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Plastic Mulch Color Effects on Reflected Light and Tomato Plant Growth

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ABSTRACT

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Effects of plastic mulch color on upwardly reflected light and on the growth of tomato plants were investigated. Plants grown in sunlight over black polyethylene mulch had fewer axillary shoots (branches) and were taller than plants grown over white polyethylene mulch. The black surface reflected less total light and less blue light, but a higher ratio of far-red (FR) relative to red (R) light.

In a controlled environment, tomato plants that were exposed to brief periods of FR at the end of the daily photosynthetic period were taller than those that received brief periods of R. The effect of FR on plant height could be reversed by R and implies phytochrome involvement.

Differences in the light spectrum reflected from the plastic, and the similar differential responses to mulch color and light treatments, suggest that tomato plants grown in plastic mulch culture may respond to relatively small changes in light environment induced by the surface color of the mulch.

Keywords: growth; light; *Lycopersicon esculentum*; mulch; phytochrome; tomato.

Abbreviations: R = red light; FR = far-red light.

INTRODUCTION

Increased yields (Downes and Wooley, 1966; Jones et al., 1977), better fruit quality (Downes and Wooley, 1966) and reduced weed pressures (Smith, 1968) are reported when plastic mulch is used in tomato production. The beneficial effects attributed to the use of plastic mulch are probably related to changes in the plant microclimate (Fritschen and Shaw, 1960; Oebker and Hopen, 1974). Soil warming (Schales and Sheldrake, 1963; Taber, 1983) and soil water

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conservation (Lippert and Takatori, 1965; Jones et al., 1977) are the most studied microclimate modifications associated with plastic mulch culture.

Little is known about the modifications of the light micro-environment with the use of plastic mulches, and its effects on crop growth and development. Light reflected off the plastic mulch surface might alter the plant light environment sufficiently to modify photosynthetic rate and/or light stimulus of morphogenic development.

The objectives of the present study were (a) to determine mulch color effects on the plant light environment and on tomato growth, and (b) to determine sensitivity of tomato seedling growth to changes in light environment.

MATERIALS AND METHODS

Mulch color study

Plant material. — Tomato (*Lycopersicon esculentum* Mill. cultivar 'Mountain Pride') plants were started in seedling trays containing a commercial potting mixture (Terralite[1]) in a glasshouse. Five-week-old seedlings were transplanted into the appropriate mulch color treatment at a 30-cm plant spacing. Seedlings in mulch treatments were trickle-irrigated as needed.

Mulch treatments. — Differences in the growth of tomatoes grown with white or black colored polyethylene mulch were evaluated in a glasshouse using a plant bed system described previously (Decoteau and Daniels, 1986). Plant beds (3.4 m × 1.0 m × 0.25 m; l × w × d) were constructed, filled with soil (Norfolk loamy sand), and fertilized and limed according to soil test results. Plots were 1.7 m in length with 2 plots per bed. Black polyethylene mulch was placed over the soil in the beds. The white mulch color treatment was obtained by applying white latex paint (Rust-oleum Gloss White No. 7792) over the black polyethylene surface. The black treatments were unpainted. Mulch color treatments were arranged in a randomized complete block design with three replicates. Plants were harvested for determination of biomass and growth characteristics 22 days after transplanting.

Measurement of plant light environment and soil temperature. — The photosynthetic photon flux density and the spectral distribution of surface-reflected light from 350 to 850 nm at 5-nm intervals were measured as previously described (Kasperbauer and Hunt, 1987) with a LiCor Model 1800 Spectroradiometer with a remote light collector on a 1.5-m fiber-optic probe. The reflected light was expressed as a percentage of direct sunlight at each measured wave-

[1]Mention of a trade name does not constitute a guarantee or warranty of the product by the South Carolina Agricultural Experiment Station or the U.S. Department of Agriculture.

length. Soil temperatures (at a 2.5-cm depth) were automatically measured in all plots at 1-min intervals with a Campbell CR7 Datalogger and copper–constantan fixed thermocouples.

Light environment study

Plant material. — Seeds of tomato ('Mountain Pride') were sown in 1-l pots (6 seeds per pot) containing a commercial potting mixture (Terralite). All plants were grown in the same controlled-environment chamber at 25 °C with 12-h days from cool-white fluorescent lamps at about 450 μmol m^{-2} s^{-1}. After emergence, seedlings were thinned to one plant per pot. R and FR treatments were initiated 8 days after seeding, when seedlings were in the cotyledon stage.

Light treatments. — Investigations of R and FR effects on tomato growth centered on the regulatory role of brief irradiations at the end of the photosynthetic period. For experimentation, seedlings were exposed to 5 min of R (3.6 W m^{-2} in the 600–700 nm waveband), 5 min of FR (3.6 W m^{-2} in the 700–770 nm waveband), or 5 min of FR followed immediately by 5 min of R at the end of the daily light period at 25 °C. After the appropriate light treatments, the seedlings were returned in darkness to the 25 °C growth chamber for the remainder of the 12-h dark period. The treatments were repeated each day for 22 consecutive days. There were 10 single plant replicates per light treatment. Seedlings were sampled at the end of the dark period following the last R and FR treatments.

RESULTS AND DISCUSSION

Mulch color study

Light reflection. — Upwardly reflected light off the polyethylene mulch influenced the light environment in the seedling establishment zone (Table I). The amount of blue light, which influences stem thickening and length (Tanada, 1984), was greater above the white surface than above the black surface. The relative FR/R ratio, which also regulates stem length and is related to phytochrome action within plants (Borthwick, 1972), was slightly higher over the black than over the white surfaces.

Soil temperatures. — The surface color of the mulch affected root-zone temperatures. Soil temperatures 2.5 cm below the black mulch surface averaged almost 1 °C higher than soil temperatures below the white mulch surface (Table I). However, the average soil temperatures for both mulch treatments were within the biologically acceptable range for tomato (Gooselin and Trudel, 1983; Gent, 1986).

TABLE I

Influence of mulch color on upwardly reflected light (10 cm above the plastic) and on soil temperatures. Light measurements were taken on a cloudless day at approximately solar noon, and soil temperatures are mean recorded values at a 2.5 cm depth under the plastic. Irradiance levels at 735 and 650 nm were used to calculate the FR to R ratios because these are phytochrome action peaks in green plants (Kasperbauer et al., 1964). The FR to R ratio of direct sunlight was assigned a value of 1.00

Mulch color	Light parameter of reflected light			Soil temp. (°C)
	Photosynthetically active radiation (400–700 nm)	Blue light (400–500 nm)	FR/R relative to direct sunlight	
	←(% of direct sunlight)→		(ratio)	
White	47	46	1.00	22.9
Black	6	6	1.06	23.7

Plant response. — Mulch color affected photosynthate partitioning and growth characteristics, but not biomass accumulation in the shoots (Table II). Plants grown over the white mulch surface had shorter stems and more lateral growth (branching). These observations suggest that the differences in plant growth were not due to more biomass (photosynthate) produced, but rather to bio-

TABLE II

Biomass and growth characteristics of tomato plants that were grown over white or black polyethylene mulch, or were treated with 5 min of R or 5 min of FR at the end of the 12-h photosynthetic period. Statistical significance of difference between treatment means is indicated by ns (non-significant at $P=0.05$), * (significant at $P=0.05$) or ** (significant at $P=0.01$)

Experiment and treatment	Leaf area/plant (cm^2)		Shoot biomass (g dry wt)	Plant height (cm)	Internode length (cm)		
	Main	Axillary			1st	3rd	5th
Mulch color							
White	735	111	33.23	16.3	1.5	2.1	3.6
Black	795	46	33.98	21.7	2.6	3.8	4.7
Significance	ns	*	ns	**	**	**	**
R or FR at end of daily photosynthetic period							
R	347	–	2.91	11.5	2.6	1.6	1.9
FR	363	–	3.19	15.3	4.1	2.1	2.9
Significance	ns	–	ns	**	**	*	**

mass partitioning among plant components, potentially influenced by the FR/R ratio. Although the differences in FR/R ratio were small (see Table I), recent observations by Andersen et al. (1985) showed that a similar ratio difference during field growth significantly affected growth and development of tobacco (*Nicotiana tabacum* L.) plants. Also, Kasperbauer and Karlen (1986) found that relatively small differences in FR/R ratio during the main light period in controlled environments affected plant height and the number of tillers in wheat (*Triticum aestivum* L.).

Light environment study

The R or FR irradiations were applied for 5 min at the end of each day to put phytochrome into the far-red-absorbing or the red-absorbing forms, respectively, at the end of the photosynthetic period. In this manner, all plants had the same light spectra and amount of photosynthetically active radiation during the day, but were influenced morphogenically by phytochrome regulation of photosynthate partitioning, as discussed by Kasperbauer (1987).

Tomato plants that were treated with daily exposure to FR at the end of the photosynthetic period had longer internodes than plants treated with end-of-day exposures to R (Table II). There were no differences in leaf area or shoot biomass between the R- or FR-treated tomato plants. The larger plant heights

Fig. 1. Representative tomato plants grown under 12-h photosynthetic periods that ended with 5 min R (left), 5 min FR (middle), or 5 min of FR followed immediately by 5 min R (right) each day for 22 consecutive days.

induced by FR treatments were photoreversibly controlled by following the FR immediately with R (Fig. 1), which suggests phytochrome as the sensing mechanism for regulation of tomato seedling growth.

Growth responsiveness of tomato plants from both the glasshouse mulch color study and the controlled light environment study suggests operation of one or more photomorphogenic control mechanisms. Mediation of photosynthate partitioning and morphological development of field-grown plants has been attributed to subtle differences in plant light environment. For example, tobacco (*Nicotiana tabacum* L.) grown in high population densities received a higher FR/R ratio and were taller than plants grown in lower population densities (Kasperbauer, 1971), and southern peas (*Vigna unguiculata* (L.) Walp.) grown over a white surface had shorter internodes than plants grown over a black surface (Kasperbauer and Hunt, 1987). It is also possible that in the present investigations the higher amounts of blue light over the white surface might contribute to regulation of tomato plant growth, resulting in shorter stems with more axillary growth, as suggested by Tanada (1984).

Regardless of the control mechanism, polyethylene mulch color can affect the plant microclimate sufficiently to alter the growth of tomato plants. The similar differential response of tomato to mulch color and to the end-of-day exposure to R and FR suggests that plants grown with plastic mulch culture can be influenced by reflected light off the mulch surface. A better understanding of mulch color effects on plant growth and development should assist in the development of alternative mulch colors and/or materials that modify the plant microclimate sufficiently to regulate seedling establishment, crop growth and the quantity and quality of yield.

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