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Fluorescent Lighting Studies With Chrysanthemum, Poinsettia and Hydrangea Pot Plants

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Fluorescent Lighting Studies With Chrysanthemum, Poinsettia and Hydrangea Pot Plants

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Introduction and Background

African violets, gloxinias, episcias, various seedlings and foliage plants, which develop well at relatively low light intensities, have been produced using only fluorescent lighting (2,6,7). Such plants grow and/or flower satisfactorily in basements or other locations in the absence of sunlight if 300 to 600 foot-candles of fluorescent light are provided for 12 to 18 hours per day (6). Scientists working in phytotrons (growth chambers) have employed combinations of fluorescent and incandescent lamps to obtain desired plant growth in a wide range of species (3,4,5).

With the advent of improved fluorescent lamps favorable for increased photosynthesis (8) it appeared that additional work with flowering plants which require higher light intensities than African violets and similar plants, might be useful, stressing lighting applications which could possibly be utilized by hobbyists or commercial growers in indoor locations receiving no sunlight. Such installations might have immediate amateur gardener appeal. Eventually, commercial production of plants in a closed environment system might become feasible, contingent of course, on a profitability of such a system.

Investigations relative to commercial possibilities of supplementary or total fluorescent lighting of certain crops have been undertaken (1,9,10). The studies reported herein were conducted to evaluate growth and flowering of pot chrysanthemums, poinsettias and hydrangeas, relatively high light-requiring crops. Chrysanthemums and poinsettias also

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have short-day limitations to flower which must be met. Fluorescent lights were used alone and to supplement natural light. The supplementary fluorescent lighting was used only with chrysanthemums.

Electric power usage was studied in poinsettia and hydrangea production.

Methods and Procedures

Chrysanthemums

Five treatments were established in this research.

Treatment 1, glass greenhouse control.

Treatment 2, fiberglass greenhouse control.

Treatment 3, glass greenhouse with daytime supplementary light from Standard Gro-Lux (F96T12/GRO/VHO) and Wide Spectrum Gro-Lux (FR96T12/GRO/VHO/235/WS with built-in reflector)[1] lamps. The lamp fixtures were 48 inches wide and 96½ inches long and each had 4 lamps, two of each type spaced 12 inches apart and left open in the center to prevent excess shading (Figure 1).

[1] Fluorescent lamps courtesy Sylvania Electric Products, Danvers, Mass.

Figure 1. Daytime supplemental fluorescent lighting on pot chrysanthemums.

Treatment 4, fiberglass greenhouse with daytime supplementary light as in Treatment 3.

Treatment 5, total fluorescent light from lamp types as described in Treatment 3 but with no built-in reflector and no sunlight. The fixtures were 36 inches wide and 96½ inches long with 8 lamps per fixture, 4 of each type. The lamps were spaced 5 inches apart. Aluminum foil was used as a reflector for the fixtures. (Figures 2 and 3).

All lamps used were 215 watt lamps. All fixtures were kept 6 inches from the tops of the plants. Treatment 5 was located in the fiberglass greenhouse, and was covered with aluminum polyethylene and sateen black cloth (64 x 104 mesh). Air exchange was accomplished by using a small exhaust fan on one end of the bench and aluminum paper water pad on the other end. Since the total fluorescent lighting treatment (Treatment 5) was not duplicated in the glass house, the results for treatments in the fiberglass and glass greenhouses were analyzed separately.

Each treatment had 3 replicates of 15 5½ inch pots, each pot contained 5 rooted cuttings[2]. The pots were placed 13 x 13 inches, in 3 rows with 5 positions per row.

[2] Courtesy Yoder Bros., Inc., Barberton, Ohio.

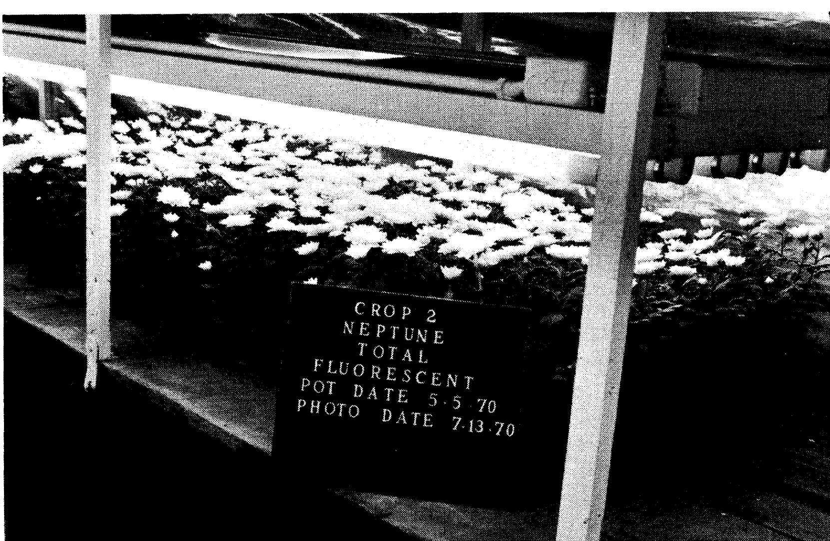

Figure 2. Pot chrysanthemums being grown under total fluorescent lighting—no sunlight.

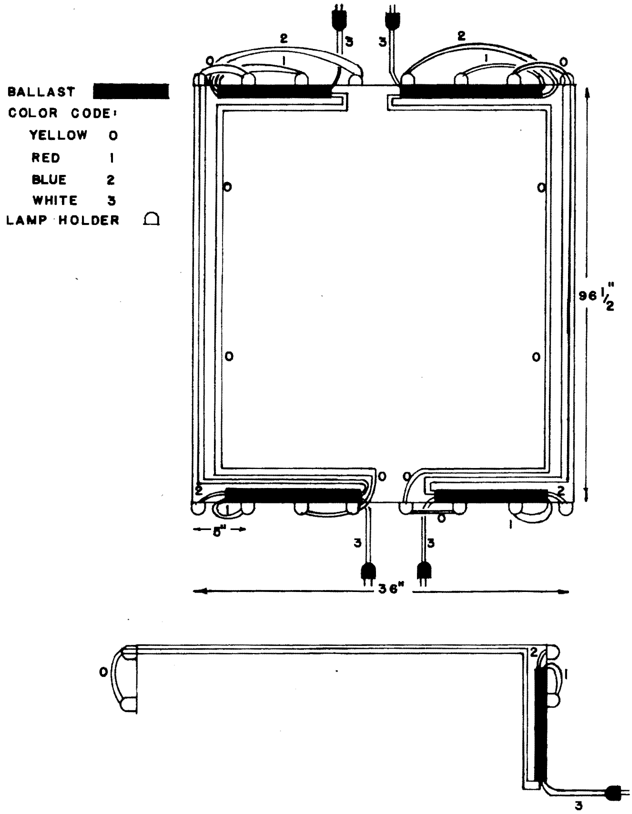

Figure 3. Simplified wiring diagram for a 36 inch x 96½ inch total fluorescent lighting unit used in production of pot chrysanthemums, poinsettias, and hydrangeas.

'Neptune', a 9-week cultivar, was selected because it is short, thus growth retardants are unnecessary to control height.

Three crops were grown, Crop 1 in the spring, Crop 2 in the summer, and Crop 3 in the fall. Plants were potted February 3, May 5, and August 25, 1970, respectively into a mixture of 1 soil, 1 peat moss, and 1 perlite.

Customary pot chrysanthemum cultural procedures were used. The plants received 200 ppm N, 88 ppm P, and 166 ppm K at every watering through a Chapin-tube watering system. For the first 10 days after potting, night and day temperatures were set at 66° and 77° respectively. Thereafter, temperatures were held as closely as possible to 60° nights, 65° cloudy days, and 70-75° clear days. Summer temperatures ranged somewhat higher.

Plants received 10 long days initially, consisting of light nightly from 10:00 PM-3:00 AM. Lighting of plants in Treatments 1 and 2 was accomplished with incandescent lamps (min. 10 ft-C), and in Treatments 3, 4, and 5 with the respective fluorescent lighting.

Plants were pinched and short days were started the eleventh day after potting. Short day treatment consisted of a 9 hr. daylength (8 AM-5 PM) with light supplied from either sunlight (Treatments 1 and 2), sunlight plus fluorescent light (Treatments 3 and 4), or total fluorescent light (Treatment 5), followed by a 15 hr. dark period.

All plants were disbudded at a uniform time, as soon as buds were large enough to handle.

Light intensity measurements by ft-C[3] and microwatts/sq. cm.[4] were recorded at pot level for each treatment and outdoors at 1:30 PM on 29, 18, and 20 randomly selected days during production of the spring, summer and fall crops respectively.

Poinsettias

'Eckespoint C-1' poinsettia plants in 2½-inch pots were shifted to 5½-inch clay pots, one plant per pot, October 13, 1971. The same type of soil mixture as for chrysanthemums was used. The plants were approximately 4 inches tall and had been grown up to this time in a glass greenhouse. Two experimental lighting treatments were establishd in the fiberglass greenhouse October 13: (1) fiberglass greenhouse control (Figure 4) and (2) total fluorescent light, identical to that used for chrysanthemums except the fluorescent lamps were maintained 3 inches above the tops of the plants instead of 6 inches (Figure 5). Light intensity was approximately 1200 ft-C at the tops of the plants.

A 9-hour photoperiod was used in the total fluorescent light treatment and natural daylength was used in the greenhouse control treatment.

The experiment had 3 replicates of a 2 x 2 Latin square. An experimental unit in the Latin square had 15 plants. Pots were spaced 8 x 9 inches.

Fertilizer application and watering were accomplished by the same method as used for chrysanthemums. No growth retarding chemical was applied.

[3] Weston Illumination Meter Model 756. Weston Electrical Instrument Corp., Newark, N. J.

[4] IL150 Plant Growth Photometer, International Light, Inc., Dexter Industrial Green, Newbury, Mass. This instrument measures 3 spectral bands: blue (400-500 nanometers), red (600-700 nanometers), and far-red (700-800 nanometers).

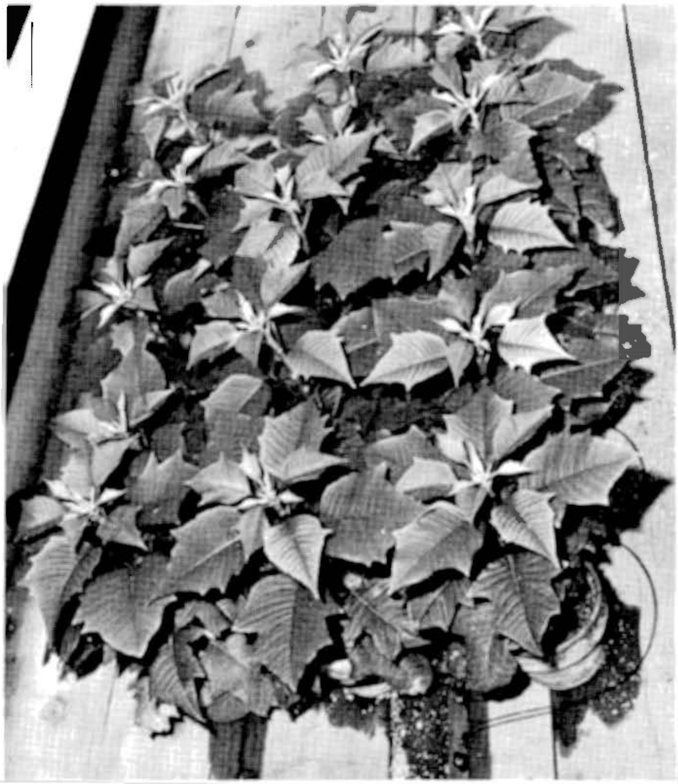

Figure 4. 'C-1' poinsettias in fiberglass greenhouse control treatment. Plants watered and fertilized by Chapin tube-injector system. Photo, November 24, 1971.

The greenhouse night temperature was maintained as closely as possible to 63-65°F, the daytime temperatures ranged 10-20°F higher than the night temperatures on clear days and 5-10°F higher on cloudy days. The temperature was usually 3-4°F higher under the fluorescent lights than in the greenhouse control plots. This should be emphasized because differences in plant development between plants under the fluorescent lights and the greenhouse control plants was due to the combined effects of light and temperature, rather than light alone. The covered fluorescent light replicates and methods of air exchange are shown in Figures 6 and 7.

Data were recorded for the 3 center plants in the middle row of each unit as follows: Number of days to bloom (number days from

Figure 5. 'C-1' poinsettias in the total fluorescent lighting treatment. Photo, November 24, 1971.

October 13 to first pollen shed in flower); plant height; bract diameter; dry weight of bracts; and dry weight of vegetation.

Electric power usage in kilowatt hours per 9 hour daylength was recorded for each fluorescent light unit by use of Duncan 15 amp, 120 volt, 2 wire meters[5]. (Figure 8).

Hydrangeas

Dormant, branched 'Merveille' hydrangea plants[6] in 6-inch pots were placed in the same lighting treatments and conditions as described for poinsettias with the same experimental design being used. Treatments began January 4, 1972. There were 15 pots per unit. The pots were spaced 13 x 13 inches. Customary hydrangea forcing methods were used. Data on plant height; inflorescence diameter; and bloom date (pollen evident in majority of flowers) were recorded for the 3 center plants of the middle row in each unit. Electric power usage was recorded in kilowatt hours per 12 hour daylength for each fluorescent light unit.

[5] Meters supplied by the Oklahoma Farm Electrical Council.
[6] Plants supplied by Furrow and Company, Inc., Guthrie, Oklahoma.

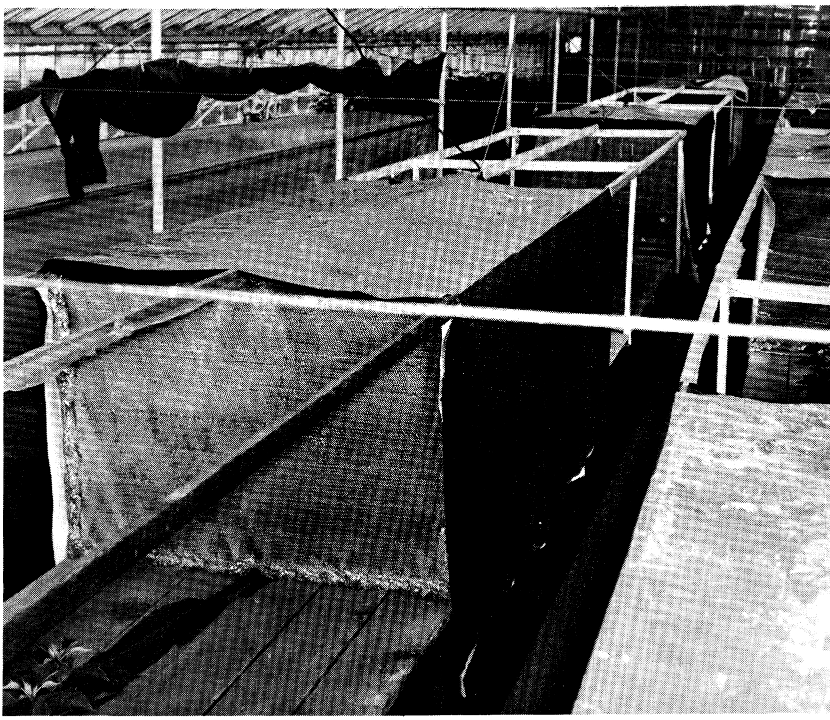

Figure 6. Six units of the total fluorescent light treatment used in the poinsettia study. Note the greenhouse control plots also.

(A 12 hour photoperiod was used for the hydrangeas under fluorescent light. Natural photoperiod was used for the greenhouse control treatment).

Experimental Results

Chrysanthemums

Table 1 illustrates the effects of the lighting treatments on plant development in the spring crop in the fiberglass house (including the total fluorescent lighting treatment) and in the glass house.

In the fiberglass house, plants receiving daytime supplementary light were significantly taller than plants in the total fluorescent lighting treatment. Otherwise, there were no significant differences in growth among the treatments. Control plants and those in the supplementary

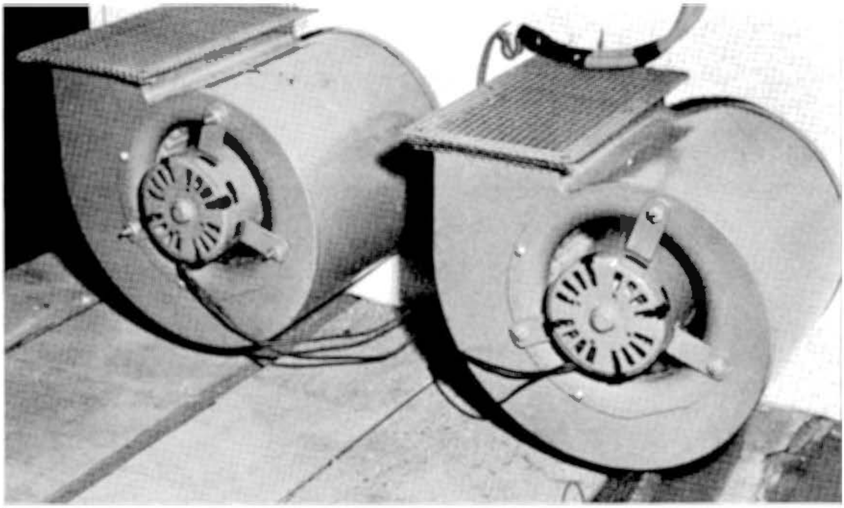

Figure 7. Fans used to exhaust air and pull fresh air through each total fluorescent light treatment area for production of poinsettias and hydrangeas.

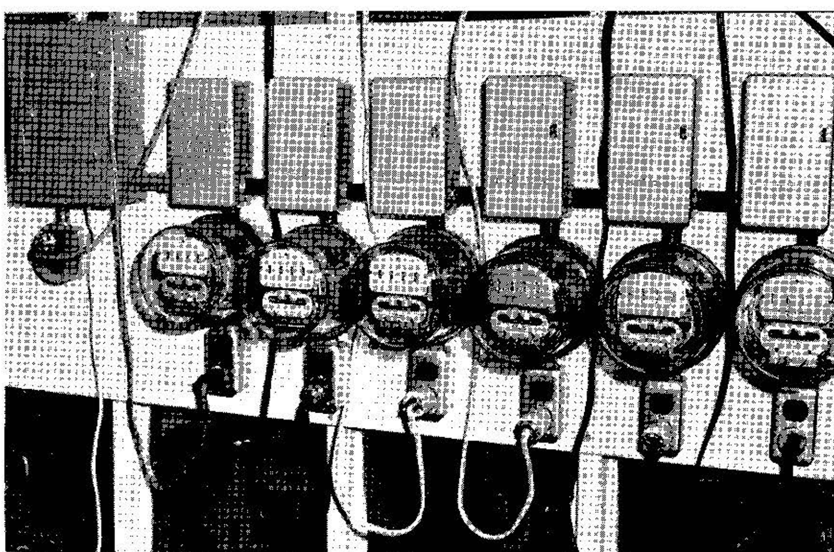

Figure 8. Day-night clocks and meters for fluorescent light treatments. Each of the 6 total fluorescent light units were individually metered for the total amount of electricity consumed.

Table 1. Effects of lighting treatments on ht, no of breaks, dry wt of flowers, and dry wt of vegetative growth on 'Neptune' pot chrysanthemums in the fiberglass and glass greenhouses, Crop 1.[1]

Light Treatment	Plant ht (inches)	No of breaks	Dry wt of flowers (g)	Dry wt of vegetation (g)
Fiberglass				
Control	10.8ab	22.7a	13.5a	15.6a
Day Supplementary	11.4a	25.0a	14.6a	18.5a
Total Fluorescent (no sunlight)	9.9b	26.7a	13.9a	18.4a
Glass				
Control	9.5a	24.5a	12.8a	16.2a
Day Supplement	10.0a	25.8a	13.9b	18.5b

[1] The figures used are a mean of 3 replicates (45 pots, 5 plants per pot) of each treatment. Means within a column within fiberglass or glass followed by the same letter are not significantly different at the 5% level according to Duncan's Multiple Range Test.

lighting treatment required 71 days from potting to reach full bloom, and 74 days were required for plants in the total fluorescent lighting treatment.

In the glass house, plants receiving supplementary lighting were significantly heavier in dry weight of flowers and vegetation than the control plants. Other differences were not significant. Sixty-nine days were required for the plants in the control and daytime supplementary lighting treatments to reach full bloom.

In Crop 2, the summer crop, (Table 2) in the fiberglass house, plants receiving daytime supplementary light and the control plants were significantly heavier in dry weight of flowers than were plants in the total fluorescent lighting treatment. Otherwise, there were no significant differences in growth among treatments. Control plants required 70 days from potting to full bloom, plants in daytime supplementary lighting required 72 days and 74 days were required for plants in the total fluorescent lighting treatment.

The number of breaks and the dry weight of flowers were significantly higher in the daytime supplementary lighting treatment than in the control plants in the glass house. Other growth differences in the glass house were not significant. Seventy-one days were required for control plants to reach full bloom and 73 days for the plants under daytime supplementary lighting.

Table 3 shows the results for Crop 3, the fall crop. In the fiberglass house there were missing data due to a malfunction of the lights in the supplementary lighting treatment. Other treatments were not affected.

Table 2. Effects of lighting treatments on ht, no of breaks, dry wt of flowers, and dry wt of vegetative growth on 'Neptune' pot chrysanthemums in the fiberglass and glass greenhouses, Crop 2.[1]

Light Treatment	Plant ht (inches)	No of breaks	Dry wt of flowers (g)	Dry wt of vegetation (g)
Fiberglass				
Control	12.7a	29.5a	15.7a	24.4a
Day Supplementary	13.2a	31.6a	15.7a	26.5a
Total Fluorescent (no sunlight)	10.2a	29.1a	10.7b	19.4a
Glass				
Control	12.8a	29.4a	16.0a	27.3a
Day Supplementary	12.8a	35.5b	17.4b	27.8a

[1] The figures used are a mean of 3 replicates (45 pots, 5 plants per pot) of each treatment. Means within a column within fiberglass or glass followed by the same letter are not significantly different at the 5% level according to Duncan's Multiple Range Test.

Table 3. Effects of lighting treatments on ht, no of breaks, dry wt of flowers, and dry wt of vegetative growth on 'Neptune' pot chrysanthemums in the fiberglass and glass greenhouses, Crop 3.[1]

Light Treatment	Plant ht (inches)	No of breaks	Dry wt of flowers (g)	Dry wt of vegetation (g)
Fiberglass				
Control	15.6a	26.9a	18.1a	27.7a
Day Supplementary	---	---	---	---
Total Fluorescent (no sunlight)	12.6a	29.4a	15.7b	28.1a
Glass				
Control	14.7a	28.2a	16.2a	26.8a
Day Supplementary	15.0a	31.0a	18.9a	30.5a

[1] The figures used are a mean of 3 replicates (45 pots, 5 plants per pot) of each treatment. Means within a column within fiberglass or glass followed by the same letter are not significantly different at the 5% level according to Duncan's Multiple Range Test.

The control plants were significantly taller and dry weight of flowers was greater than for plants in the total fluorescent lighting treatment. Other growth differences were not significant. Plants in both the control and total fluorescent light treatments required 74 days from potting to reach full bloom.

There were no significant growth differences between control plants and plants in the supplementary lighting treatment in the glass house.

Over all crops, there were few easily observed quality differences among plants in the various lighting treatments even though plants in the total fluorescent lighting treatment tended to be slightly shorter, have lower flower dry weights, be delayed a few days in maturity and have darker green foliage. Plants in the daytime supplementary lighting treatment tended to be slightly taller with heavier flower dry weights. Randomly selected plants from each treatment for each crop are shown in Figure 9.

Figure 10 presents a graphic comparison of light intensity and radiant energy measurements at pot level on 29, 18, and 20 randomly selected days respectively, for the three crops in the various treatments and for outdoors. In the spring crop, all treatments and the outdoors location were highest in the blue range of radiant energy except total fluorescent in which blue and red were equal. The red/blue and red-blue/far-red ratios for the total fluorescent lighting treatment conformed very closely to measurements made at the outdoors location, though they were of smaller magnitude. The glass house had higher radiant energy and light intensity readings than the fiberglass house.

In the summer crop, all the treatments and the outdoor location were highest in the red range of radiant energy. The total fluorescent treatment and outdoors location compared in ratios but differed in magnitude. The glass house had higher radiant energy and light intensity readings than the fiberglass house.

In the fall crop treatments 1, 2, 3, and 4 were highest in the blue range of radiant energy. Treatment 5 and the outdoors location (6) were highest in the red range of radiant energy. The red/blue and red-blue/far-red ratios for the total fluorescent lighting treatment conformed closely to those outdoors, though they were smaller in magnitude. The glass house had higher radiant energy and light intensity readings than the fiberglass house.

In all of the crops, the total fluorescent lighting treatment had much lower radiant energy and light intensity readings than the other treatments, but the plants compared generally in quality with plants in the other treatments. The total fluorescent lighting treatments radiant energy quality conformed closely to that of the outdoors, though of smaller magnitude. The radiant energy and light intensity for the total fluorescent lighting treatment remained relatively constant during a particular crop cycle, while the lights were on, whereas the energy received by the other treatments in the greenhouses and outdoors varied during the daylight hours.

All measurements were recorded at 1:30 p.m., one of the brightest parts of the day. The light intensity measurements in foot candles and

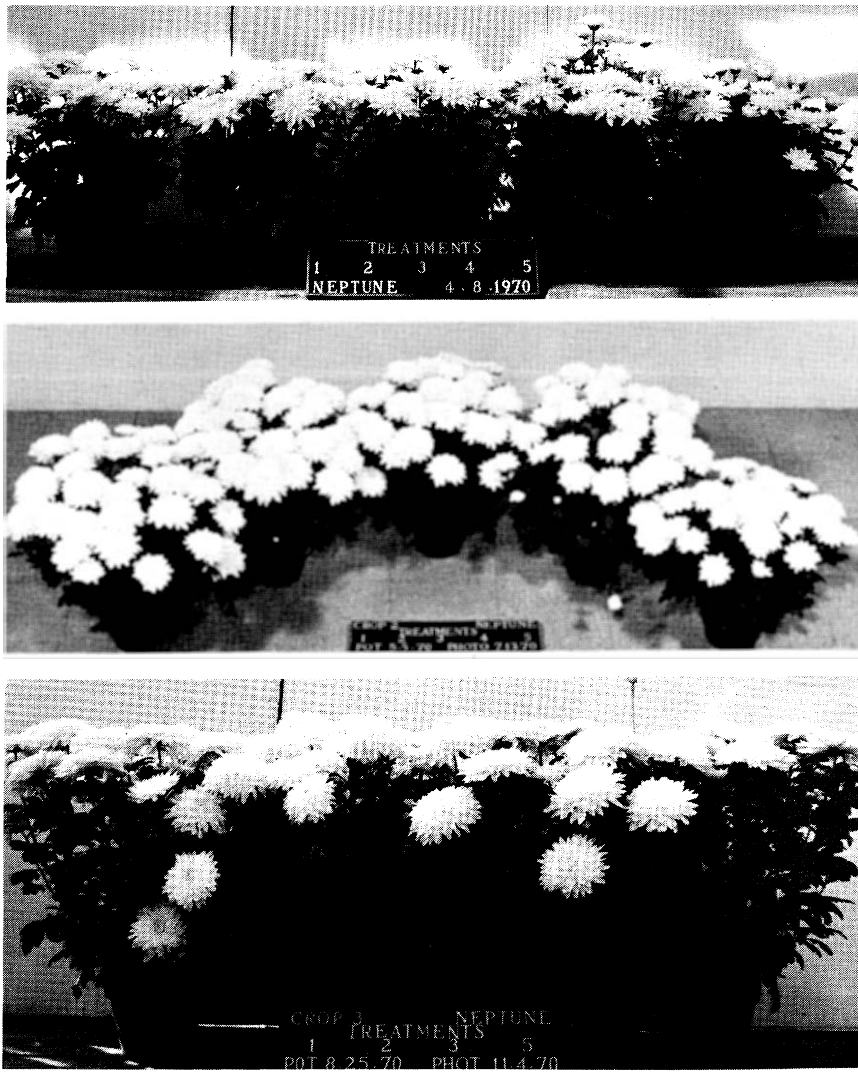

Figure 9. Randomly selected plants from the spring, summer and fall crops. Upper—spring; middle—summer; and lower—fall. Treatments: 1—control glass, 2—control fiberglass, 3—daytime supplementary flourescent light—glass, 4—daytime supplementary fluorescent light—fiberglass, and 5—total fluorescent light.

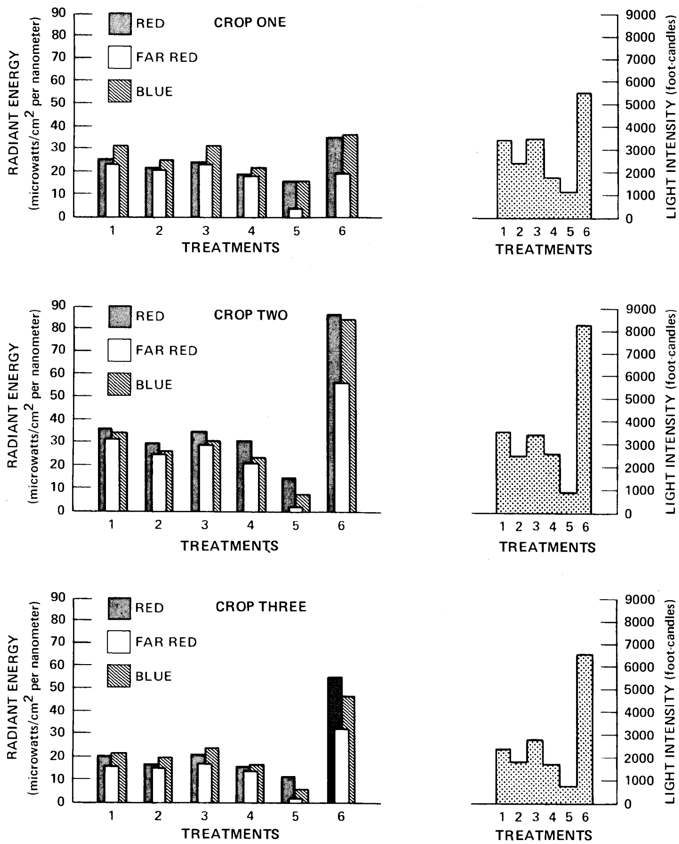

Figure 10. Mean radiant energy and light intensity readings from the spring, summer, and fall crops. Upper, spring; middle, summer; and lower fall. Treatments 1—control glass, 2—control fiberglass, 3—daytime supplementary flourescent light-glass, 4—daytime supplementary fluorescent light—fiberglass, 5—total fluorescent light, and 6—outdoors.

the radiant energy in the red, far-red, and blue ranges transmitted by the fluorescent lamps, decreased with each crop. This indicated aging of the lamps whose life expectancy is 9000 hours if in constant use. Some loss in light intensity from crop to crop could have been caused by the fixtures. The lamps fit loosely into the connection on the fixtures causing an arcing of electrical current between lamps and connections.

In all of the crops, the light measurements in the glass house were higher than the measurements in the fiberglass house.

Poinsettias

The effects of the lighting treatments on development of the 'C-1' poinsettia plants are shown in Table 4. The plants grown under flourescent light flowered earlier, were shorter, and had larger and heavier bracts than the greenhouse control plants. There was no significant difference in vegetative dry weights.

Figure 11 illustrates the difference in rate of development on November 24. The more rapid development of plants under fluorescent light

Table 4. Effects of lighting treatments on 'C-1' poinsettias.

Treatment	Days to bloom	Plant ht (inches)	Bract diameter (inches)	Dry wt of bract (g)	Dry wt of vegetation (g)
Fiberglass Greenhouse Control	55.44a[1]	15.44a	10.89a	1.54a	7.16a
Total fluorescent Light	40.89b	12.67b	12.56b	2.18b	6.43a

[1] Average of 18 plants. Means within a given column followed by the same letters do not differ significantly at the 0.05 level.

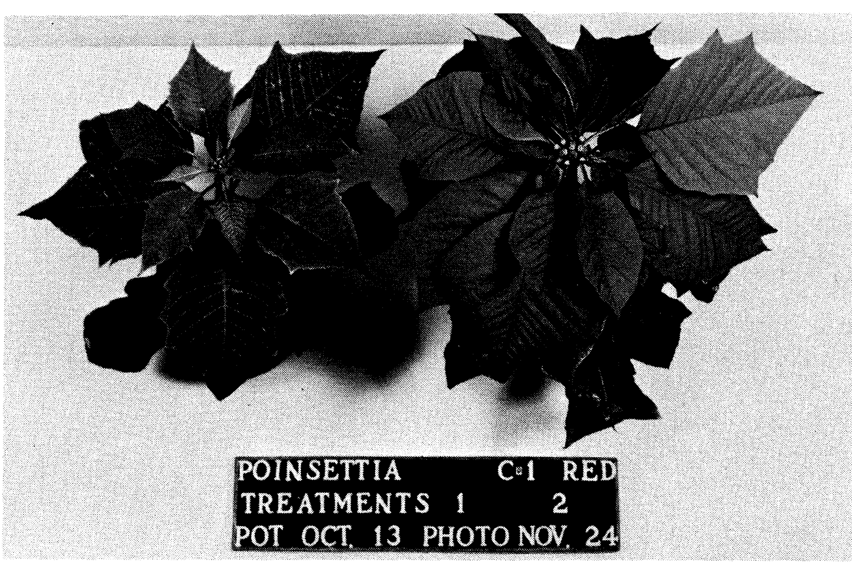

Figure 11. Comparison in rate of development, November 24. Treatment 1, left—fiberglass greenhouse control; Treatment 2, right—total fluorescent light temperature, as well as light, played a part in differences shown.

was partially due to the slightly higher temperatures prevailing under the fluorescent lights, although this was not specifically studied. Recording thermographs usually showed a 3 to 4 degree difference between the fluorescent light treatment and the greenhouse control treatment. This should be kept in mind when evaluating the differences in plant development. It was clear, however, that good quality poinsettia plants resulted in the total fluorescent light treatment. Figure 12 compares the appearance of the plants on December 21.

The electric power usage for the fluorescent lights averaged 15 kilowatt hours per 9 hour photoperiod for a 3 x 8 feet bench area (24 sq. ft.). Each plant occupied 0.5 sq. ft., thus 48 plants could be produced in the 24 sq. ft. area. On a per plant basis the power usage was 0.313 kilowatt hours per day. Assuming a 1½ cent per kilowatt hour cost and an average production time of 41 days, the total electricity cost per plant would be 19 cents. If the plants remained under the lights for 60 days, the cost would be about 28 cents per plant. At a one cent per kilowatt hour rate, the cost would be about 13-19 cents per plant.

As stated earlier, the expected useful life of the fluorescent lamp is 9000 hours. For a 9 hour photoperiod this would be 1000 days; a 12 hour photoperiod, 750 days; and a 24 hour photoperiod, 375 days.

Hydrangeas

Plants grown under fluorescent light matured in an average time of 76 days and the greenhouse control plants required 86 days. The plants

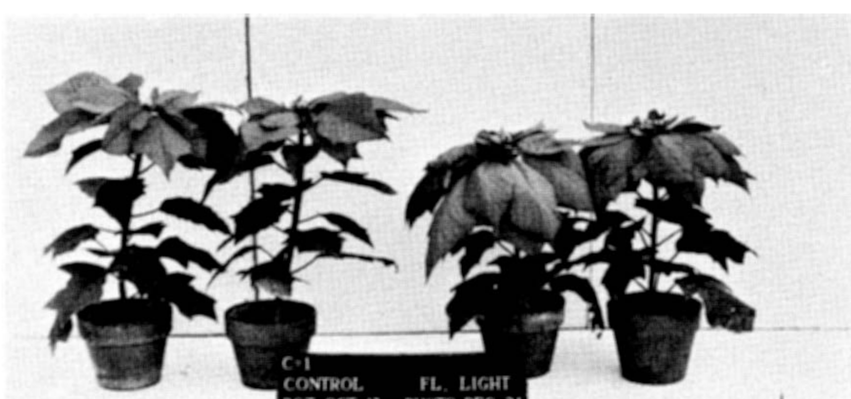

Figure 12. December 21 comparison. Two plants on left—fiberglass greenhouse control; two plants on right—total fluorescent light treatment.

under fluorescent light had significantly smaller inflorescences than the greenhouse control plants (Table 5). This is not evident in Figure 13, but the inflorescences of the control plants were not fully expanded by March 10, the date of the photograph.

Plants under fluorescent light were significantly shorter than the control plants.

Table 5. Effects of lighting treatments on 'Merveille' hydrangeas[1].

Treatment	Plant ht (inches)	Inflorescence diameter (inches)
Fiberglass Greenhouse Control	15.3a	9.9a
Total Fluorescent Light	13.7b	8.3b

[1] Average of 18 plants. Means within a given column followed by the same letters do not differ significantly at the 0.05 level.
Days to bloom not shown. Control plants averaged 86 days, total fluorescent light plants averaged 76 days.

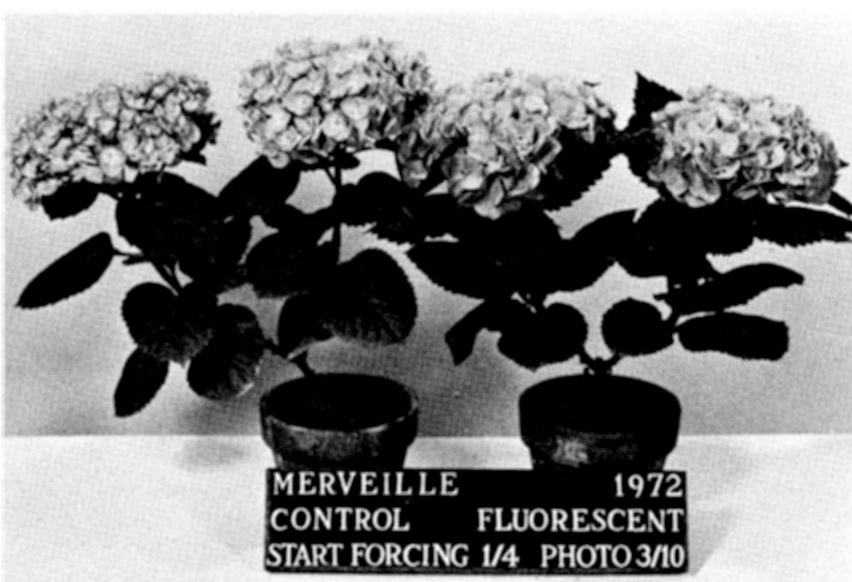

Figure 13. 'Merveille' hydrangeas. Left—Fiberglass greenhouse control, sepals not fully expanded; Right—total fluorescent light treatment, sepals more fully expanded than control. Control plants sepals expanded to a greater mature size than those of fluorescent light plants.

Power usage for a 3 x 8 feet bench area averaged 20 kilowatt hours per 12 hour photoperiod. At 13 x 13 inch spacing, 20 plants could be grown in the 24 sq. ft. area. Thus, one kilowatt hour per plant per day would be required. If 80 days growing time were required, then 80 kilowatt hours per plant would be used: 80 x 1½ cents = $1.20 total electric power cost per plant.

Discussion and Conclusions

A total fluorescent lighting fixture providing about 900-1200 foot candles, but with radiant energy similar in quality to sunlight, was generally successful in producing flowering pot plants that were about equal in "salable quality" to greenhouse grown plants. The principal visual difference noticeable with chrysanthemums was that the plants grown under the total fluorescent light matured 2 to 4 days later than plants in the other treatments. Also, plants in the total fluorescent lighting treatment were consistently slightly shorter than plants grown in the fiberglass greenhouse. In only one instance was that difference statistically significant.

Daytime supplementary fluorescent lighting of chrysanthemums in Oklahoma appears to be of questionable value.

Poinsettia plants grown under fluorescent light were of especially good quality. Hydrangeas, though of acceptable flower size, had somewhat smaller flowers than greenhouse grown plants. In the small enclosures used, with air exhaust fans timed to turn off at night when the lights were off, the inflorescences appeared to be "softer" in texture than the greenhouse grown plants. It is felt that with normal nighttime air circulation and with attention to humidity control, this would not be serious.

These experiments were promising relative to possible application of high intensity fluorescent lighting for indoor gardening. It would enable amateur horticulturists to grow successfully those plants requiring relatively high natural light intensities.

One 36 inch x 96½ inch fixture or equivalent commercial fixtures containing 8 lamps would cost approximately $200.00. Operation costs would be approximately $18.00 to $27.00 per month at 1½ to 2 cents per kilowatt hour if operated 24 hours per day, or one-half that amount if operated 12 hours daily. Lamps should operate about 9000 hours before a replacement is needed.

Future development of controlled environmental structures utilizing fluorescent lighting for commercial crop production might be possible if volume power use would permit a lower per kilowatt hour price rate, and if the heat produced by lighting could be utilized in heating an insulated growing structure. It would also appear possible to utilize a given set of lamps twice during a 24 hour period. Such a system in England was described by Rathmell (10).

It would also be of interest to study air exchange systems and effects of intermittent lighting schedules on plants to determine if one set of lamps could be utilized to light a greater number of plants per unit area (make lamps or plant benches mobile).

Light measurements from the 3 chrysanthemum crops indicated that the light intensity and radiant energy from the fluorescent lamps decreased with each crop. Apparently, aging of the lamps would be a definite economic factor to consider in future work. It was observed that when the lamps were tightened better in the fixtures, light intensity increased somewhat.

It is quite possible that the fluorescent lamp as currently manufactured is not the final answer to a light source for such plant production indoors on a commercial or amateur basis. Lights such as those described by Norton (9)—the mercury, metal halide and high pressure sodium types, may have application in such plant production.

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