plastic mulch recorded highest light transmission in PAR and Total band where as followed by black plastic mulch. Silver-black plastic mulches transmitted lowest light after 120 days of use and field exposure. However, in case of transparent plastic mulch after field exposure, the light transmission was observed to be increased over light transmission through its unexposed or unused sample.

The reduction in light transmission through black and silver-black plastic mulches was observed higher in Total wavelength band as compared to PAR wavelength band.

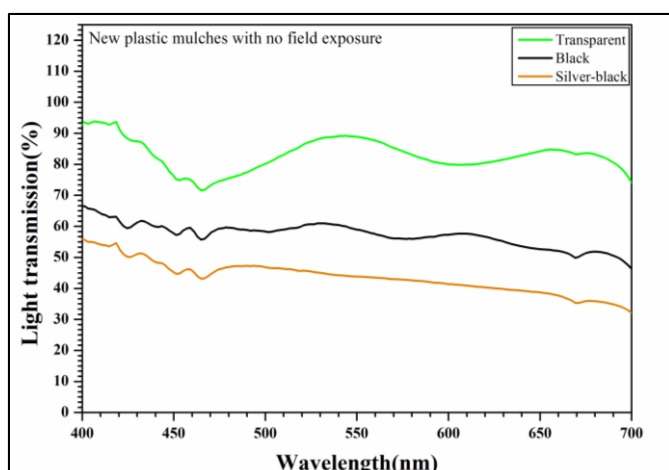


Fig 1: Transmission of light (%) through unused plastic mulches 2017

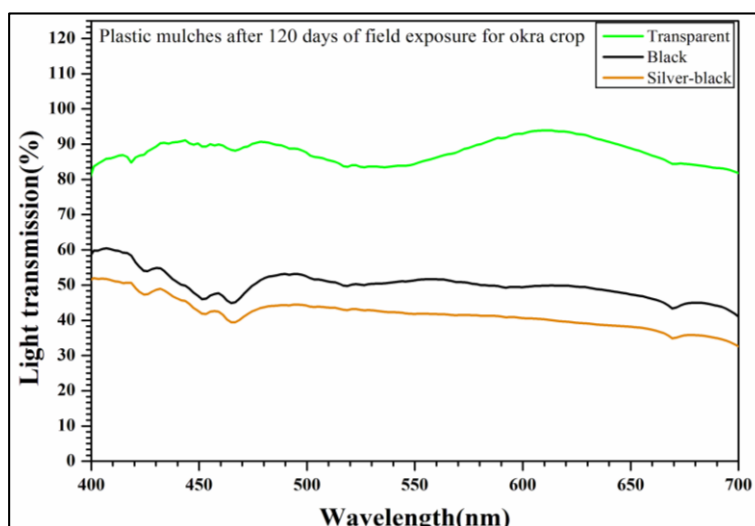


Fig 2: Transmission of light (%) through used plastic mulches 2017

Transparent plastic mulch transmits more incoming solar radiation than black and silver-black plastic mulch and under surface of transparent mulch usually is covered with condensed water droplets and allow facilitates incoming shortwave radiation but is opaque to outgoing long wave radiation; so much of the heat is retained within transparent plastic mulch (Ham *et al.*, 1993, Coleman, 1995) [6, 3].

3.2 Light absorption on used and unused plastic mulches

Observation on light absorption of different types of plastic

unused and used mulches for 120 days were recorded during testing in the laboratory along with the light transmission. Data on light absorption were recorded during testing in the laboratory along with the light transmission in two wavelength bands on PAR and Total band. Data on light absorption of different plastic unused and used mulches are presented in Table 2, Figure 3 and Figure 4.

Table 2: Light absorption through unused and used plastic mulches 2017

Types of plastic mulch	Light absorption (%)			
	Unused plastic mulch		Used plastic mulch	
	PAR	Total	PAR	Total
Transparent	0.14	0.20	0.14	0.21
Black	3.60	3.75	3.96	3.97
Silver-black	1.92	2.14	2.00	2.36

Total wavelengths = 400 to 1100 nm

Photosynthetically active radiation (PAR) = 400 to 700 nm

Data presented in Table 2, Figure 3 and Figure 4 indicated that unused black plastic mulch absorbed the highest amount of light in the PAR band to the tune of 3.60% and in total band of 3.75%. Silver-black plastic mulch to the tune of 1.92 and 2.14% respectively on PAR and Total band, whereas transparent plastic mulch absorbed the lowest amount of light

of 0.14 and 0.20% in PAR and Total band respectively. In general, it was observed that, all plastic mulches absorbed more light after 120 days of field exposure (Figure 3, 4 & Table 2) as compared to unused or unexposed plastic mulches. Similar results were reported by Ham *et al.* 1993 [6].

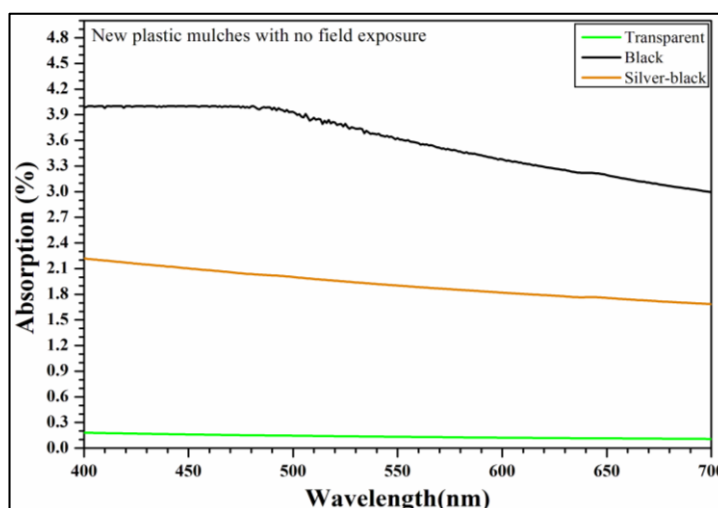


Fig 3: Absorption of light (%) through unused plastic mulches, 2017

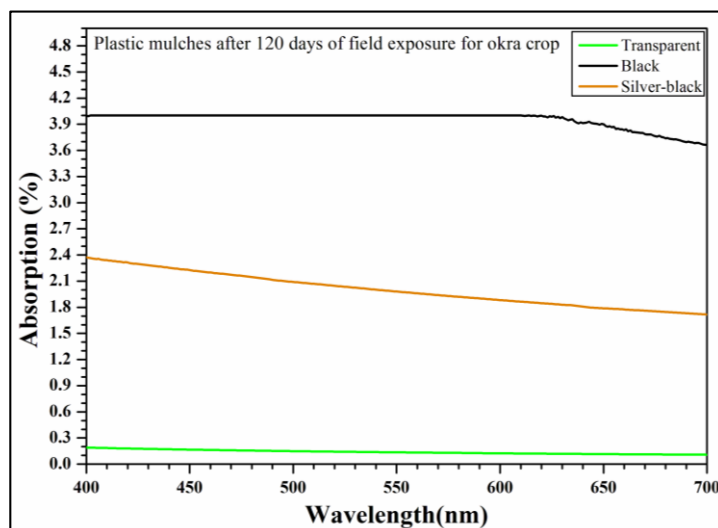


Fig 4: Absorption of light (%) through used plastic mulches 2017

3.3 Effect of plastic mulches on weed infestation

Different plastic mulches were evaluated owing to its light transmission in terms of weed infestation. Weed infestation under different plastic mulches were monitored and recorded.

Table 3: Weed density and total biomass of weeds during crop growing session 2017 and 2018

Types of plastic mulch	Light transmission (%)		Weed density (No./m ²)		Weed biomass (gm./m ²)	
	PAR	Total	2016-17	2017-18	2016-17	2017-18
Transparent	83.01	78.18	152.33	149.36	129.19	126.67
Black	57.28	49.30	0.00	0.00	0.00	0.00
Silver/black	43.61	35.84	3.7	3.2	3.11	2.71

Total wave lengths = 400 to 1100 nm,

Photosynthetically active radiation (PAR) = 400 to 700 nm.

After observation of Table 3 and plate 1, it is indicated that weed infestation was observed highest in transparent plastic mulch and negligible in silver-black plastic mulch. Highest weed density and total weed biomass 152.33 No./m² and 129.19 g/m² were observed in transparent plastic mulch, whereas total absences of weeds were observed in black plastic mulch.

Similar results were reported by (Mathieu Ngouajio and Jeremy Ernest, 2004). Colored plastic mulches varied greatly in their ability to transmit incident light. The transmitted light affects weed seed germination and growth determining weed pressure under plastic mulch. Optical properties of plastic mulches can therefore be used as an indicator of weed infestations in the field.



Plate 1: Biomass of weed under different plastic mulches

4. Conclusion

Different plastic mulches were evaluated owing to its light transmission in terms of weed infestation and results revealed that weed infestation was observed highest in transparent plastic mulch and negligible in silver-black plastic mulch, whereas total absence of weeds were observed in black plastic mulch. Coloured plastic mulches varied greatly in their ability to transmit incident light. These mulches could be considered in double cropping for weed suppression and could help reduce inputs related to purchase, laying, and disposal of the plastics.

5. Acknowledgement

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