ASPECTS OF NIGHT LIGHTING IN THE GARDEN

By

CHARLES CLAYTON FISCHER

A THESIS

Submitted to the School for Advanced Graduate Studies of Michigan
State University of Agriculture and Applied Science
in partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE

Department of Horticulture

1956

THESIS

7-10-56
g

ACKNOWLEDGMENTS

The author expresses sincere appreciation to Professor Donald P. Watson, under whose direction the investigation was conducted. To Dr. Fred B. Widmoyer, Jr. for his valuable assistance. To Barbara Ann Fischer for her patient encouragement.

Acknowledgment is extended to: Cottage Gardens Nursery, Lansing; Laetz Hobby Farm Nursery, Bay City; McDonald Nursery, Saginaw; Miller Nursery, Jackson; and Stark Nursery, Midland for the loan of plant materials.

TABLE OF CONTENTS

INTRODUCTION

The practice of lighting home gardens at night is becoming increasingly popular in the United States. The spring, summer and fall seasons in most parts of the country provide countless evening hours of outdoor enjoyment which can not be appreciated without artificial illumination. In recognition of this potentiality numerous manufacturers of electrical equipment have been interested in outdoor night lighting of gardens. These manufacturers have developed extensive equipment which is available to the home owners.

Many requests have been received from nurserymen, operators of garden stores, and landscape gardeners for information about the use of night lighting. They wish to assist the home owners with installation of lights. This will extend their season of sales into the summer and winter months when there is more free time to devote to this work.

The present investigation was conducted to provide information to improve existing practices of garden lighting, with emphasis upon developing new lighting techniques by accenting the plant material. Standard lighting practices were studied to improve recommendations, as well as to study the influence of additional illumination of various wave lengths on the growth habits of selected garden plants.

LITERATURE REVIEW

Early Development

Some of the earliest outdoor night lighting in the United States was used to illuminate Niagara Falls, New York, and the Natural Bridge, Virginia, as a tourist attraction (Rodes, 1936). An editorial in Business Week, 1954 stated that by the late 1930s home owners were interested. It explained that shortages created by the second world war (1941-1945) temporarily terminated the electrical supplies and that since then at least five electrical manufacturers have conducted research programs to improve equipment and promote lighting.

The increase of suburban homes (Fossum, 1953) and the use of small homes account for the increased use of outdoor garden lighting. These smaller homes employ picture windows to add a feeling of spaciousness (Business Week, 1954). This is effective during the day, but outside lights are needed to create this same effect of spaciousness at night (Business Week, 1954).

Lighting Fixtures

It has been stated that the appearance of light fixtures in the daylight is important to their placement in the landscape (Southern Florist and Nurseryman, 1955). The Scientific American in 1936 cautioned that the appearance of a beautiful garden might be destroyed by visible light sources.

For the best effect, lighting equipment should be invisible or concealed with natural plant material (Ashworth, 1936; Greeves-Carpenter, 1941; Popular Mechanics, 1935; Rodes, 1936; Warren, 1937). Concealment of the light fixtures eliminates any feeling of artificiality in the landscape (Warren, 1937). Equipment small enough for easy concealment and others which are attractively designed are available (Bowser, 1954). Many of the lighting fixtures may be utilitarian by lighting walks and steps as well as creating aesthetic effects with plants in the garden (Sunset, 1956) Others may light an outdoor dinner table (Life, 1954) or supply light for garden work after dark (Bowser, 1954).

Many of the lighting fixtures available for outdoor garden use have been illustrated (Hibben, 1940; Howland, 1955; Popular Mechanics, 1935; Quaintance, 1939; Rebhan, 1955). This equipment included standard flood lights and spot lights and some more ornamental designs simulating objects commonly found in a garden. The Scientific American, 1936 illustrated lighting fixtures which appeared as bird-houses. Other examples of unique designs were those which resembled lily pads, tree stumps, flowers and other plant materials (Greeves-Carpenter, 1941; Polster and Fahsbender, 1954).

Effect on Plants

Investigators have utilized various types of lamps for photoperiodic research. Poesch (1935) reported Mazda lamps superior to mercury and neon sources in producing earlier flowering, greater flower production and stem length of annual Chrysanthemum, Calceolaria, Didiscus, Leptosyne, Viola, and Tagetes. Further, he found (1936) that flowering of Chrysanthemum was retarded more effectively by Mazda lamps than daylight, medium and light blue, and mercury lamps. Post demonstrated in 1942 that incandescent bulbs properly fitted with reflectors obtained maximum light efficiency for growth and flowering of florist crops. Withrow and Withrow (1947) showed incandesxcent sources gave as good or better growth responses than fluorescent or mercury types with Callistephus, Glycine, and Lycopersicum.

Other investigators have studied the effects of increased daylength with artificial light on the growth and flowering of plants. Laurie in 1930 reported results of additional illumination consistent for "long day" plants. Earlier maturity, increased number of flowering stems, and longer stems were the significant results with the following plants: Antirrhinum, Calendula, Dianthus, bulb crops and pot plants. Hydrangea responded to an additional photoperiod with increased plant height and stem length during the growing season (Piringer and Stuart, 1955). Long photoperiods increased the length of lateral shoots of Chrysanthemum (Post, 1950).

The effect of light quality was reported by Vince in 1956; total dry weight of the species Lycopersicon and Pisum was greatest in red light and in the complete spectrum, and least in green and blue light Post (1942) advised that temperature control and daylength were equally important for flower bud formation of most florist crops. Increased illumination resulted in earlier flowering of Lathyrus and bulb crops (Laurie, 1930). He found Dianthus, Gladiolus and Lathyrus responded by increased flower production. Earlier flower initiation of Callistephus occurred with long day treatments (Lin and Watson, 1950). Poesch reported in 1931 earlier flowering of annual, perennial and potted plants and heavier flowering of Iris and Viola when forced with artificial light. Withrow and Benedict (1936) demonstrated that Callistephus, when grown under all wave lengths of additional light, as well as Viola and Mathiola under orange-red bands of light responded with earlier flowering. All three genera had greatest fresh weight and top-root ratio under the orange and red radiation. Gardenia flower production was increased by supplementary illumination and a temperature of 70° F, followed by an unstated low temperature during the dark period (Keyes, 1939).

Harmful effects of additional illumination by retarding Poinsettia flowering were reported by Laurie in 1930. Under supplementary daylengths the Cattleya orchid delayed flower bud development (Holdson and Laurie, 1951) Cooper and Watson (1952) reported cleistogamous flowering of

Viola when exposed to extended periods of additional illumination. Poesch in 1936 found *Chrysanthemum* bud differentiation retarded when supplementary light was applied.

In general, the use of supplementary lights resulted in earlier flowering of selected annuals and bulb crops (Laurie, 1930; Lin and Watson, 1950; Poesch, 1931 and 1935; Post, 1942; Withrow and Benedict, 1936; Withrow and Withrow, 1947). In addition to earlier flowering various perennial plants responded with increased flower production and greater growth (Piringer, 1955; Poesch, 1931; Post, 1942). Some greenhouse crops subjected to additional illumination also had increased growth, earlier flowering and increased flower production (Keyes, 1939; Laurie, 1930; and Post, 1942 and 1950).

Good Effects in Garden

The most popular and aesthetically effective technique of illuminating home grounds was to emphasize the plant materials in the garden (Better Homes and Gardens, 1948; Howland, 1955; Life, 1954; Rebhan, 1955; Rodes, 1936; Southern Florist and Nurseryman, 1955; Toland, 1934). This type of lighting was adopted for larger gardens and municipal parks (Cutler and LaWall, 1934; Hibben, 1940).

The practice of night lighting in the landscape had other advantages. It was used for recreational areas, safety lighting along walks, steps and drives and for such utilitarian purposes as outdoor work after dark. Better Homes and Gardens, 1948; Bowser, 1954; Howland, 1955; Life, 1954; Southern Florist and Nurseryman, 1955; Sunset, 1956 have provided illustrations of these specialized phases of garden lighting.

The lightweight, portable fixtures and extension cords were best as temporary preliminary outdoor lighting to determine the best locations for permanent wiring and outlets (Rebhan, 1955). Later permanent outlets could be installed more effectively at central points in the landscape; Rodes (1936) allowing the freedom for seasonal movement of the lighting fixtures. Procedure for wiring and installation of electrical outlets have been illustrated by Corey (1954); Heath (1938) and Hibben (1940).

Stern (1954) stated that outdoor lighting was a valuable garden investment which greatly increased the utility and beauty of a landscape by providing added hours of enjoyment. Business Week, 1954 recommended night lighting as a "relatively inexpensive decorative scheme for the average suburban home". Life magazine, 1954 stressed small operating costs for most homes, and estimated a year's electric bill of about $20 for outdoor night lighting.

To create good effects with outside lighting the best features of the landscape are emphasized and the poorest features eliminated by shadows (Life, 1954; Quaintance, 1939; Warren, 1937). This procedure often causes the lighted garden to appear more beautiful than during the day (Ashworth,

1936). No definite rules or methods are essential to insure this result. Toland in 1939 concluded that subtle effect of lighting requires the discreet use of few lights with sources well concealed. Greeves-Carpenter (1941), Kroscher (1933) and Quaintance (1939) recommended experimenting with the location, size, angle and color of the light until the best effect was obtained.

Utilizing a flood light to establish an over-all basic illumination was effective in addition to the accent lighting of outstanding garden features according to Howland (1955) and Rodes (1936). Popular Mechanics (1935) suggested flood lights were useful for emphasizing the background of a garden. Accent lighting, or concentration of light on specimen plants resulted in a monotonous two-dimensional appearance. Rodes in 1939, advised the use of two light sources from different angles and intensities to avoid the effect of "flatness"

The colors and textures of plant materials are emphasized with night lighting (Rebhan, 1955). By utilizing tinted lights predominately the same color as the plant material, the best results can be achieved (Person, 1932). An impression of depth and distance can be created by side placement of the lighting fixtures and utilization of blue and purple colored lights (Person, 1932; Rebhan, 1955). Quaintance (1939) suggested the use of white and blue colors or two lights of unequal intensity to achieve contrast. Ash-

worth in 1936 preferred numerous colors when lighting water in garden pools, especially fountains and waterfalls. The yellow and orange light sources do not attract flying insects when used for night garden lighting (Bowser, 1954; Person, 1932; Rebhan, 1955).

The most widely used type of light source for outdoor illumination is the incandescent lamp. The mercury-vapor sources have had limited application in garden lighting (Hibben, 1940; Howland, 1955).

PROCEDURE

Effect on Plants

To study the influence of colored light on representative garden plants, a preliminary investigation was conducted at the Plant Science greenhouse in a four by fifty foot bench using a night temperature of 60° F. The bench was equally divided to form six individual areas, each separated by a black polyethylene strip. To prevent reflection of light, an overhead wire frame was constructed with black shading cloth to cover the area.

Plant material was selected to provide representative groups of plants commonly used in Michigan gardens. Mixed seedlings of *Zinnia elegans*; rooted cuttings of *Chrysanthemum morifolium* cultivar Indianapolis White and Yellow; rooted cuttings of *Pelargonium hortorum* cultivar Scarlet Princess; *Spiraea vanhouttei*; *Euonymus vegetus*; *Juniperus chinensis columnaris*; and *Taxus media hicksii* were chosen to represent annual, perennial, deciduous, and evergreen ornamental plants.

After approximately five months, on February 1, 1955, electrical outlets were installed in each of five areas and one space left unlighted Four 100-watt incandescent lamps were the source of additional light in each area which received blue, green, red, white or yellow light from these four lamps. Additional light was given the test plants between 5 and 12 p. m., using an automatic timing device.

The following was recorded: total growth, time and amount of flowering of Chrysanthemum; number and elongation of new shoots of Euonymus; the time of flowering, stem length and plant height of Pelargonium and Zinnia; plant height and amount of growth of Juniperus, Spirea and Taxus.

A second investigation was conducted in outdoor planting beds. Four beds of equal size were constructed southeast of the Plant Science greenhouse. Each area was enclosed on all sides with canvas to eliminate light reflection.

A different and more representative selection of plant material was used in this study; as annuals Callistephus chinensis and Salvia splendens, Coreopsis lanceolata and Delphinium cultorum to represent herbaceous perennial plants; Deutzia lemoinei, Euonymus alata compacta, Hypericum prolificum and Rosa hybrids to represent deciduous perennials, and Buxus sempervirens and Juniperus Pfitzeriana to represent broad and narrow-leaved evergreens.

After two weeks, on July 1, 1955, electrical outlets were installed as before using three 100-watt incandescent lamps as a source of green, white and yellow light.

Amount of frost injury was observed for the annuals, the herbaceous perennials and some of the woody deciduous perennials. In addition, the condition of winter hardiness and dormancy were recorded for some of the perennials and the evergreens.

Plants of *Chrysanthemum morifolium* cultivar Indianapolis Yellow, *Spirea vanhouttei*, *Taxus media hicksii*; cut flowers of *Antirrhinum majus*, *Chrysanthemum morifolium* cultivar Corsair, *Dianthus caryophyllus*, and *Rosa* hybrids were sprayed with a fluorescent paint* to test the effect upon the selected plant materials.

The 100-watt lamps used in the investigations were sprayed with blue, green, yellow and red paint. The wave length transmittions (Table 1) of these colored incandescent lamps were obtained by using a Bausch and Lomb spectroscope

Table 1

The Wave Length Transmittions of 100-Watt Lamps.

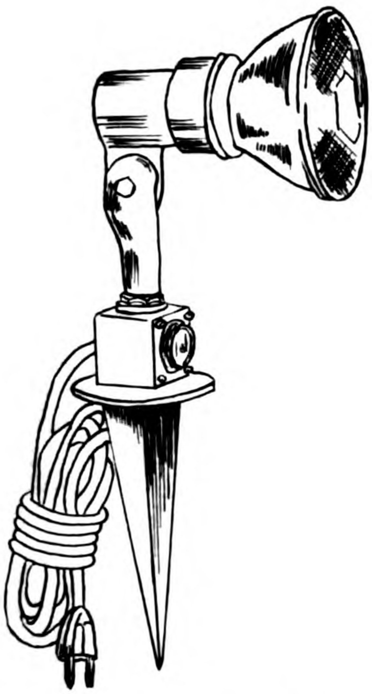
Lamp Color	Angstrom Units
Blue	4100 - 7600
White	4250 - 7600
Green	4650 - 7150
Yellow	5100 - 7250
Red	6000 - 7400

---

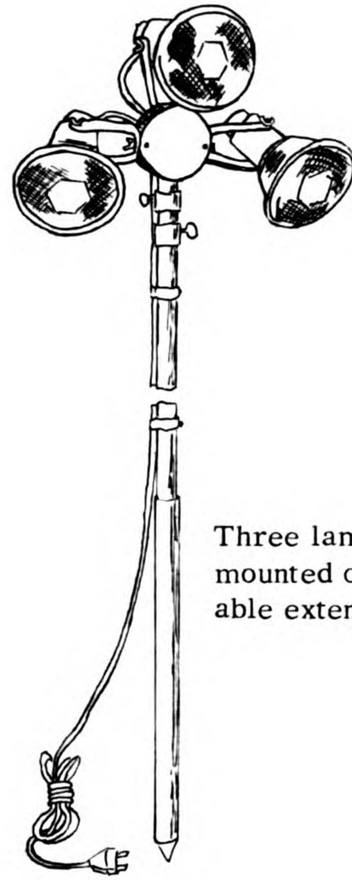
*Day-Glo, made by the Craftint Manufacturing Company, Cleveland, Ohio

Good Effects in Garden

The illumination of a private residence in June, 1955, the horticultural garden at Michigan State University in January, 1956, and Jones Nursery in Grand Rapids in 1956, served as examples of lighting procedure. The development of new techniques of lighting was emphasized in order to accentuate plants. Standard lighting equipment (Figure 1) including many designs of spot lights, flood lights, colored lenses, incandescent lamps and waterproofed extension cords were used. Part of the lighting equipment was supplied by Steber Manufacturing Company, Broadview, Illinois.



Fixture with ground spike.
For PAR-38 flood or spot lamps.
Convenient outlet for adding
extra fixtures.



Three lamp unit
mounted on adjust-
able extension pole.

Enclosed floodlight, re-
sistant to moisture, heat
or cold Lenses may be
clear or colored.

PAR-38 sealed beam
lamp and lensholder.
Spring clip holds blue,
green, red or yellow
glass lenses in place.

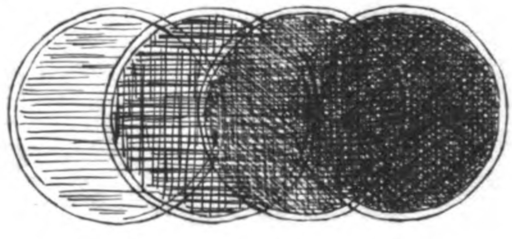


Figure 1. Examples of standard lighting equipment.

DISCUSSION OF RESULTS

Effect on Plants

Greenhouse Study: All *Zinnia elegans* plants grown under additional illumination of white lamps were inhibited in linear growth (Table 2). The average stem length of the other lighted plants was greater than the unlighted plants. Those exposed to the green source of light had a total of six inches additional elongation compared with those receiving no supplementary illumination The green and red lighted plants had significantly more linear growth than those exposed to the white light.

As shown in Table 2, the plants which received no supplementary illumination produced approximately twice as many flowers as the lighted plants. Of those receiving additional light, the red source stimulated the greatest flower production. There was no significant difference in flower diameter on plants grown under the blue, green, red and yellow light, but the plants grown under the white light produced flowers which were reduced approximately one inch in diameter.

In general, plants of *Zinnia elegans* responded to additional illumination with greater linear growth and a larger flower diameter. Support of these findings was offered by Post in 1942, when he found stem length and flower size increased with supplementary light. Total flower production was inhibited with the use of longer photoperiods Those plants grown

Table 2

Growth Responses of Zinnia elegans to Various Wave Lengths of Light (Average of Five Plants).

Wave Lengths		Length of Stem (Inches)	Total Number of Flowers	Flower Diameter (Inches)
Blue		14.96	1.75	2.89
Green		18.14	1.75	2.60
Red		16.14	2.25	2.91
White		9.55	1.63	1.90
Yellow		14.13	1.88	2.90
Unlighted		12.13	3.13	2.45
LSD	.05	5.99	1.22	.87
	.01	8.02	NS	NS

with white light were consistently inhibited in linear growth, total flower production and size of flower. The results of the experiment presented in Table 2 and by Post showed that flower production was greatest for those plants which received no additional light.

The linear growth of Chrysanthemum morifolium exposed to various light sources showed highly significant increases in stem length (Table 3). A comparison of plants grown under the light sources shows that no one wave length was superior to any other in the production of growth. The chrysanthemums receiving no additional light were grown with naturally

Table 3

The Effect of Various Qualities of Light on Growth of Chrysanthemum morifolium and Euonymus vegetus (Average of Five Plants).

Wave Length		Chrysanthemum	Euonymus	
		Stem Length (Inches)	Number of Shoots	Stem Length (Inches)
Blue		7.20	4 25	3 85
Green		6 46	2 50	3.38
Red		6.60	11.00	6.43
White		6.80	5.00	2.63
Yellow		6.14	6.50	3 20
Unlighted		3 88	14.00	4 23
LSD	.05	1.84	6 48	3.73
	.01	2.51	NS	NS

short photoperiods of the latitude and resulted in uniform flowering, as was previously shown by Post (1948). Those plants exposed to a longer photoperiod exhibited retarded flowering, a finding confirmed by Poesch (1936). The use of additional light of all wave lengths stimulated vegetative growth of Chrysanthemum; the unlighted plants flowering on short stems.

Table 3 lists the number of new shoots being inhibited on Euonymus vegetus grown under blue, green, white and yellow light sources. Euonymus plants exposed to red illumination produced significantly more new shoots than other lighted plants, although this was an average of three shoots less than the unlighted plants. A comparison of the plants which received additional light shows red illumination promoted the largest number of new shoots and greatest elongation. All plants grown under longer photoperiods had reduced total elongation with the exception of those receiving the red source of light. These plants produced an average of 2.2 inches more linear growth than the unlighted test plants. Euonymus was inhibted in the development of new shoots when exposed to additional illumination. In general, the plants were inhibited in total stem elongation. During the first four months of this experiment, all Euonymus test plants remained in a dormant condition, which was broken by exposing the plants to a two-week cold period (32 to 35° F)

These data show in Table 4 that the average flower production of Pelargonium hortorum was inhibited by supplementary illumination. This inhibition was highly significant for the green and yellow sources as compared with the plants exposed to blue illumination and those which remained unlighted. Total flower production was increased when plants were grown with blue, red and white light, over those which received normal daylength. The blue and red sources of illumination promoted greater total flower production than any other color.

All Pelargonium plants grown under additional light produced longer flower stems than unlighted plants. This was a highly significant result for all test plants, with the exception of those exposed to white light. When

Table 4

Flowering Responses of Pelargonium hortorum to Selected Wave Lengths of Artificial Illumination (Average for Five Plants).

Wave Lengths		Average Number of Flowers	Total Number of Flowers	Flower Stem Length (Inches)
Blue		1.96	22.80	5.38
Green		1.46	13.80	5.90
Red		1.74	20.60	6.64
White		1.68	18.80	5.20
Yellow		1.48	15.80	5.76
Unlighted		1.92	18.60	4.44
LSD	05	.29	5.45	69
	.01	.40	7.44	94

comparing the lighted plants, the green and red sources produced the longest flower stems

In general, the use of additional light inhibited average flower production of Pelargonium hortorum. The total flower production was increased under blue, red and white light, as compared with unlighted plants. All plants grown under supplementary illumination produced longer flower stems. These findings are contrary to Post (1942), who found that daylength did not affect the flowering of Pelargonium hortorum Plants exposed to longer daylengths had an average of 9.4 inches greater height than those not given additional light. This response was especially evidenced by the plants grown under red light which had an average 21.8 inches greater height than the unlighted. This agrees with Vince (1956) who noted total stem and internode length of Lycopersicon species increased with increases in wave lengths of light.

Table 5

Linear Growth Response of Taxus media hicksii, Juniperus chinensis columnaris and Spiraea vanhouttei to Selected Light Qualities.

Wave Lengths	Taxus*	Juniperus** (length given in inches)	Spiraea*
Blue	2.50	19.0	11.52
Green	2.88	16.0	12.88
Red	2.14	21.5	11.74
White	2 30	1.5	12.20
Yellow	2.10	14.3	11.92
Unlighted	2.74	15.0	10.82
LSD .05	NS	--	NS

*Average for five plants.

**Insufficient plants for statistical analysis due to a high mortality rate.

Growth of Taxus media hicksii in general was slightly inhibited by additional illumination (Table 5). Plants grown under the red source of light were an exception, although growth was not sufficiently greater than the unlighted plants. The response comparison between lighted plants showed the red and yellow sources of illumination had the greatest inhibiting effect on growth.

Data in Table 5 show further that Juniperus chinensis columnaris responded to supplementary light of blue, green and red sources with an increased growth. The greatest response was shown for the red illumination which averaged 6.5 inches over the unlighted plants. The white source of light apparently had the most inhibiting effect on growth of Juniperus.

Spiraea vanhouttei grown under additional light had increased linear growth over those which received normal daylength (Table 5) Plants exposed to the green and white sources of light were the most influenced, averaging 1.7 inches more growth than those with no additional illumination.

The response of the woody plants grown with supplementary light was not consistent among the genera. According to Table 5, Taxus showed an inhibition of growth with additional light of the various sources with the exception of red wave lengths The growth of Juniperus was increased when supplementary light of blue, green and red sources were used. An inhibition of linear growth occurred for those plants given additional white and yellow light. Spiraea exhibited uniform increases of lateral growth when supplied with additional light, which were observed but were not sufficiently significant.

Outdoor Study: Experimental plants of Callistephus chinensis, Salvia splendens, Coreopsis lanceolata, Delphinium cultorum, Deutzia lemoinei, Euonymus alata compacta, Hypericum prolificum, Rosa hybrids, Buxus sempervirens and Juniperus Pfitzeriana were examined weekly to compare the time of frost injury No differences were observed in time of frost injury as a result of lighting Time of defoliation, as a measure of dormancy, varied from October 24 for Deutzia to November 30, 1955 for Rosa. The annuals were killed by frost earlier The only genera which light had any influence on time of defoliation was Euonymus. When these plants were grown under white light the defoliation was complete on November 18, six days later than other plants.

The use of additional illumination apparently influenced germination and growth of weeds. Few weeds germinated in any of the lighted beds. Of the lighted areas, the white source was less effective in inhibition as compared with the green and yellow areas where fewer weeds germinated

Heat from the lights in this experiment was not sufficient to prevent frost injury under the autumn of 1955 weather conditions. It would be necessary to extend this test for several years to be certain that lights were of no value as a frost preventative measure

The *Buxus* and *Rosa* exhibited slight winter injury which was consistent in all plots. Observations during the spring of 1956 showed uniform development and growth for all plants. No inhibitory effects were caused by the continued lighting of the plants.

Lighting in the Garden

Observations of Lighting: An objective of night garden lighting is to increase the hours of outdoor living and enjoyment. The spring, summer and fall seasons offer pleasant evenings which have limited enjoyment after sundown. With few carefully located lighting units the beauty of trees, shrubs and flowers can be emphasized and the landscape enjoyed after dark.

Integration of indoor-outdoor living areas has become a standard landscape practice. The use of garden lighting can effect this integration during the hours of darkness. This lighting will also serve to feature a residence in a proper setting after dark

At night the good features, the points of greatest current interest may be emphasized and others left unlighted to create a beautiful garden Careful placement of lighting fixtures and selection of colors to accent foliage and texture of plant materials can improve the appearance of most plants. Lighting which emphasizes the beauty of a garden should be planned to be functional. Light reflection can illuminate recreational areas, garden walks or steps.

This paper is supplemented with three kodachrome transparencies for better illustration of the following techniques.

Suggested Techniques: A fundamental requirement for effective night lighting of gardens was the concealment of all light sources. This has been recognized by Ashworth (1936), Greeves-Carpenter (1941), Rodes (1936), and Warren (1937). When lighted, exposed fixtures produce a glare of light which distracts from the garden and during the daylight hours they rarely add to the beauty of the setting. Plant material may conceal lighting fixtures, especially when smaller units are used.

If the lighting units were used on the ground, they were placed behind low growing shrubs or other plants for concealment from the main viewing areas When the fixtures were used in elevated positions they were hidden among tree branches or an unexposed area of a building. Howland (1955) also recommended this treatment for elevated light sources.

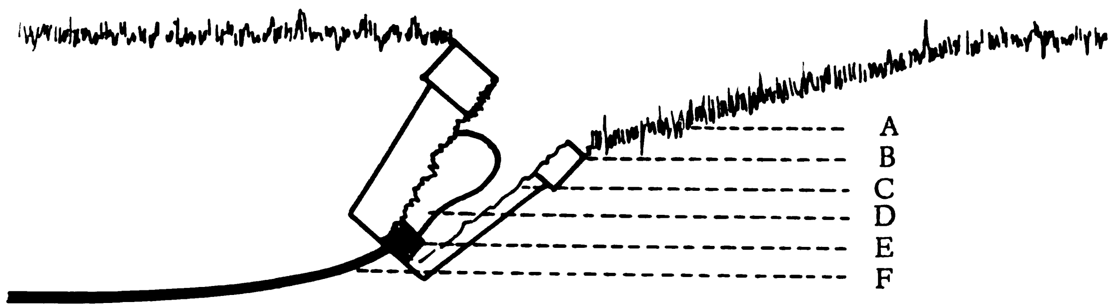
After the fixtures were carefully concealed for night-time appearance, they were not in a position to distract from the beauty of a garden during the daytime

Lighting units were hidden by metal sheets. Southern Florist and Nurseryman (1955) also found this an effective means of concealing the lighting fixtures. These shielding devices of non-rusting material were placed close to the light source, thus eliminating glare. Although these shields resulted in an unattractive daytime appearance in the garden, they were frequently useful for temporary lighting.

When fixtures were not concealed with existing plant material or shields, they were sunken beneath the soil. During this study, an inexpensive fixture was designed. An 8-inch clay pot and waterproof electrical wiring was utilized as a practical unit for submerging (Figure 2). By inserting the electrical cord through the drainage hole in the bottom of the pot the socket and lamp was wired in position. Sides of the pot were lined with aluminum foil which served as a reflector for the lamp This entire unit was buried under the turf to completely hide the fixture and allow for easier clipping of the lawn.

When outdoor lighting was used on home grounds, especially with foundation plantings, an interesting technique was added to the lighting by creating shadows on walls. This emphasized the plant texture and resulted in unusual shapes and patterns. A method of lighting shadows was developed during this study. By creating shadows with one source of light, a second fixture was used to illuminate and add color to the shadows. Figure 3 shows how the shadow of a Juniperus was formed by placing a 150-watt fixture in front of the plant. This achieved an outline on the brick wall and accented the growth pattern of the vine Immediately behind the evergreen a unit containing a 100-watt colored lamp was located to light the shadow. The intensity of the first lamp was strong enough to prevent an overlap of colors. This technique was used with various color combinations. Use of green and white, as in the illustration, achieved an illusion of a double planting

Figure 2 Practical lighting unit for concealment below surface of soil.



A. Turf
B. Clay pot
C. Aluminum foil reflector
D. Lamp
E. Waterproof socket
F. Electrical cord

Figure 3

Shadow Lighting Technique

Shadow of Juniperus sp. created by a 150-watt spotlamp. The shadow was then lighted by concealing a 100-watt green lamp behind the evergreen.

To accent specimen shrubs a flood lamp was used as a background light, a method suggested by Howland (1955) and earlier by Rodes (1936) Figure 4 is an application of accent lighting used on a simple planting. The principal function of the background light was the addition of the illusion of depth to the scene secondary to the accent light

Unusual effects were attained using colored lamps or colored cover lenses attached to regular lamps. The predominate color of the plant material was accentuated if an analogous color of light was used. This method was effectively utilized when lighting branches, trunks, foliage or flowers

The use of colored light sources for winter lighting added much interest and subtle effect to the dormant garden It was found necessary to caution against a bizarre and unnatural scene. Figure 5 provides an example of good color use in the winter landscape. To emphasize the natural branch color of the _Malus_, a red lens was used on a 150-watt spotlamp. Two smaller units supplied white light to add width to the lighted scene. A fourth fixture containing a 150-watt floodlamp fitted with a green lens was used to create depth by lighting the background planting of _Thuja occidentalis_.

Color was used to reduce attraction of flying insects in a night lighted garden. Bowser (1954), Person (1932) and Rebhan (1955) suggested

Figure 4

Accent Lighting Specimen Shrubs

The specimen Syringa persica was accented with a 75-watt unit. Background Syringa chinensis was lighted with a 150-watt floodlamp.

Figure 5

Color in the Winter Garden

Natural bark color of _Malus floribunda_ emphasized by red lens on PAR-38 spotlamp.
The white side lights added width, while the green floodlamp created depth.

this effective means of reducing insects Yellow or orange proved the most effective colors for this purpose, however these colors may not complement the plant material and undesirable effects may occur. Another control measure was to locate the lighting some distance from the main outdoor living areas

When one source of light was used on shrubs or trees a flat or two-dimensional effect occurred To eliminate this flatness and accent the plant shape, two light sources may be used from different angles or distances This procedure coincided with that of Quaintance (1939) and Rodes (1936). Lamps of unequal intensities or different colors were used to increase the effectiveness by emphasizing plant forms

Night lighting large public gardens required planning for distant viewing. Mass lighted areas and the predominate use of white light sources were most effectively used for this type of lighting.

Outdoor garden lighting was not limited by definite rules. The best procedure was use of lightweight portable equipment for individual trial in the garden This method helped locate the best features and determine the location, wattage and color of light which gave the best views. By using portable lighting equipment, permanent location of electrical outlets and lighting fixtures was reduced to a minimum.

A standard neon tube was adopted for lighting the edges of the flower borders with tubes constructed to fit the border. The neon source of light provided an over-all illumination; individual accent areas required additional fixtures for concentrations of light. This light was especially adopted for silhouette effect behind tall flower spikes and upright plants

A light fixture equipped with fluorescent tubes and a lens to transmit ultra-violet wave lengths was used for lighting plants. Commercially known as "Black Light", this ultra-violet illumination was used on plants that had been sprayed with fluorescent paint. A moderate application of this paint produced aesthetic lighting. Completely eliminating visible light, the painted surfaces were illuminated with a brilliant glow using red color on flowers and green on leaves and stems.

The fluorescent spray painted *Chrysanthemum morifolium* cultivar Indianapolis Yellow, *Spiraea vanhouttei* and *Taxus media hicksii* exhibited no harmful growth effects. Keeping quality of sprayed *Chrysanthemum morifolium* cultivar Corsair and *Dianthus caryophyllus* cut flowers was not decreased. Sprayed *Antirrhinum majus* and *Rosa* did not wilt as quickly as those not treated.

SUMMARY

Growth responses of selected plant materials exposed to supplemental illumination of various wave lengths was observed. Existing garden lighting procedures were evaluated and new outdoor lighting techniques developed.

Selected plants were exposed to additional light of blue, green, red, white and yellow wave lengths. Plants were grown for one year in a 60° F greenhouse. Zinnia elegans produced greater linear growth and flower size when exposed to supplementary light. Those grown with normal day-length had greatest flower production. The lighted Chrysanthemum morifolium plants had greater linear growth and reduced flowering. Additional light inhibited new shoot development and total stem elongation of Euonymus vegetus Pelargonium hortorum plants had reduced average flower production, increased flower stem elongation and greater plant height when grown under supplementary illumination. Growth of Taxus media hicksii was slightly inhibited by additional light. The growth of Juniperus chinensis columnaris was generally increased by light Supplementary illumination uniformly increased linear growth of Spiraea vanhouteii

To observe frost injury, dormancy and winter hardiness, selected plants were grown in an outdoor area with additional green, white and yellow wave lengths of light. No differences were shown in preventing frost injury

by additional illumination. Dormancy and winter hardiness were uniform for all plants Germination of weed seeds was observed to be inhibited in the lighted areas.

The night lighting of outdoor gardens showed that concealment of the light source increased effectiveness of the garden scene. Light fixtures were best concealed by plants, metal shields and submerged fixtures Creating and lighting shadows with color added unusual effects in foundation plantings. Accenting specimen plants emphasized form and texture in the night lighted gardens. Flat appearances were eliminated by using two fixtures located at different angles. Colored light sources were used to accentuate plant color, improve appearance of plants, increase winter beauty of gardens, and reduce attraction of insects. Subtle lighting in large gardens was not effective for distant viewing. Neon fixtures were used to illuminate flower borders Fluorescent light sources and fluorescent paint provided aesthetic garden lighting without harmful effects on plants. Portable equipment was effective for illuminating the best garden features and eliminated permanent location of electrical outlets and lighting fixtures

BIBLIOGRAPHY

Anon. 1935. Painting your garden with lights. Pop. Mech 64: 180-183.

Anon. 1936. Garden lighting sources beautified. Sci. Amer 154: 336.

Anon. 1948. Light up. Better Homes and Gard 26: 50-51.

Anon. 1954 All outdoors lit up; home gardens. Life 37: 67-69.

Anon. 1954. Shrub lights. Bus. Week 1297: 104-105.

Anon. 1955 Outdoor lighting Southern Flor. and Nurseryman (series)

Anon. 1956. To light guests to your door Sunset 116: 86-87.

Ashworth, Donna. 1936. Garden magic. Amer. Home 16: 84-86.

Bowser, Bernice. 1954 Night life for your garden. Amer. Home 52: 52-53

Cooper, Calvin C., and Donald P. Watson. 1952. Influence of day length and temperature on the growth of greenhouse violets Proc Amer. Soc Hort. Sci 59: 549-553.

Corey, Paul. 1954 How to install outdoor lights. Pop. Sci 164: 224-230.

Cutler, C. M., and T. R. LaWall. 1934 Garden lighting brings magic by night. Good Housekeeping 99: 72-73.

Fossum, M. Truman. 1953. Trade in horticultural specialties. U. S D. A. Marketing Res. Rep. No. 33: 44, 51, 72.

Greeves-Carpenter, C. F. 1941. The magic of a lighted garden. Arts and Dec. 54: 18-19.

Heath, William A. 1938. Lighting the garden Good Housekeeping 107: 60-61.

Hibben, S G 1940. Lighting municipal gardens. Am. City. 55: 109.

Holdson, John H., and Alex Laurie 1951 The effect of supplementary illumination on the flowering of the orchid Cattleya triavae. Proc. Amer Soc. Hort. Sci 57: 379-380.

Howland, Joseph E. 1955. Pace setter way to light a garden. House Beautiful 97: 142-145.

Keyes, C. G. 1939. Bud formation, abscission, and flower production of gardenia as affected by light and temperature Proc. Amer. Soc Hort Sci. 37: 1034-1036.

Kroscher, Ralph M 1933. Garden lighting. Am. Phot 27: 472-476.

Laurie, Alex. 1930. Photoperiodism--practical application to greenhouse culture Proc. Amer. Soc. Hort. Sci. 27: 319-322.

Lin, Lok-Chien, and Donald P. Watson. 1950. The influence of daylength and temperature on the growth and flowering of Callistephus chinensis Nees. Proc. Amer. Soc. Hort. Sci. 55: 441-446.

Person, Charles. 1932. Gardens that bloom in the night. Pop Mech. 58: 328-330

Piringer, A A., and Neil W. Stuart. 1955. Responses of hydrangea to photoperiod. Proc. Amer Soc. Hort Sci. 65: 446-454.

Poesch, G. H. 1931 Forcing plants with artificial light. Proc. Amer Soc Hort. Sci. 28: 402-406.

Poesch, G. H. 1935. Supplementary illumination from mazda, mercury and neon lamps on some greenhouse plants. Proc. Amer. Soc. Hort. Sci. 33: 637-638.

Poesch, G H. 1936 Prolonging the flowering period of chrysanthemums with the use of supplementary illumination. Proc. Amer Soc. Hort. Sci. 34: 624-626.

Polster, Edythe, and Myrtle Fahsbender. 1954. Garden lighting. Pilgrim Press Corp.

Post, Kenneth. 1942. Effects of daylength and temperature on growth and flowering of some florist crops. Cornell Univ. Agr. Exp. Sta. Bul 787.

Post, Kenneth 1948. Daylength and flower bud development in chrysanthemums. Proc. Amer. Soc Hort. Sci 51: 590-592

Post, Kenneth. 1950. Controlled photoperiod and spray formation of chrysanthemums. Proc Amer Soc Hort. Sci 55: 467-472

Quaintance, Ethel. 1939. Making garden moonlight Better Homes and Gard 17: 110-111.

Rebhar, John R. 1955 Garden lighting Flower Grower 42: 82-85

Rodes, Marjorie Reed. 1936 Lighting to make the garden more colorful at night. House and Gard 69: 32-33.

Stern, Gladys Gillies. 1954. Report of the month. Flower Grower 41: 10.

Toland, Helen. 1934. A step in the light direction. Amer Home 12: 144-145.

Vince, Daphne 1956. Studies on the effects of light quality on the growth and development of plants. Jour Hort Sci 31: 16-24

Warren, Dean. 1937. And so into the night Better Homes and Gard 15: 54-55.

Withrow, Alice P., and R B. Withrow. 1947. Comparison of various lamp sources for increasing growth of greenhouse crops Proc Amer Soc. Hort Sci. 49: 363-366.

Withrow, R. B., and H. M. Benedict. 1936 Photoperiodic responses of certain greenhouse annuals as influenced by intensity and wavelength of artificial light used to lengthen the daylight period. Plant Phys 11: 228-249.

ASPECTS OF NIGHT LIGHTING IN THE GARDEN

By

CHARLES CLAYTON FISCHER

AN ABSTRACT

Submitted to the School for Advanced Graduate Studies of Michigan
State University of Agriculture and Applied Science
in partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE

Department of Horticulture

1956

Approved Donald P. Watson

CHARLES CLAYTON FISCHER ABSTRACT

Growth responses of selected plant materials exposed to supplemental illumination of various wave lengths was observed. Existing garden lighting procedures were evaluated and new outdoor lighting techniques developed.

Selected plants were exposed to additional light of blue, green, red, white and yellow wave lengths. Plants were grown for one year in a 60°F greenhouse. Zinnia elegans produced greater linear growth and flower size when exposed to supplementary light. Those grown with normal daylength had greatest flower production. The lighted Chrysanthemum morifolium plants had greater linear growth and reduced flowering. Additional light inhibited new shoot development and total stem elongation of Euonymus vegetus. Pelargonium hortorum plants had reduced average flower production, increased flower stem elongation and greater plant height when grown under supplementary illumination Growth of Taxus media hicksii was slightly inhibited by additional light. The growth of Juniperus chinensis columnaris was generally increased by light. Supplementary illumination uniformly increased linear growth of Spiraea vanhouteii.

To observe frost injury, dormancy and winter hardiness, selected plants were grown in an outdoor area with additional green, white and yellow wave lengths of light No differences were shown in preventing frost injury by additional illumination. Dormancy and winter hardiness were uniform for all plants. Germination of weed seeds was observed to be inhibited in the lighted areas.

The night lighting of outdoor gardens showed that concealment of the light source increased effectiveness of the garden scene Light fixtures were best concealed by plants, metal shields and submerged fixtures Creating and lighting shadows with color added unusual effects in foundation plantings Accenting specimen plants emphasized form and texture in the night lighted gardens. Flat appearances were eliminated by using two fixtures located at different angles. Colored light sources were used to accentuate plant color, improve appearance of plants, increase winter beauty of gardens, and reduce attraction of insects. Subtle lighting in large gardens was not effective for distant viewing. Neon fixtures were used to illuminate flower borders Fluorescent light sources and fluorescent paint provided aesthetic garden lighting without harmful effects on plants. Portable equipment was effective for illuminating the best garden features and eliminated permanent location of electrical outlets and lighting fixtures

Accompanied by three colored figures, two black and white figures and five tables.

ROOM USE ONLY

Date Due

~~NOV 1 3 1960~~			
~~JAN 2 8 1962~~			
ROOM USE ONLY			

Demco-293