INFLUENCE OF FLUORESCENT LIGHT AND NATURAL GREENHOUSE LIGHT ENVIRONMENTS ON POT CHRYSANTHEMUM DEVELOPMENT AND MEASURED LIGHT INTENSITIES

By

ROBERT EARL MOON

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Thesis Approved:

Richard N. Payne
Thesis Adviser

W R Kays

Robert D Morrison

D D Durham
Dean of the Graduate College

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CHAPTER I

INTRODUCTION

Greenhouses are relatively inefficient structures for plant production under conditions of low light intensities and in cold regions [6], and must be cooled in warmer regions if they are to be utilized properly during the summer [10]. Even with washed air cooling heat delay in crops such as chrysanthemums is common [7]. The many variables of temperature, humidity, carbon dioxide, light and pest entrance make total environmental control difficult.

Supplementary lighting to increase yields or control the rate and quality of plant development of greenhouse crops such as tomatoes [4], carnations [8, 13, 18, 20], and bedding plants [21, 22] has been investigated. Effects of such supplemental lighting are either photoperiodic [2, 14] or photosynthetic [2, 14], and may or may not be economical on a commercial basis [1].

Production of African violets, gloxinias, episcias, and many low light-requiring foliage plants using only fluorescent lighting has been accomplished [12, 16], and with the advent of improved fluorescent lamps favorable for increased photosynthesis [15], production of good quality plants requiring higher light intensities became a possibility [17]. Supplementary light studies using the new fluorescent lamps in comparison with cool-white fluorescent lamps showed that chrysanthemums grown under the new lamps (Gro-Lux lamps) had greater dry and fresh weights [11]. It has been shown that complete environmental control will give the grower more control over plant growth and flowering [9]. At this time, high light requiring plants may be grown successfully in expensive high light intensity growth chambers [3], but these units are not suited to large scale plant production.

The present study was undertaken to:

A. Determine the potential to produce successfully a high light-requiring crop with a short day limitation (pot chrysanthemums) using only a fluorescent light source and a much less sophisticated installation than would be found in an experimental growth chamber, possibly leading to commercial application in a totally controlled environment.

B. Compare growth and flowering of pot chrysanthemums under the above conditions with plants grown with and without daytime supplementary fluorescent lighting in glass and fiberglass greenhouses.

C. Record light intensity data for use in future research relating to production of economic crops in total environmental control situations.

CHAPTER II

MATERIALS AND METHODS

Five experimental treatments were established as follows:

Treatment 1, control - total sunlight transmitted through glass.

Treatment 2, control - total sunlight transmitted through fiberglass.

Treatment 3, daytime supplementary fluorescent light - light transmitted through glass and supplemented with Standard Gro-Lux Lamps (F96T12/GRO/VHO) and Wide Spectrum Gro-Lux Lamps (FR96T12/GRO/VHO/235/WS with built-in reflector).[1]

Treatment 4, daytime supplementary fluorescent light - light transmitted through fiberglass and supplemented with Standard Gro-Lux Lamps (F96T12/GRO/VHO) and Wide Spectrum Gro-Lux Lamps (FR96T12/GRO/VHO/235/WS with built-in reflector).

Treatment 5, total fluorescent light - light of relatively high intensity supplied from Standard Gro-Lux Lamps (F96T12/GRO/VHO) and Wide Spectrum Gro-Lux Lamps (F96T12/GRO/VHO/WS with no built-in reflector), <u>no sunlight</u>.

All of the lamps in this study were 215 watt lamps with estimated life of 9000 hours of use [19].

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

Treatments 1 and 3 were located in a glass greenhouse, and treatments 2, 4, and 5 were located in a fiberglass greenhouse. Although the total fluorescent lighting treatment (treatment 5) was located in the fiberglass greenhouse, it was not affected by the transmitted light since the bench was completely 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 an aluminum paper water pad on the other end. No sunlight reached the plants. With this method of air exchange, plants in treatment 5 received almost identical environmental conditions as the plants in the other treatments in the fiberglass greenhouse with the exception of the light source, and possibly air velocity.

Due to a limited amount of equipment available for the experiment, the total fluorescent light treatment was not duplicated in the glass greenhouse. This somewhat confounds treatment results with location, but it was the opinion of the author that location effect was very minor. The results for treatments in the fiberglass and glass greenhouses were analyzed separately.

Three crops were grown. Crop 1 was grown in the spring, crop 2 in the summer, and crop 3 in the fall. Each treatment had three replicates. Each replicate consisted of 21 randomly selected 5½ inch pots, each containing 5 rooted cuttings of the 'Neptune' cultivar. The pots were spaced 13 x 13 inches [5] in 3 rows with 7 positions per row. The pot plants in the first and seventh positions of each row were discarded in each treatment. Only three rows with five positions per row were used in the analysis.

The lamp fixtures for treatments 3 and 4 were 48 inches wide and 96½ inches long. Each fixture had four alternately spaced lamps, two FR96T12/GRO/VHO/235/WS and two F96T12/GRO/VHO. The lamps were spaced 12 inches center to center. The daytime supplementary lighting output was 26.9 watts per square foot. The fixtures were left open in the center to minimize shading. The fixtures designed for the total fluorescent lighting treatment were 36 inches wide and 96½ inches long. There were eight alternately spaced lamps in each fixture, four F96T12/GRO/VHO/WS and four F96T12/GRO/VHO. The lamps were spaced five inches apart from center to center. The total fluorescent lighting output was 77.7 watts per square foot. Aluminum foil was used as a reflector for the fixtures. All fixtures were maintained six inches from the tops of the plants.

Alternating lamp types were used since Wide Spectrum and Standard Gro-Lux Lamps have been shown to produce better foliage and earlier fruit set in tomatoes when used as a blend on an alternate basis rather than when used alone or in a combination with cool-white fluorescent or incandescent lamps [15].

Chrysanthemum morifolium L. cv. 'Neptune', a nine-week white cultivar was selected for use because it is a short growing cultivar and no growth retardant chemical is necessary to control height. Five rooted cuttings[2] per 5½ inch pot were potted February 3, 1970, May 5, 1970, and August 25, 1970 into a soil mixture of 1 part soil, 1 part peat moss, and 1 part perlite. Customary pot chrysanthemum cultural procedures were used, with plants receiving 200 ppm N, 88 ppm P, and

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

166 ppm K at every watering through a Chapin-tube watering system. For the first ten days after potting, the temperature was maintained as closely as possible at 66°F nights and 77°F days. From the eleventh day of production until flowering, the night temperature was maintained at 60°F and daytime temperatures were held as closely as possible to 65°F on cloudy days, and 70-75°F on bright days.

Plants in all treatments received ten long days after potting, consisting of light applied nightly from 10:00 p.m. - 3:00 a.m. Lighting of plants in treatments 1 and 2 was accomplished with incandescent lamps (minimum 10 foot candles), and in treatments 3, 4, and 5 with the respective fluorescent lighting fixtures.

The plants were pinched and short days were started on all plants the eleventh day after potting. Short days were continued until the plants flowered. Short day treatment consisted of a nine hour day-length (8 a.m. - 5 p.m.) with light supplied from either sunlight (treatments 1 and 2), sunlight plus supplemental fluorescent light (treatments 3 and 4), or total fluorescent light (treatment 5). The nine hour day-length was followed by 15 hours of darkness (5 p.m. - 8 a.m.).

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

Light intensity measurements were recorded at pot level for each treatment and outdoors at 1:30 p.m. on 29 randomly selected days during production of the first crop, 18 randomly selected days during production of the second crop, and 20 randomly selected days during production of the third crop. Foot candle[3] and microwatts/sq. cm.[4] measurements were compared.

[3]Weston Illumination Meter Model 756. Weston Electrical Instrument Corporation, Newark, New Jersey 07105.

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

CHAPTER III

RESULTS

Table I illustrates the effects of the lighting treatments on plant development in the spring crop, fiberglass house, including the total fluorescent light treatment. Plants receiving daytime supplementary fluorescent light were significantly taller than plants in the total fluorescent lighting treatment. Otherwise, there were no significant differences in growth among the treatments. Plants in the control light and daytime supplementary lighting treatments required 71 days from potting to reach full bloom, and 74 days were required for plants in the total fluorescent lighting treatment.

In the spring crop, glass house, (Table II), plants receiving daytime supplementary fluorescent lighting were significantly heavier in the dry weight of flowers and the dry weight of vegetation than the control plants. Other growth and flowering differences were not significant. Since the total fluorescent lighting treatment was not located in the glass house, it was not included with the glass house analysis. However, differences in growth and flowering between plants in the total fluorescent lighting treatment and treatments in the glass house were slight. Sixty-nine days were required for the plants in the control and daytime supplementary lighting treatments to reach full bloom.

TABLE I

EFFECTS OF LIGHTING TREATMENTS ON HEIGHT, NUMBER OF BREAKS, DRY WEIGHT OF FLOWERS, AND DRY WEIGHT OF VEGETATIVE GROWTH OF 'NEPTUNE' POT CHRYSANTHEMUMS IN THE FIBERGLASS HOUSE, CROP 1[1]

Treatment	Plant Height	Number of Breaks	Dry Weight of Flowers	Dry Weight of Vegetation
	(inches)		(g)	(g)
Light Type				
Fiberglass				
Control	10.8ab	22.7a	13.5a	15.6a
Day Supplementary	11.4a	25.0a	14.6a	18.5a
Total Fluorescent	9.9b	26.7a	13.9a	18.4a
Error MS (d.f. 4)	.2824	6.6074	3.2758	3.1671

[1]The figures shown are a mean of 3 replicates (45 pots, 5 plants per pot) of each treatment. Means within a column of a particular light treatment followed by the same letter are not significantly different at the 5 percent level according to Duncan's multiple range test.

TABLE II

EFFECTS OF LIGHTING TREATMENTS ON HEIGHT, NUMBER OF BREAKS, DRY WEIGHT OF FLOWERS, AND DRY WEIGHT OF VEGETATIVE GROWTH OF 'NEPTUNE' POT CHRYSANTHEMUMS IN THE GLASS HOUSE, CROP 1[1]

Treatment	Plant Height	Number of Breaks	Dry Weight of Flowers	Dry Weight of Vegetation
	(inches)		(g)	(g)
Light Type				
Glass				
Control	9.5a	24.5a	12.8a	16.2a
Day Supplementary	10.0a	25.8a	13.9b	18.5b
Error MS (d.f. 2)	.3527	46.7111	.9364	.1034

[1]The figures used are a mean of 3 replicates (45 pots, 5 plants per pot) of each treatment. Means within a column of a particular light treatment followed by the same letter are not significantly different at the 5 percent level according to the student's t test.

In the summer crop, fiberglass house, plants receiving daytime supplementary fluorescent light and the control plants were significantly greater in dry weight of flowers than were plants in the total fluorescent lighting treatment. Otherwise, there were no significant differences in growth among the treatments (Table III). Plants in the control treatment required 70 days from potting to reach 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 fluorescent lighting treatment than were plants in the control lighting treatment in the summer crop, glass house (Table IV). However, there were no other differences in growth between the treatments. Seventy-one days were required for the control plants to reach full bloom and 73 days for the plants under daytime supplementary fluorescent lighting.

In the fall crop, fiberglass house, there were missing data relative to plants in the daytime supplementary fluorescent lighting treatment. The time clock controlling the daytime supplementary fluorescent lights malfunctioned and as a result the plants received continuous light. Fortunately, the other treatments were not affected by this malfunction. The control plants were significantly taller and dry weight of flowers was greater than for plants in the total fluorescent lighting treatment. The other growth measurements were not significantly different (Table V). Plants in the control and total fluorescent light treatments required 74 days from potting to reach full bloom.

TABLE III

EFFECTS OF LIGHTING TREATMENTS ON HEIGHT, NUMBER OF BREAKS, DRY WEIGHT OF FLOWERS, AND DRY WEIGHT OF VEGETATIVE GROWTH OF 'NEPTUNE' POT CHRYSANTHEMUMS IN THE FIBERGLASS HOUSE, CROP 2[1]

Treatment	Plant Height (inches)	Number of Breaks	Dry Weight of Flowers (g)	Dry Weight of Vegetation (g)
Light Type				
Fiberglass				
Control	12.7a	29.5a	15.7a	24.4a
Day Supplementary	13.2a	31.6a	15.7a	26.5a
Total Fluorescent	10.2a	29.1a	10.7b	19.4a
Error MS (d.f. 4)	1.6879	18.4185	3.1938	14.7421

[1]The figures shown are a mean of 3 replicates (45 pots, 5 plants per pot) of each treatment. Means within a column of a particular light treatment followed by the same letter are not significantly different at the 5 percent level according to Duncan's multiple range test.

TABLE IV

EFFECTS OF LIGHTING TREATMENTS ON HEIGHT, NUMBER OF BREAKS, DRY WEIGHT OF FLOWERS, AND DRY WEIGHT OF VEGETATIVE GROWTH OF 'NEPTUNE' POT CHRYSANTHEMUMS IN THE GLASS HOUSE, CROP 2[1]

Treatment	Plant Height	Number of Breaks	Dry Weight of Flowers	Dry Weight of Vegetation
	(inches)		(g)	(g)
Light Type				
Glass				
Control	12.8a	29.4a	16.0a	27.3a
Day Supplementary	12.8a	35.5b	17.4b	27.8a
Error MS (d.f. 2)	1.7527	4.2111	1.0083	10.5614

[1]The figures used are a mean of 3 replicates (45 pots, 5 plants per pot) of each treatment. Means within a column of a particular light treatment followed by the same letter are not significantly different at the 5 percent level according to the student's t test.

TABLE V

EFFECTS OF LIGHTING TREATMENTS ON HEIGHT, NUMBER OF BREAKS, DRY WEIGHT OF FLOWERS, AND DRY WEIGHT OF VEGETATIVE GROWTH OF 'NEPTUNE' POT CHRYSANTHEMUMS IN THE FIBERGLASS HOUSE, CROP 3[1]

Treatment	Plant Height	Number of Breaks	Dry Weight of Flowers	Dry Weight of Vegetation
	(inches)		(g)	(g)
<u>Light Type</u>				
Fiberglass				
Control	15.6a	26.9a	18.1a	27.7a
Day Supplementary	--	--	--	--
Total Fluorescent	12.6b	29.4a	15.7b	28.1a
Error MS (d.f. 2)	1.2694	13.7333	1.1974	33.8057

[1]The figures shown are a mean of 3 replicates (45 pots, 5 plants per pot) of each treatment. Means within a column of a particular light treatment followed by the same letter are not significantly different at the 5 percent level according to the student's t test.

There were no significant differences between plants in the control and daytime supplementary fluorescent lighting treatments in the fall crop, glass house (Table VI). Plants in the control and daytime supplementary fluorescent lighting treatments required 74 days from potting to reach full bloom.

The number of days recorded from potting until full bloom was a judgement reading. Trying to decide when plants in each treatment had reached full maturity left a margin for error. As a result, the dry weights of flowers were probably affected by this judgement. Therefore, the comparisons of flower dry weights could be slightly inaccurate due to this judgement factor.

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 a darker green foliage color. The plants in the daytime supplementary fluorescent lighting treatment tended to be slightly taller and have heavier flower dry weights. Randomly selected plants from each treatment for each crop are shown in Figure 1.

Figure 2 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

TABLE VI

EFFECTS OF LIGHTING TREATMENTS ON HEIGHT, NUMBER OF BREAKS, DRY WEIGHT OF FLOWERS, AND DRY WEIGHT OF VEGETATIVE GROWTH OF 'NEPTUNE' POT CHRYSANTHEMUMS IN THE GLASS HOUSE, CROP 3[1]

Treatment	Plant Height (inches)	Number of Breaks	Dry Weight of Flowers (g)	Dry Weight of Vegetation (g)
<u>Light Type</u>				
Glass				
Control	14.7a	28.2a	16.2a	26.8a
Day Supplementary	115.0a	31.0a	18.9a	30.5a
Error MS (d.f. 2)	.6250	14.6778	13.4547	46.0203

[1]The figures used are a mean of 3 replicates (45 pots, 5 plants per pot) of each treatment. Means within a column of a particular light treatment followed by the same letter are not significantly different at the 5 percent level according to the student's t test.

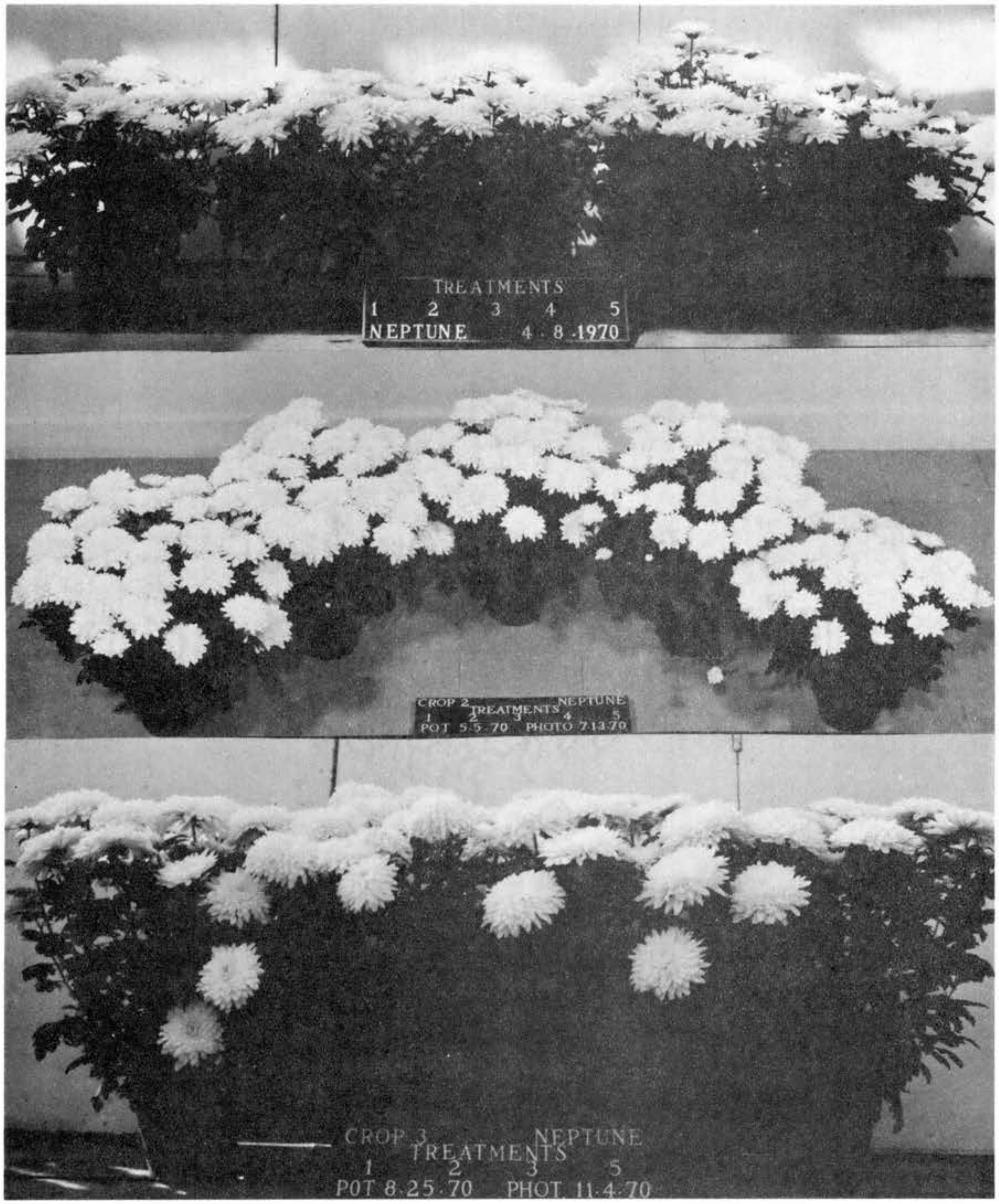

Figure 1. Randomly selected plants from the spring, summer and fall crops. Upper, spring; middle, summer; and lower, fall. Treatments 1-control glass, 2-control fiberglass, 3-daytime supplementary fluorescent light-glass, 4-daytime supplementary fluorescent light-fiberglass, and 5-total fluorescent light.

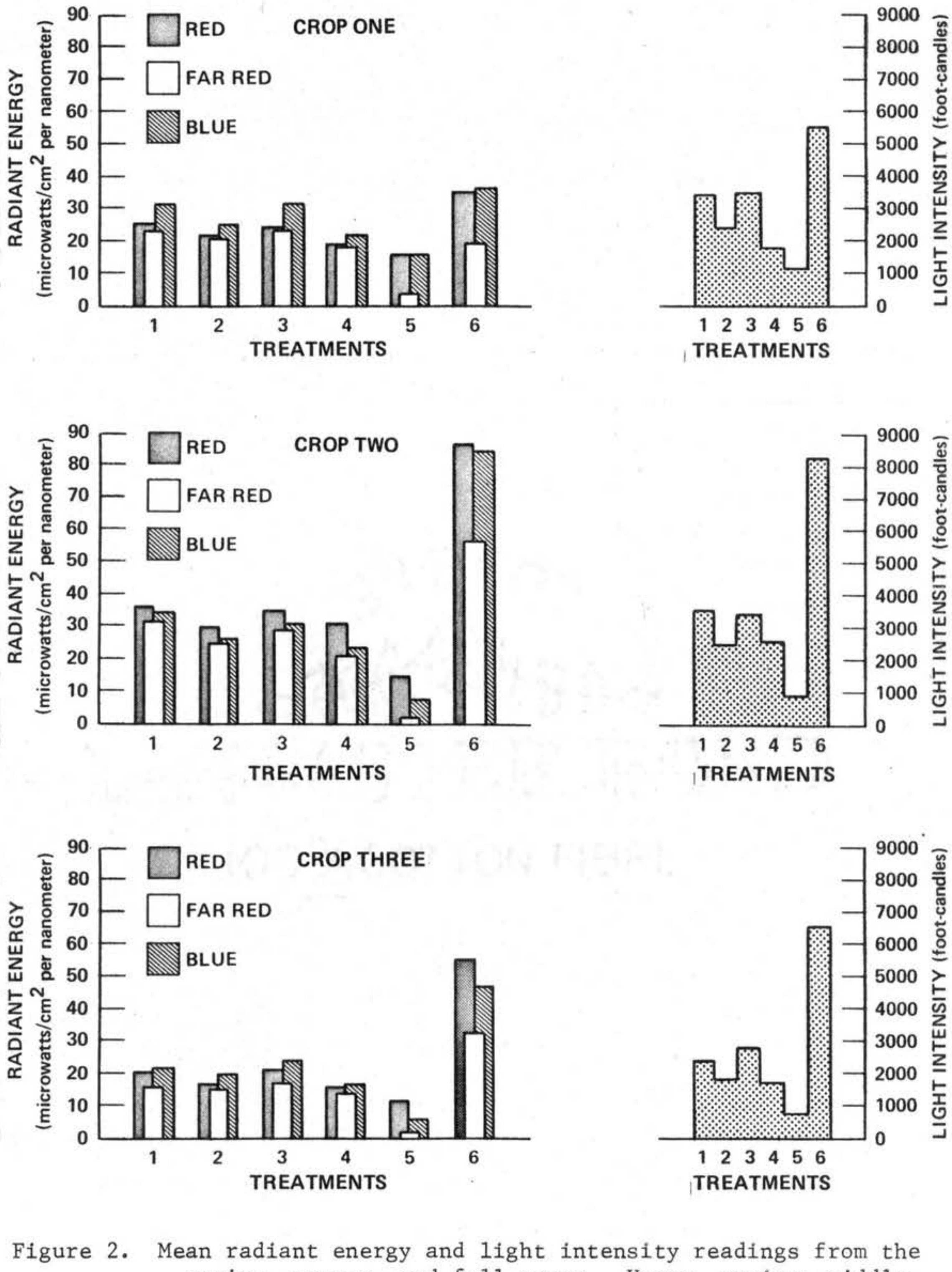

Figure 2. Mean radiant energy and light intensity readings from the spring, summer, and fall crops. Upper, spring; middle, summer; and lower, fall. Treatments 1-control glass, 2-control fiberglass, 3-daytime supplementary fluorescent light-glass, 4-daytime supplementary fluorescent light-fiberglass,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

location, though they were of small 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 outdoors 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 treatments 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 conformed very closely to those of the outdoors treatments, though they were of smaller magnitude. The radiant energy and light intensity for the total fluorescent lighting treatments 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 of these measurements were recorded at 1:30 p.m., one of the brightest parts of the day. The light intensity measurements in foot candles and the radiant energy in the red, far-red, and blue ranges transmitted by the fluorescent lamps used in the total fluorescent lighting treatments decreased with each crop, indicating 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.

CHAPTER IV

DISCUSSION

Plants grown under total fluorescent lighting of 1200 foot candles or less, but with radiant energy similar in quality to sunlight, compared favorably in quality with greenhouse grown plants. There were some statistically significant differences between plants in the total fluorescent light treatment and the other treatments, but the principal visual difference that was noticeable was that the plants grown under the total fluorescent lighting treatments matured 2 to 4 days later than did those in the other treatments. Plants in the total fluorescent lighting treatment were also consistently slightly shorter than plants grown in the fiberglass greenhouse, but in only one instance was the difference statistically significant. These experiments were especially encouraging relative to possible future development of controlled environmental structures utilizing fluorescent lighting rather than sunlight for commercial crop production. It is felt that the lights might be placed even closer to the plants to increase intensity, and that an increased level of carbon dioxide might be beneficial. Air velocity and humidity in relation to plant development should also be studied. In addition, if only 9 to 10 hours of light per day were required, the lights could be movable to allow dual use during a 24 hour period. Light measurements from the three 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. Loss of light intensity could have, in part, been caused by the fixtures. It is quite possible that the fluorescent lamp as currently manufactured, is not the final answer to a light source for controlled environment plant production, and that other types of lamps and lighting cycles should be considered.

From the results obtained, it appears that in northern Oklahoma, daytime supplementary lighting on pot chrysanthemums would be of questionable value. Plants in some of the crops grown under the daytime supplementary lighting treatments were significantly taller, heavier in dry weight of flowers and vegetation, and produced more breaks, but there were not enough visual differences to warrant commercial use.

Radiant energy and light intensity measurements were not correlated with plant growth. Measurements recorded were to show light intensity and radiant energy levels for each treatment in each crop at 1:30 p.m. and also to gain information which might be helpful in future work relating to the economic production of crops in the total environmental control situations.

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VITA

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Robert Earl Moon

Candidate for the Degree of

Master of Science

Thesis: INFLUENCE OF FLUORESCENT LIGHT AND NATURAL GREENHOUSE LIGHT ENVIRONMENTS ON POT CHRYSANTHEMUM DEVELOPMENT AND MEASURED LIGHT INTENSITIES

Major Field: Horticulture

Biographical:

Personal Data: Born in Walters, Oklahoma, June 21, 1947, the son of Mr. and Mrs. C. A. Moon.

Education: Graduated from Walters High School in 1965; attended Cameron College from 1965-67; received the Bachelor of Science degree from Oklahoma State University in 1969 with a major in Agricultural Education; completed requirements for a Master of Science degree in Horticulture in May, 1971.

Professional Experience: Graduate Teaching Assistant, Horticulture, Oklahoma State University, 1969-1971.