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# Mulch Color Effects on Reflected Light, Rhizosphere Temperature, and Pepper Yield

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ABSTRACT

Peppers (*Capsicum annuum* L. cv. Lady Bell) were grown with white, blue, red and black plastic mulches in trickle-irrigated field plots. Data were collected on rhizosphere temperature, spectral balance of reflected light, and fruit yield. When plants were transplanted early (at the first "frost-free" date of spring), fruit yields were highest over red mulch even though rhizosphere temperatures did not differ under red, black, and blue mulches and were 24 ± 0.5°C. However, plants grown over red mulch received more reflected far-red light and higher far-red to red light ratios. When transplanting was delayed until about a month after the frost-free date, highest yields were obtained with white mulch which kept rhizosphere temperature near 25°C. Under red, blue, and black mulches, rhizosphere temperature was 28.5 to 29.3°C. It was concluded that yields of peppers grown with different colored mulches were influenced by both rhizosphere temperature and the relative amounts of far-red and red light reflected from the various mulches.

## INTRODUCTION

Plastic mulches are used in a number of horticultural crops to suppress weeds, conserve soil moisture, and alter temperature in the rhizosphere. Traditionally, plastic mulches are black or white. Black plastic is often used to warm soil early in the season, and white plastic can moderate soil temperature in summer. Recent studies of the effects of soil and mulch colors revealed differences in plant growth in response to spectral balance of reflected visible [including red (R)] and near-visible [especially far-red (FR)] light (4, 8).

Experiments conducted under controlled environments have demonstrated that plants respond differently to different colors of light, such as R and FR (3). The ratio of FR photons relative to R photons controls the equilibrium of the phytochrome system (7), which regulates a number of developmental responses, such as stem elongation, leaf shape, shoot/root biomass ratios and partitioning of photosynthate among shoots, roots and fruits (6). The responses of plants to FR/R ratio are independent of the source of altered light [i.e., colored light bulbs or colored filters below the bulbs (3), sunlight reflected from green plants (5) or upward reflection from different colored soils (4, 8)].

Use of colored plastic mulches offers the possibility of using basic principles of photomorphogenesis to enhance plant productivity in the field at a relatively low cost. In such a system, plants will grow in sunlight and mulches of the appropriate surface color will reflect light of predetermined spectral balance up to the plant where it will be absorbed by photoreceptors, such as phytochrome, and result in a desired plant response such as larger fruits or an altered shoot/root biomass ratio (1, 2, 5, 9). The present study was undertaken to investigate the effects of different surface colors of plastic mulches on spectrum of reflected light and yield of field-grown green pepper (*Capsicum annuum* L.). Possible influence of planting date on effects of mulch colors was also examined.

## MATERIALS AND METHODS

### Plant Material

Seedlings (cv. Lady Bell) were started and grown in 5-cm peat pots of potting soil (Ball No. 2 potting mixture,[1] Ball Seed Co., West Chicago, Illinois) in a polyethylene covered greenhouse for six weeks before transplanting to field plots. The day and night temperatures in the greenhouse were maintained at 27 ± 2½°C and 17 ± 2½°C, respectively.

[1] Mention of a trade name does not constitute a guarantee or warranty of the product by Kentucky State University, USDA/CSRS or USDA/ARS and does not imply approval to the exclusion of other products that may also be suitable.

### Experimental Design

For each experiment, 6-week-old seedlings were transplanted to field plots on the Kentucky State University research farm near Frankfort. The soil was a Lowell silt loam (fine, mixed, mesic Typic Hapludalfs). The plots were plowed, and broadcast with 100 kg/Ha $K_2O$ and 55 kg/Ha $NH_4NO_3$. Trickle irrigation tubes and plastic mulches were placed before transplanting. The plastic panels were 4.2 m wide so that the only light reflected up to the plants would be from the indicated surface color. For the early transplanting date, plants were transplanted during the second week of May (very soon after the danger of frost was over). The other set was transplanted during the second week of June (after the soil had warmed).

Four replicated 15 × 4.2 m blocks were prepared by placing trickle irrigation tubes 1.5 m apart throughout the length of each block before placing the mulch. Within each block, four 3 × 4.2 m plots were covered with 4 mil black plastic mulch, and a 3 × 4.2 m plot was left uncovered (i.e., bare soil). One of the mulched plots remained black (unpainted) while others were painted with oil-based exterior paint to get white, blue, and red mulch surfaces. The colors were randomized within each block. Ten-cm diameter holes were cut in the plastic mulch at 45 cm intervals in rows that were 1.5 m apart. Peat pots containing the transplants were hand set in these openings, and were similarly spaced on the bare soil plots. Fifteen plants (i.e., 5 plants in each of 3 rows) were grown in each 3 × 4.2 m plot. All plots were irrigated as needed, and bare soil plots were weeded and cultivated as necessary.

### Data Collection and Analysis

There were 6 harvests per plot at 10-day intervals. Peppers were harvested when they were at marketable size. All mulch color treatments within an experiment were harvested on the same dates. The fruits were classified according to U.S. grade standards and grouped as "U.S. Fancy," "U.S. No. 1," or "other." Weights in each class and the totals per plot were recorded. Data are presented as mean weight per hectare (under the experimental conditions described there would be approximately 14,500 plants per hectare). Yield data were analyzed by analysis of variance and mean separation was done by Duncan's procedure.

Rhizosphere temperatures were taken 15 cm away from the main stem 10 cm below the soil surface using an Orion SA 250 portable meter (Orion Research, Inc., Boston, MA) fitted with a stainless steel temperature probe. Temperature readings were taken in the middle of each plot at 10:00 a.m. ± 1 hr at least once per week for the first 3 weeks after transplanting. This period was selected because plant shading of the soil surface was not a major factor, as it was later.

Reflected light from each mulch color was determined at solar noon ±30 min on a cloudless day, using a LI-COR 1800 spectroradiometer (LI-COR, Lincoln, Nebraska) with a remote light collector on a 1.5-m fiber optic probe. Upwardly reflected light was measured at a point 10 cm above the mulch surface in order to measure relative spectral differences received by plants growing over the various colors. Measurements were taken at 5-nm intervals from 400 to 800 nm. The reflected light was expressed as a percentage of incoming sunlight at each measured wavelength. Far-red/red light ratios in reflected light were calculated.

## RESULTS AND DISCUSSION

The yields from plants grown on bare soil were lower than those from plants grown on any of the plastic mulches, regardless of the transplant date.

When transplanting was done soon after the first frost-free date of spring (the second week of May), the highest early harvest yield as well as the highest total harvest yield were obtained from the plants grown on red plastic mulch (Table 1). The lowest yields, among the plants grown on mulched plots, were obtained from plants growing on white mulch (Table 1). The yields from plants grown on blue and black plastic mulch were intermediate between those on red and white mulch (Table 1). However, when transplanting was done after the soil had warmed (the second week of June), the highest early as well as total yield were obtained on white mulch (Table 2).

The differences in yield responses to mulch color between the early and late transplanting dates suggest that early season soil warming under dark colors (Table 3) may have favored higher yields; whereas, excessive soil warming under the dark colors later in the season may

TABLE 1. Effects of colored plastic mulches on yield of May-transplanted peppers. Yields are expressed as metric tons per hectare. Early harvest included the fruits picked during the first three weeks of harvest. Within each column, entries followed by the same letter do not differ significantly at the 5% level.

| Mulch color | Early harvest: U.S. Fancy + U.S. No. 1 | Early harvest: Total | Total harvest: U.S. Fancy + U.S. No. 1 | Total harvest: Total |
|---|---|---|---|---|
| White | 3.19c | 7.83d | 12.62bc | 23.78b |
| Blue | 5.08bc | 10.88bcd | 11.31bcd | 24.36b |
| Red | 10.73a | 15.08a | 23.20a | 36.98a |
| Black | 7.25ab | 12.47abc | 16.82ab | 30.02ab |
| Bare soil | 1.45c | 4.35e | 7.25cd | 14.21c |

have contributed to higher yields under lighter colored mulches (i.e., white versus red, black or blue).

Although comparison of yields from the two transplanting dates (Tables 1 and 2) suggests influence of soil temperature, it must be noted that recent studies (4, 8) demonstrated significant differences in shoot and root growth when plants were grown over different soil colors, even when insulation panels kept soil temperatures constant below the various surface colors. Those authors concluded that the FR/R ratio in the upwardly reflected light over the various soil surface colors acted through the phytochrome system and played a major role in plant development, especially in the relative amount of photosynthate partitioned to various parts of the plant.

In the present study, highest early season yields from the May transplants were obtained from plants grown over the red mulch (Table 1). This is consistent with the observations of Decoteau et al. (2), who obtained higher tomato (*Lycopersicon esculentum* Mill.) yields over red than over white or black plastic mulch. At least part of the difference in pepper yield in the present study appears to be related to the differences in FR/R ratios received by the plants. In previous investigations, modifications in plant growth patterns by very subtle changes in FR/R ratios have been documented in controlled environments (7) and in the field (1, 5, 9). Nevertheless, it is apparent from our results (Tables 1, 2 and 4) that change in FR/R ratio is not the only factor determining photosynthate partitioning and yield. Likewise, the highest amount of photosynthetically active light (Table 4) did not always result in the highest yields (Table 1). Also, higher soil temperature in early season (Table 3) did not always result in higher early yields. For example, although rhizosphere temperatures were not significantly different under red, black and blue mulches (Table 3), early yield on blue mulch was significantly lower than that on red mulch (Table 1). Thus, under field conditions, green pepper yield appeared to be influenced by a

TABLE 2. Effect of colored plastic mulches on yield of June-transplanted peppers. Yields are expressed as metric tons per hectare. Early harvest included the fruits picked during the first three weeks of harvest. Within each column, entries followed by the same letter do not differ significantly at the 5% level.

| Mulch color | Early harvest: U.S. Fancy + U.S. No. 1 | Early harvest: Total | Total harvest: U.S. Fancy + U.S. No. 1 | Total harvest: Total |
|---|---|---|---|---|
| White | 21.03a | 22.77a | 29.58a | 35.82a |
| Blue | 12.04b | 14.94b | 16.39b | 23.49b |
| Red | 11.46b | 14.36b | 17.26b | 25.23b |
| Black | 11.31b | 14.36b | 14.50b | 21.03b |
| Bare soil | 4.06c | 7.40c | 6.53c | 13.20c |

TABLE 3. Effect of mulch color on rhizosphere temperatures for about three weeks after the early and late transplanting dates. The temperature readings were taken 10 cm below the soil level. Within each column, entries followed by the same letter do not differ significantly at the 5% level.

| Mulch color | May 19 to June 3 (mean of 7 readings) | June 13 to July 8 (mean of 5 readings) |
|---|---|---|
| White | 20.2ab | 24.8a |
| Blue | 23.5bc | 28.5ab |
| Red | 24.0c | 28.5ab |
| Black | 24.3c | 29.3b |
| Bare soil | 23.9c | 27.2ab |

TABLE 4. Effect of mulch color on upwardly reflected light (10 cm above the surface). Data were collected at solar noon ± 30 min on a cloudless day. Data are means of duplicate readings. The FR/R ratio in sunlight was arbitrarily assigned a value of 1.00. Other ratios are relative to that in sunlight.

| Mulch color | Reflected light, 10 cm above surface: Photosynthetic (400–700 nm) (as % of sunlight) | Reflected light, 10 cm above surface: FR/R ratio (relative to sunlight) |
|---|---|---|
| White | 42 | 1.00 |
| Blue | 8 | 1.05 |
| Red | 13 | 1.12 |
| Black | 6 | 1.03 |

combination of rhizosphere temperature, photosynthetically active light and spectral properties of reflected light, all of which are affected by mulch color. Based on the results presented, we conclude that appropriately colored mulches can improve pepper productivity under field conditions. But the appropriate color will vary depending upon the planting conditions.

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