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Growth and Subsequent Yield of Tomatoes following End-of-day Light Treatment of Transplants

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Abstract. **The influence of end-of-day (EOD) light treatments of tomato *(Lycopersicon esculentum* Mill. cv. Mountain Pride) transplants on growth and subsequent fruit production was investigated. In the first experiment, transplants were treated with EOD red (R) and far-red (FR) light for 2 weeks in a controlled environment and then placed in the greenhouse under ambient light conditions from November to March. Before transplanting to the greenhouse, transplants treated with EOD R light were shorter and had less total leaf length than plants that were not treated with EOD light (controls). EOD R light increased the number of flowers on the plants before first harvest but had no effect on subsequent fruit production (as compared to plants treated with EOD FR light or control plants). In the second experiment, cool-white fluorescent lights (a light source high in red wavebands) were used to supplement solar light that transplants received in a nonshaded glasshouse for 1 hour before the end of the natural photoperiod. The fluorescent light reduced transplant height and total leaf length as compared to plants not treated with supplemental light. Supplemental fluorescent light for transplants had no effect on subsequent fruit production in the field. These results suggest that EOD light treatments that affect tomato transplant growth do not affect subsequent fruit production.**

Growing conditions during tomato transplant production can affect the subsequent yield performance of the transplants in the field (Knavel, 1965; Nicklow and Minges, 1963). Transplants grown in large cells (4.5 cm cell length, 39.5 cm^3) produced earlier yields but total yields similar to transplants grown in small cells (2.0 cell length, 4 cm') (Weston and Zandstra, 1986). Location of transplant production can influence plant performance. For example, transplants grown in Michigan produced higher early yields than similarly grown transplants in Florida (Weston and Zandstra, 1986). Also, transplants produced in wide spacings (30 x 30 cm) on the greenhouse bench produced more early fruit than those produced in close spacings (5 × **7.5** cm) (Knavel, 1965). Recent research directed at nutrient conditioning of tomato transplants has investigated optimum fertilizer rates for superior transplant growth. Weston and Zandstra (1986) reported that transplants conditioned with moderate (200 $mg \cdot liter^{-1}$) to high (400 $mg \cdot liter^{-1}$) N levels produced earlier and higher tomato yields. Melton and Dufault (1991) reported that the optimum nutrient solution for tomato transplants should contain at least 225 mg N/liter and 45 mg P/liter. Also, insufficient light during transplant production is often implicated as a cause of "leggy," undesirable transplants.

Supplemental lighting of greenhouse-grown crops is not currently widely practiced in the United States. Only 5% of the commercial greenhouse space in the United States is fitted with supplemental lighting systems (Thomas, 1990). Greenhouses with these supplemental lighting systems are primarily used in ornamental crop production for prolonging the natural photoperiod during short days, supplementing light on overcast days, and night period interruption. Supplemental lighting has not been traditionally used in the production of vegetable transplants in the United States, and research on the effects of supplemental lighting on transplant development and subsequent yield performance is limited. Tomato transplants grown in greenhouses in Canada during the winter months supplemented with irradiance from high--pressure sodium lamps [100 $\mu mol \cdot m^{-2} \cdot s^{-1}$ photosynthetic photon flux (PPF) supplement for a 17-h photoperiod] were larger and produced higher early marketable yields than transplants that received no supplemental lighting (Boivin et al., 1987). With lettuce grown in England, supplemental lighting of transplants with tungsten lights (13 $\mu mol \cdot m^{-2} \cdot s^{-1}$ PPF) for 4 h after dusk increased transplant shoot dry weight but had no effect on head weight at maturity (Wurr et al., 1986).

Even though research has been directed at duration of supplemental lighting systems, little has been done to investigate the influence of light quality on early transplant development and subsequent performance of the plant after transplanting. Our research (Decoteau et al., 1988) and that of others (Tucker, 1975) has implicated phytochrome as a growth-sensing pigment in early tomato plant development. Tomato seedlings treated for 5 min with far-red (FR) light at the end of the daily photoperiod were taller and generally had longer internodes than plants that were treated with end-of-day (EOD) red (R) light (Decoteau et al., 1988). The effect of EOD FR light on tomato seedling height was reversed by immediately following the FR treatment with R light. The influence of these EOD light treatments during seedling growth on subsequent field performance is not known. The objective of the present studies was to determine the influence of supplemental (EOD) light treatments during tomato transplant development on transplant growth and subsequent fruit production.

Two experiments were conducted to determine the effects of EOD light treatments during the production of transplants on growth and subsequent fruit production of 'Moun-

Table 1. Influence of end-of-day (EOD) red (R) and far-red (FR) light exposure (Expt. 1) and EOD fluorescent light exposure (Expt. 2) during tomato transplant production on growth of seedlings and subsequent flower count.

	Sampling period		
	Before transplanting		Before first harvest
EOD treatment during transplant production	Plant ht (cm)	Leaf length/ plant (cm)	Flowers/ plant (no.)
	Expt. 1, EOD R and FR light exposures		
R	9.1 a[z]	88.7 a	26.3 a
FR	14.5 c	115.2 b	17.3 b
FR/R	10.1 ab	102.0 ab	21.8 b
Control	13.4 bc	116.6 b	20.3 b
Significance	*	*	*
	Expt. 2, EOD fluorescent light exposure		
Fluorescent	18.6	75.3	---
Control	22.1	90.3	---
Significance	*	*	---

'Mean separation within columns by **LSD,** $P = 0.05$.
*Significant at $P = 0.05$.

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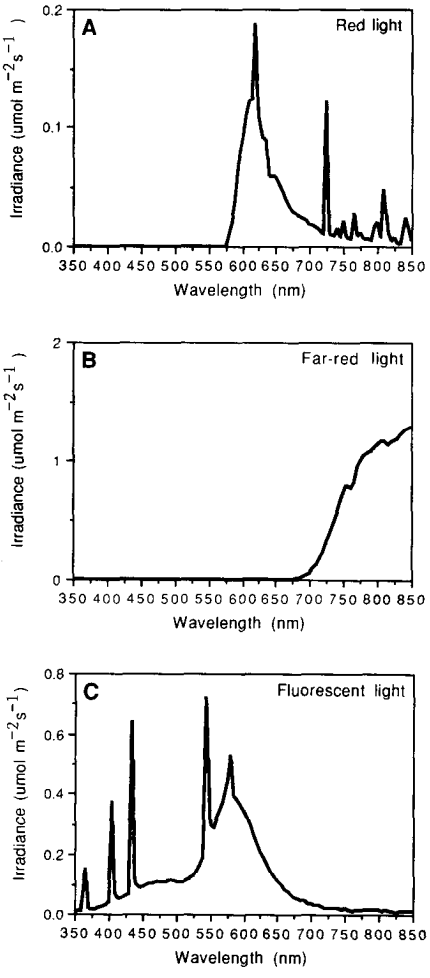

Fig. 1. Light spectra of end-of-day treatments: (A) red light, (B) far-red light, and (C) fluorescent light.

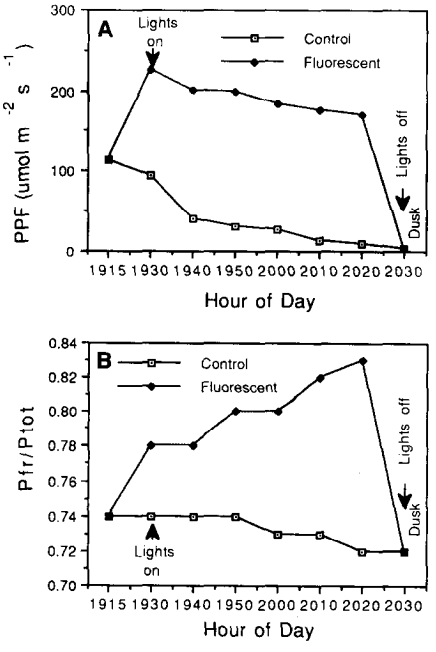

Fig. 2. Influence of 1 h of end-of-day supplemental fluorescent light on PPF (A) and Pfr : Ptot (B) of the seedling light environment as measured on 30 May 1989. Measurements are representative of a typical end-of-day fluorescent light exposure (fluorescent) and no end-of-day supplemental light exposure (control). Sunset (dusk) is <2µmol·m^{-2}·s^{-1}.

tain Pride' tomato. In the first experiment, the effects of EOD R and FR light on transplant performance were determined. These light treatments convert phytochrome into the FR- or R-adsorbing form, respectively, at the end of the daily photosynthetic period (Kasperbauer, 1971; Kasperbauer et al., 1964) and have been previously shown to affect the growth of young tomato seedlings (Decoteau et al., 1988). Tomato seeds were planted in 0.5-liter pots containing a commercial potting mix (Fafard Soilless Peat Mix no. 3; Anderson, S. C.) and held in a controlled-environment room (10 m long x 15 m wide) for germination and seedling growth. Three to five seeds were placed per pot with emerging seedlings thinned to one per pot after selection for uniformity. The controlled-environment room was equipped with multivapor high-intensity discharge lights that provided 315 µmol·m^{-2}·s^{-1} PPF during a 12-h photoperiod. Day and night means were 27 and 21C, respectively.

The plants were treated with EOD light treatments 18 days after seeding. At the end of each daily photosynthetic period, plants were placed either in a R or FR light-exposure chamber for 15 min of treatment and then returned in darkness to the plant-growing area of the controlled-environment room. One set of plants was exposed to 15 min of FR light followed immediately with 15 min of R light, and another set of plants were not exposed to EOD light (controls). Light spectra of all light treatments were measured using a LI-COR 1800 spectroradiometer (LI-COR, Lincoln, Neb.) with a remote light collector on a 1.5-m fiber optic probe. EOD R light treatment (6.7 µmol·m^{-2}·s^{-1} in the 600- to 700-nm waveband, Fig. 1A) was obtained by filtering light from six cool-white, fluorescent lamps through a Roscolux #19 acetate filter (Rosco, Port Chester, N.Y.). EOD PR light treatment (43.7 µmol·m^{-2}·s^{-1} in the 700- to 780-nm waveband, Fig. 1B) was obtained by filtering radiation from two 150-W internal-reflector incandescent-filament lamps through a polyacrylic sheet of cast acrylic #2711, dark red (Rohm and Haas, Bristol, Pa.). There were four plants per light treatment.

After 14 days of EOD light treatment, we recorded height of the plants from the soil surface to the apical bud, number of nodes, and each leaf length as nondestructive indicators of relative leaf area. Plants were then transplanted into 11.4-liter pots containing the Fafard potting mix and placed in a glass greenhouse for growth under ambient light conditions. The plants were in the greenhouse from November to March. Before the first fruit harvest, the number of visible fruit and flowers were recorded. Fruit at the breaker color stage (Fahey, 1976) was harvested once a week. Marketable yield consisted of fruit graded U.S. no. 1 or U.S. no. 2. After the final harvest, plants were cut at the soil surface and leaf area and dry weights of the top growth determined.

The second experiment evaluated the effects of supplemental fluorescent light at the end of photoperiod on transplant growth and performance. Fluorescent light is characteristically high in the red component of the light spectrum (Fig. lC) and has been used as a R light source in determining phytochrome effects on plant development (Lockhart, 1964). Plants were started in a glasshouse on 3 Apr. 1989 in Speedling seedling trays (Speedling, Sun City, Fla.) (4.5 cm cell length, 39.5 cm^3) containing Fafard potting mix. EOD supplemental fluorescent light treatment was initiated on 21 Apr. Supplemental irradiance was supplied for 1 h immediately before sunset each day until transplanting. Supplemental fluorescent light was provided from two (4-ft) cool-white fluorescent tubes (Sylvania workshop F40) suspended ≈ 25 cm above the top of the seedlings. Identical bulbs and fixtures suspended above the seedlings were used in the control treatment, but the tubes were never illuminated. Two flats were placed under each treatment. Light characteristics of PPF and phytochrome equilibrium (Pfr : Ptot) (Sager et al., 1988) were measured on a representative day immediately before the light treatments began and thereafter every 10 min until sunset (<2 µmol·m^{-2}·s^{-1}).

Seedlings were transplanted to the field at the Clemson Univ. Bottoms Research Site, Clemson, S. C., on 28' May 1989. The soil was a Congaree silt loam (Typic Paleudults). Fertilizer was applied at N, P, and K rates of 560, 1120, and 1120 kg·ha^{-1}, respectively, and disked into the top 0.2 m of soil. Black polyethylene mulch, trickle-irrigation tubing, and methyl bromide fumigation were applied to all plots by machine on 22 May. A randomized complete-block design was used with four replications. Plots were 6.1 m long with rows 1.8 m apart. In-row spacing was 0.6 m and recommended cultural practices for tomato production, including staking and pruning (removal of all axillary shoots below the first inflorescence cluster), were followed throughout the study. Before first harvest, three plants from each plot were harvested and top fresh weights, total leaf area, and fruit count and weight were determined. Fruit were harvested at a breaker color stage, two to three times a week. After final harvest, plants were cut at the soil surface and dry weight of the top growth was determined after complete drying at 60C. Results from both experiments were tested by analysis of variance, and LSD values were calculated for use in pairwise comparison of treatment means.

EOD R light treatment of tomato transplants reduced plant height and total leaf length, as compared to transplants that received no EOD light treatment (Table 1). EOD FR light had no effect on tomato transplant growth as compared to controls. The reduction of plant height by EOD R light was partially reversed by immediately following the R light treatment with FR light, suggesting the involvement of phytochrome, EOD light treatments had no effect on num-