

# PLANT RESPONSES TO WAVELENGTH SELECTIVE MULCHES AND ROW COVERS: A DISCUSSION OF LIGHT QUALITY EFFECTS ON PLANTS

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**Abstract:** The radiant environment surrounding young seedlings can be modified using cultural practices such as wavelength selective mulches and row covers. In general, plants grown with mulch colors that reflect or row covers that transmit greater amounts of far red relative to red (FR:R) light are taller (longer stems) than plants grown in light environments that contain lesser amounts of FR:R light. Phytochrome is the plant pigment implicated in sensing light quality and in regulating plant morphogenic development. Manipulation of the quality of light in the plant environment using the cultural practices of plastic mulches and row covers, and why these changes in light quality affect plant development will be discussed.

## Introduction

Plastic (polyethylene) mulches and row covers are commonly used in the production of several vegetable and small fruit crops. Reported benefits with the use of plastic mulches include earlier yields (Bhella, 1988; Schalk *et al.*, 1979; West and Pierce, 1988), better fruit quality and greater total yields (Brown *et al.*, 1986; Wien and Minotti, 1987). In general, these responses have been attributed to enhanced soil warming, more efficient use of water (Bhella, 1988) and fertilizers (Bhella, 1988; Wien and Minotti, 1987), and better control of weeds (Smith, 1968).

Row covers have been effectively used to enhance early season production of several crops (McGraw, 1986; Miller, 1989). Reported benefits have been primarily attributed to enhanced warming under these materials (Reed *et al.*, 1989). Recently we have documented alterations in the plant light environment with the use of plastic mulches and row covers. These alterations are a result of either differential reflectivity (colored mulches) or transmission (row covers) and were sufficient to influence the development of young seedlings (Decoteau *et al.*, 1986, 1988, 1990; Friend and Decoteau, 1990) and affect yield (Decoteau *et al.*, 1989). The objectives of this paper are (a) to discuss the importance of the plant pigment phytochrome in regulating plant development, (b) to document how the plant light environment is modified using cultural practices such as wavelength selective (colored) mulches and row covers, and (c) to explain the mechanism of phytochrome-mediated plant growth as it applies to changes in spectral quality (wavelength distribution) of the plant light environment as influenced by wavelength selective mulches and row covers.

## Characterization of Light

Light is a form of radiant energy from a portion of the electromagnetic spectrum. The electromagnetic spectrum has been divided into units of wavelength and frequency. In plant photobiology, light is generally categorized into wavelength (nm) and energy (photons or quanta). The spectral distribution or quality of light is the breakdown of radiant energy into its wavelength components, which allows specific reference to a section of the electromagnetic spectrum. For example, photosynthetically active radiation (PAR) is the quantum energy utilized by plants for photosynthesis and is an integrated measurement over a spectral range (wavelengths) of 400 to 700 nm. For our discussions, the plant light environment will be defined as the amount and spectral distribution of radiation measured in close proximity to the plant canopy or plant structure.

## Phytochrome - A Plant Pigment that Regulates Plant Development

The ability to perceive the light environment is necessary for the survival of most biological species. Radiant energy sensitive cells (photoreceptors) exist in plants as pigments. Plant pigments can be divided into two categories according to their physiological function: photosynthetic pigments and photomorphogenic pigments. Photosynthetic pigments, chlorophyll and its accessory pigments, function in the capture of radiant energy which produces chemical energy and sugars through the process of photosynthesis. The photomorphogenic pigments function in perception of specific wavebands of light (red, far-red, and blue) as indicators of the plant environment and in the regulation and the development of the plant.

Phytochrome, the only plant photomorphogenic pigment that has been isolated and characterized, can perceive the relative amounts of far-red and red (FR:R) light in the environment. The relative amount of FR:R increases as the plant becomes crowded and/or is shaded by other plants (Kasperbauer, 1987). Plants generally respond to this increase in the FR:R by becoming taller and shifting biomass to the aerial portions of the plant in an apparent attempt to grow taller to avoid the existing ecological environment and enhance its chance for survival. The phytochrome pigment has been implicated in many physiological plant responses such as seed germination and flowering (Schofer, 1985)

There is also increasing evidence for the existence of a blue light receptor within plants called cryptochrome. The cryptochrome pigment has not been chemically or physically identified and, therefore, remains a postulate or theory derived from physiological experiments (Schofer, 1985). Some reported blue light effects on plant development include anthocyanin formation, phototropism, and hypocotyl elongation. An interdependent coaction of phytochrome and cryptochrome may also promote certain plant responses.

### Modifying the Plant Light Environment Using Wavelength Selective (Colored) Mulches and Row Covers

Mulch colors. Plastic mulches affect the plant light environment by altering the wavelength composition and amount of radiation reflected from the surface of the mulch up into the plant canopy. In our research, mulches of different color were established by applying enamel paint to the black surface (Decoteau *et al.*, 1989). Using various colors of mulch altered the amount and wavelength composition of the reflected light (Table 1). Quantification of upwardly reflected light from the mulch was calculated according to amount of photosynthetically active light (PAR) and photomorphogenic light (FR: R). Spectral irradiances at 735 and 645 nm were used to calculate FR: R ratios as these values have been previously shown to approach the peaks for phytochrome action spectra in green plants (Kasperbauer *et al.*, 1964). The lighter colored (white and yellow) mulches reflected more photosynthetic light and smaller FR: R ratios than the darker (black and red) mulches. The colored mulch treatments in the field not only affected the plant light environment but also root zone temperatures under the mulch (Decoteau *et al.*, 1990).

Table 1. Reflective characteristics of selected mulch colors (Decoteau *et al.*, 1990).

Mulch Color	Reflected Light (% of incident radiation)	
	PAR	FR:R
Red	10.0	1.15
Black	5.6	1.01
Yellow	33.0	0.99
White	47.4	0.95

Row covers. Row covers affect the plant light environment by serving as potential selective filters to the incident in-coming radiation. In our research, the spectral transmission properties of several commercially available brands of row covers were calculated (Friend and Decoteau, 1990) and these results are summarized in Table 2.

Clear polyethylene row covers were the most transparent to PAR (93% of incident radiation) of the materials evaluated. The fabric row cover materials (spunbonded polyester) reduced the PAR to 67% of incident radiation, while the white-tinted polyethylenes reduced PAR to 23% of incident radiation. Clear polyethylene and spunbond polyester had no affect on relative FR: R, and white polyethylene increased the relative FR: R.

Table 2. Transmission characteristics of selected row cover materials (summarized from Friend and Decoteau, 1990).

Row Covers	Transmitted Light (% of incident radiation)	
	PAR	FR:R
White polyethylene	22.7	1.12
Spunbond polyester	66.7	1.01
Clear polyethylene	93.3	1.00

#### Implications of Modifications in the FR:R in the Plant Light Environment on Plant Development

Subtle changes in the wavelength distribution of the plant light environment as affected by either mulch color reflection or row cover transmission can affect plant growth and development. In Figure 1, the relative growth of tomato (mulch color) and watermelon (row cover) was plotted against the relative FR:R light environment as influenced by mulch color (Decoteau *et al.*, 1990) or row cover treatments (Friend and Decoteau, 1990). In general, as the relative FR:R light environment increases to greater than 1.0; stem elongation and thus taller plants occur. With a reduction in the FR:R due to mulch color treatments, there is also a relative reduction in plant height. With increases in the FR:R due to mulch color, increase in plant biomass of young pepper plants (Decoteau, 1990), increase in axillary shoot and internode lengths of young tomatoes (Decoteau *et al.*, 1988), and increase in early fruit yield of tomato (Decoteau *et al.*, 1989) were reported. Increases in the FR:R due to differential row cover transmission caused an increase in petiole length of watermelons (Friend and Decoteau, 1990).

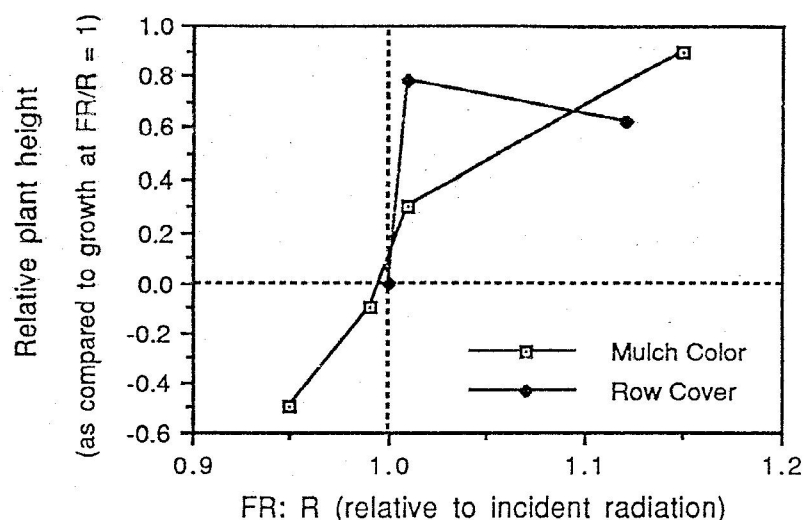


Figure 1. Relative growth of young pepper plants due to mulch color (FR:R values from Table 1 and relative growth calculated from Decoteau et al, 1990) and young watermelon plants due to row cover treatments (FR:R values from Table 2 and relative growth calculated from Friend and Decoteau, 1990).

Supporting Evidence Implicating Phytochrome as a Regulator of Plant Growth  
in Response to Changes in the Plant Light Environment as a Consequence  
of Using Wavelength Selective Mulches and Row Covers

The sensitivity of plants to subtle changes in the wavelength composition of the plant light environment can be illustrated by treating plants with 5 to 15 minutes of end-of-day (EOD) red (R) or far-red (FR) light (Decoteau *et al.*, 1990). These light treatments convert phytochrome into the far-red or red absorbing form, respectively, at the end of the daily photosynthetic period. In this manner, all plants receive the same light spectra and amount of PAR during the day but are influenced by phytochrome regulation of plant development at the EOD (Kasperbauer, 1987). Resulting plant developmental responses from EOD treatments are considered phytochrome-mediated. These results can then be compared to the data observed with light quality modifications of the FR:R with our wavelength selective mulches and row covers.

For example, tomato plants treated with EOD FR light were taller and had longer internodes than plants treated with EOD R light (Table 3). The plant growth generated by EOD FR light was similar to tomato plant development when grown over a mulch color (white) that reflected a relatively high FR:R. Also, tomato plants treated with EOD R light had growth trends similar to plants grown with a mulch color (black) with a relatively low FR:R. Similar correlations of plant growth with high FR:R and EOD FR and with low FR:R and EOD R with peppers in a mulch color evaluation and with watermelons in a row cover evaluation have been observed. The similar responses of plant growth when exposed to FR:R associated with mulch color or row cover treatments and EOD light treatments suggest that plants respond to changes in the plant light environment induced by phytochrome perception of light quality and mediation of plant development.

Table 3. Growth characteristics of tomato plants that were grown over white or black colored mulch, or were treated with 5 min of R or 5 min of FR at the end of the daily photosynthetic period (Decoteau *et al.*, 1988). Statistical significance of difference of treatment means is indicated by \*(significant at  $P = 0.05$ ) or \*\* (significant at  $P = 0.01$ ).

Experiment and Treatment	FR:R	Plant Height (cm)	Internode Length (cm)		
			1st	3rd	5th
Mulch Color					
White	low	16.3	1.5	2.1	3.6
Black	high	21.7	2.6	3.8	4.7
Significance		**	**	**	**
R or FR at the end of daily photosynthetic period					
R	low	11.5	2.6	1.6	1.9
FR	high	15.3	4.1	2.1	2.9
Significance		**	**	*	**

### Conclusions

Wavelength selective mulches and row covers can affect the plant light environment and influence plant growth and development. The growth responses to the altered plant light environment have been suggested to be mediated by photochrome. A better understanding of wavelength selective mulches and row cover effects on altering the plant light environment and on plant growth and development should assist in the development of alternative colors of mulch and row cover materials that modify the plant microclimate sufficiently to regulate seedling establishment, crop growth, and the quantity and quality of yield.

### Literature Cited

- Bhella, H.S. 1988. Tomato response to trickle irrigation and black polyethylene mulch. *J. Amer. Soc. Hort. Sci.* 113:543-546.
- Brown J.E., C.A. Lewis, J.T. Eason, M.E. Ruf, D.W. Porch, and M.E. Marvel. 1986. Effect of black plastic mulch and drip irrigation on bell pepper performance. *Proc. Natl. Agr. Plastics Congr.* 19:256-262.
- Decoteau, D.R., D.D. Daniels, M.J. Kasperbauer, and P.G. Hunt. 1986. Colored plastic mulches and tomato morphogenesis. *Proc. Natl. Agr. Plastics Cong.* 19:240-248.
- Decoteau, D.R., M.J. Kasperbauer, D.D. Daniels, and P.G. Hunt. 1988. Plastic mulch color effects on reflected light and tomato plant growth. *Scientia Hort.* 34:169-175.
- Decoteau, D.R., M.J. Kasperbauer, and P.G. Hunt. 1989. Mulch color affects yield of fresh market tomatoes. *J. Amer. Soc. Hort. Sci.* 114:216-220.
- Decoteau, D.R., M.J. Kasperbauer, and P.G. Hunt. 1990. Bell pepper development over mulches of diverse colors. *HortScience* 25:460-462.
- Friend, H.H. and D.R. Decoteau. 1990. Transmission properties of selected row cover materials and implications in early plant development. *Proc. Natl. Agr. Plastics Cong.* 22:1-6.
- Kasperbauer, M.J., H.A. Borthwick, and S.B. Hendricks. 1964. Reversion of phytochrome 730 (Pfr) to P660 (Pr) in *Chenopodium rubrum* L. *Bot Gaz.* 125:75-80.
- Kasperbauer, M.J. 1987. Far-red light reflection from green leaves and effects of phytochrome-mediated partitioning under field conditions. *Plant Physiol.* 85:350-354.
- McGraw, D. 1986. Row covers increase earliness, yield and value of fresh market tomatoes. *Proc. Natl. Agr. Plastics Cong.* 19:34-356.
- Miller, G.A. 1989. Row cover effects on harvest date of watermelons. *Proc. Natl. Agr. Plastics Cong.* 21:123-126.
- Reed, G.L., G. Clough, D.E. Hemphill, Jr., and R.C. Wilson. 1989. The effect of slit, perforated and net row covers on mulched soil and crop temperatures and periodicity of muskmelon yield. *Proc. Natl. Agr. Plastics Cong.* 21:116-122.
- Schalk, J.M., C.S. Creighton, R.L. Fery, W. Sitterly, B.W. Davis, T.L. McFadden, and A. Day. 1979. Reflective film mulch influences insect control and yield in vegetables. *J. Amer. Soc. Hort. Sci.* 104:759-762.
- Schofer, P. 1985. Photomorphogenesis. In: *Advanced Plant Physiology*, Pittman press, Marshfield, MA, pp. 380-407.
- Smith, D.F. 1968. Mulching systems and techniques. *Proc. Natl. Agr. Plastics Conf.* 8:112-118.
- West, J. and L.C. Pierce. 1988. Yields of tomato phenotypes modified by planting density, mulch, and row covers. *HortScience* 23:321-324.
- Wien, H.C. and P.L. Minotti. 1987. Growth, yield, and nutrient uptake of transplanted fresh-market tomatoes as affected by plastic mulch and initial nitrogen rate. *J. Amer. Soc. Hort. Sci.* 112:759-763.