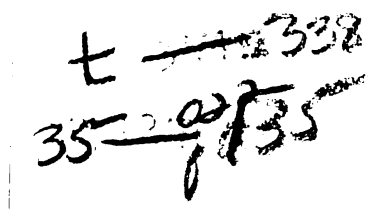
THE EFFECT OF HIGH INTENSITY LIGHTING OF ROSES IN THE GREENHOUSE

Thesis for the Degree of M. S.

MICHIGAN STATE UNIVERSITY
GARY ALLEN ANDERSON

1970



ABSTRACT

THE EFFECT OF HIGH INTENSITY LIGHTING
OF ROSES IN THE GREENHOUSE

By

Gary A. Anderson

A comparison was made of the growth and flowering of rose clones 'Forever Yours' and 'Shocking Pink' grown: 1) under normal greenhouse light conditions from December 15, 1969 to May 15, 1970, 2) lighted with wide-spectrum Gro Lux lamps at about 250 foot candles for 8 hours (6 p.m. to 2 a.m.) nightly, and 3) lighted continuously with wide-spectrum Gro Lux lamps during the daylight hours and 8 hours nightly. Records included flower production, days required for a return of stems to flowering, number of flowers per cane, flower stem length, fresh weight and number of nodes. Additional measurements were made of the total reducing sugars in the leaves after exposure to each of the treatments for 24 hours.

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Gary A. Anderson

Rose 'Forever Yours' responded well to supplemental lighting of high intensity. Numbers of flowers per plant were increased significantly and bottom breaks developed in large numbers. Clone 'Shocking Pink' responded less to lighting. Sugar levels were increased in both clones by lighting, while flower stem lengths, fresh weights, and number of nodes were reduced slightly.

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By

Gary Allen Anderson

A THESIS

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE

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INTRODUCTION

Commercially-grown cut roses are one of the nation's leading cut flower crops. Like many other areas of agriculture, the rose industry has become highly competitive and fewer growers are producing more roses in larger establishments. There are many factors affecting the success of rose growing in a particular geographical area, including sales opportunities, management of the business, and the environment of the locale. Among the environmental considerations is the amount of sunlight received. Light is perhaps the dominant factor in the greenhouse environment.

During the short winter days light can become a problem in the greenhouse because of its regulating influence on plant growth. In Michigan, winter days are frequently cloudy and often less than one-half the potential sunlight is received. Fortunately this situation can be controlled by the use of artificial illumination. This study was undertaken to investigate the possible benefits of high intensity lighting with wide spectrum Gro Lux lamps placed in close proximity to rose plants.

REVIEW OF LITERATURE

Development of Low Intensity Lighting

Light is known to be an important factor in the vegetative and reproductive development of greenhouse plants. Researchers have attempted to explain the morpho-physiological changes induced by the various lighting conditions. As early as 1905, Blackman and Matthaei (4) recognized that increased light intensity was accompanied by increased assimilation in the plants treated. However, research in this area was not greatly accelerated until the work of Garner and Allard (14) in 1920. At this time the controlling influence of daily exposure to light on the flowering of plants was realized. Garner and Allard reiterated Blackman's hypothesis that there was an optimum light intensity for the growth of each species of plant.

During the 1920's and 1930's a number of research programs were conducted to determine light's effect on photosynthesis and the photoperiodic response of plants. Several studies (1,6,24,28,29) were initiated to make qualitative observations of the effects of daylength on the growth of plants. These workers reported considerably different results from extending the daylength, in spite of the fact that their procedures were essentially the same. Ramaley (28) postulated

this apparent contradiction resulted from inherent differences among the varieties in their responses to light. Even today, one can observe two varieties of the same plant responding differently to the same conditions. During this period workers (9,12) began to examine those factors affecting photosynthesis and the relationship of light to the products formed in leaves under both natural and artificial light. Although extremely refined biochemical techniques were not available, these workers did report that the percentage of total carbohydrates in plant tissue could be changed by varying the light intensity or length of the day. Went (34) reported in the early 1940's that although qualitatively a number of effects were known, understanding of the quantitative relationship between wavelength, light intensity, and total energy and their physiological effects was still shockingly deficient.

In the 1940's serious work with daylight intensities and photoperiod's effect on roses began. Post and Howland (26) showed graphically that flower production was a direct function of daylight intensities. Post (25) labeled the rose as nonphotoperiodic but recognized daylength and light intensity as directly related to the plant's growth. He postulated that duration and intensity of light were manifested in changes in the rate of production and utilization of photosynthetic material by the plant. However, the economic feasibility of even low intensity incandescent

lighting was seriously questioned and most thought of commercial lighting was dismissed.

During the same decade, Howland (20) worked on the rate of photosynthesis of greenhouse roses under normal and reduced daylight intensities using the twin leaflet method based on weight to indicate an increase in photosynthesis. He concluded that the greenhouse rose is surprisingly efficient in net food synthesis over a wide range of light intensities. Many other contributions dealing with the effect of light on the photosynthetic mechanism came from work with reduction in light intensity as a result of shading (8,13, 23,29). Research dealing specifically with roses was done by Chandler and Watson (8) in the mid-1950's. They estimated that total sugars were highest in plant tissues grown in full radiation, intermediate in plants grown in light shade, and lowest in plants grown in heavy shade.

Other workers (11,15) have compared the various light sources available. The three basic lamp types (incandescent, mercury vapor, and fluorescent) have been evaluated with regard to light quality, intensity, uniformity of irradiation, the effect of lamp heat on plant temperature, and instalation and operating costs. Some work (15) has been done on the recently developed wide-spectrum Gro Lux fluorescent lamps which have been specifically designed for plant growth.

Although studies (2,18) continue to evaluate the effect of light intensity on the metabolic pathways of photosynthesis,

little has been done in this area specifically with roses.

Most recently studies by Carpenter, Rodriguez, and Carlson (7) measured the effect of low intensity lighting on greenhouse roses and found significant alterations in plant morphology and crop production as a result of extending the daylength. The significant increase in fresh and dry weight of roses exposed to extended daylengths was the basis for their suggestion that increased photosynthesis resulted during low intensity supplemental lighting. They alluded to the possibility of using improved biochemical procedures to accurately measure carbohydrate levels after short periods of low intensity lighting.

Morphological Changes Induced by Light

Supplemental lighting is known to alter the morphology of many plants. However, the extent to which this occurs varies greatly depending upon the variety of plant, type of light source, length of additional light period and season of the year (24,28).

Early reports by Ramaley (28) indicate that supplemental lighting of Caryophyllaceous plants resulted in an etiolated appearance of the plants. He presumed that stems of plants which had been given the extra illumination were generally weak as a result of their small diameter rather than as a decrease in the amount of strengthening tissue. However, studies by Dunn and Went (11) have shown that these effects

can be overcome by changes in the spectral quality of the light used. The Sylvania wide-spectrum Gro Lux lamp emits a spectral distribution closely approximating the spectral quality of daylight and is therefore well suited for plant growth (15).

In 1931, Poesch (24) noted morphological modifications in over 70 greenhouse crops which had been given additional illumination. Although no specific reference was made to the rose, the varietal differences in response to similar lighting conditions were emphasized.

In the 1940's, Post (25) observed some specific effects of daylength on roses. He noted that lengthening the day during the winter months increased growth at the expense of the strength of the stem and other desirable qualities in the flower. He concluded that food production was not increased from lighting but elongation of the buds was more rapid with a lack of stem hardening. This was not supported by experimental evidence.

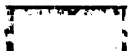
In 1954 Farmer and Holley (13) reported that light intensity had very little effect on petal color, stem length and diameter, and production of 'Better Times' roses. They attributed the morphological changes to the higher temperatures accompanying the high light intensities.

Recently, Carpenter, Rodriguez, and Carlson (7) have used a combination of wide-spectrum Gro Lux fluorescent and incandescent light to extend the daylength for greenhouse roses,

including the variety 'Forever Yours'. The most significant morphological change resulting from the extended daylength was a marked increase in stem length. Although there was no change in the number of nodes per stem, this increase resulted from a lengthening of the internodes. Leaf areas were similar for all daylength treatments and petal number per flower also remained unchanged. Data were collected for the variety 'Forever Yours' during the winter period from November through April; the average stem length was 43.8 cm. with 10.6 nodes.

The production of new canes from the root-stock area of the rose plant, referred to as bottom-break development, is one means by which flower production can be greatly increased. Little information is available on the effect of light as related to the stimulation of this type of development. Throughout Carpenter, Rodriguez, and Carlson's low intensity lighting study, no bottom breaks were observed to develop at the bud union for any rose plant studied during the winter months.

Continuous lighting has been found to produce in some plants considerable morphological alterations (1,11). Continuous illumination of tomato produces a very poorly developed plant which does not bear fruit. Continuous lighting studies (1,25) have revealed that many plants, including begonia, cotton, and geranium, show excellent leaf color and flowering. Mastalerz (22) reported that continuous lighting of 'Better Times' roses with wide-spectrum Gro Lux fluorescent



lamps resulted in shorter stem length and lower fresh weight of flowers than unlighted plants. He attributed this injury to contact with hot lamp surfaces.

Flower Production

The number of roses harvested from a given number of plants over a particular time interval depends upon the number of flowering shoots as well as the time required for a cut rose stem to flower again.

Flower production has been correlated with light intensity (13,26), with highest yields being produced during the summer months. However, the quality of the greenhouse rose is often poor during this time of maximum light intensity. Yet, Post and Howland (26) have concluded that the light intensity at Ithaca, New York never becomes great enough to reduce production.

Increases in daylength have been found (7) to be accompanied by increases in number of roses harvested per plant. This was true for four rose clones including 'Forever Yours'. This increase could not be totally accounted for by the very slight decrease in the number of days required for a cut rose stem to flower again. Since no bottom breaks were developed at the bud union for any rose plant during the study, this was not the source of increased production. Yet, there was a higher percentage of flowering branches in the extended daylength treatments at the end of the study.

The fact that not all the shoots will terminate in flowers is a source of loss of a large part of the potential flower production. These so-called "blind shoots" are particularly prevalent during the winter months. Although flower bud initiation begins in all shoots of the hybrid-T rose, not all of these flower buds reach maturity. Because blindness is prevalent during the winter, many growers attribute this situation to poor light conditions which may act through a hormonal mechanism (22).

The spacing of rose plants in the bench has little effect on the total yield of cut roses, although the standard spacing is one square foot per plant (22). However, individual plant productivity is influenced by its position on the bench. More flowers are produced from outside rows than inside rows, and generally the south outside row yields more than the north outside row (22).

The average number of days from cut to cut has been shown to vary several days from one year to the next on the same bench of roses (22). For the 1969-70 winter season the number of days to harvest a flower from a cut stem of 'Forever Yours' roses was shown to average 46.0 days with 10.4 flowers cut per plant over a 6 month period (7).

Light and Photosynthesis

Light is very important for the growth and flowering of the green plant because of its role in the photosynthesis of

organic foods. The photosynthetic process yields carbohydrates. Some of these are converted to other organic materials while others are used directly by the plant's metabolic systems (27). However there is some accumulation of these materials. The percentage carbohydrates in plant tissue can be changed by varying light intensity or length of day (1,4,6). Furthermore the percent carbohydrates found in the plant tissue has been used as an indication of the amount of photosynthesis which has occurred (1,8,9,18). The amount of photosynthesis, as determined by the total sugar content of the tissue, may in turn be correlated with morpho-physiologic changes in the plant. Since light affects sugar contents, the effect of various lighting durations and intensities can be quantitatively measured by an accurate determination of carbohydrates in the plant tissue.

The effect of light on plants is not entirely limited to the interaction of light with the photosynthetic mechanism. If this were the only consideration and other conditions were favorable, photosynthesis should proceed unchecked in continuous light. In this case the carbohydrates available for growth might be expected to vary with the time exposed to light. However the daily light period not only affects the quantity of material formed, but also affects the way in which the plant can use it (6). Furthermore, light influences the absorption of minerals and regulation of water supply (27).

When plants are exposed to short periods of darkness, photosynthesis stops and there is a decrease in carbohydrates. In 1930, Arthur, Guthrie, and Newell (1) reported that a decrease in total carbohydrates could be detected in leaves after 17 hours in darkness.

Chandler and Watson (8) reported daily variation in total sugar content of rose tissue. Analyzing dry tissue according to a modified Munson-Walker gravimetric method, they claimed daily increases in total sugars during the daytime and decreases during the night.

There is some disagreement as to the photosynthetic efficiency of plants in response to various daylengths and light intensities. Some researchers (12) along with many greenhouse growers have felt that the photosynthetic yields become limited at high light intensities. Davis and Hoagland (10) suggest that a plant may function more efficiently from the point of view of tissue production when available radiant energy is distributed over a longer period of time at a lower intensity than when high intensities are maintained for relatively short intervals. Yet, Howland (20) reports that the greenhouse rose is surprisingly efficient in food production over a wide range of light intensities.

Moss (23) reported that net photosynthesis of single maize leaves increased with increasing illumination to at least 10,000 foot candles. Earlier observations had indicated that the photosynthetic process was saturated with light at

about one-quarter of this illumination. Moss (23) found that providing half the saturation illumination to both surfaces of a leaf permitted nearly as much photosynthesis as a saturating illumination on only one surface. Thus he was able to obtain rapid rates of photosynthesis in dim light by irradiation of both leaf surfaces.

Post and Howland (26) have shown that monthly differences in flower production of greenhouse roses can be correlated with monthly differences in light intensity. These differences have further been correlated with total sugars in the plant tissue (8). Plants given full radiation contained the most total sugars while those in shade contained the least.

Changes in the weight of plant tissue have often been used to indicate changes in photosynthetic activity. Arthur, Guthrie, and Newell (1) found plants increased greatly in tissue weight when they were given daylight plus six additional hours of light per day. This weight was observed to increase with daylength up to approximately an 18 hour day. There was no corresponding increase when given a 24 hour day.

Not only daylength but also intensity and spectral quality affect the weight of tissue, and therefore presumably photosynthesis. Dunn and Went (11) showed that increased light intensity led to increased dry matter production up to a point at which other factors became limiting. The spectral emission of the blue and red light sources, and particularly of the combination of the two, was positively correlated with

dry weight increase. Changes in dry weight of matched rose leaflets were used by Howland (20) to measure photosynthesis in his studies.

In 1964 Barua (2) studied the photosynthetic rates of detached tea leaves as influenced by various light intensities. He found significantly different assimilation rates for the various light intensities which could not be explained by the thickness of the leaf lamina nor the chlorophyll concentration of the leaves. Shade adapted leaves had significantly higher rates of photosynthesis in the weakest light and lower rates in the higher intensities than the corresponding sun adapted leaves. Therefore it is likely that tissues adapt to specific conditions and their response at any particular time is influenced by their previous conditioning.

MATERIALS AND METHODS

Two-hundred plants each of rose clones 'Forever Yours' and 'Shocking Pink' were planted in separate but adjacent east to west oriented benches in April 1969. The rose plants were spaced and grown according to the recommended cultural practices to develop vigorous well-branched plants (22).

The 42-inch wide, V-bottom benches were subdivided into six 8-foot plots containing 32 rose plants with guard rows on each end of the benches. Plants received one of three lighting treatments: a) no additional light, b) 8 hours daily of supplemental light and c) 20 hours daily of supplemental light. Treatments were randomly allocated to the 6 plots on each bench (Figure 1).

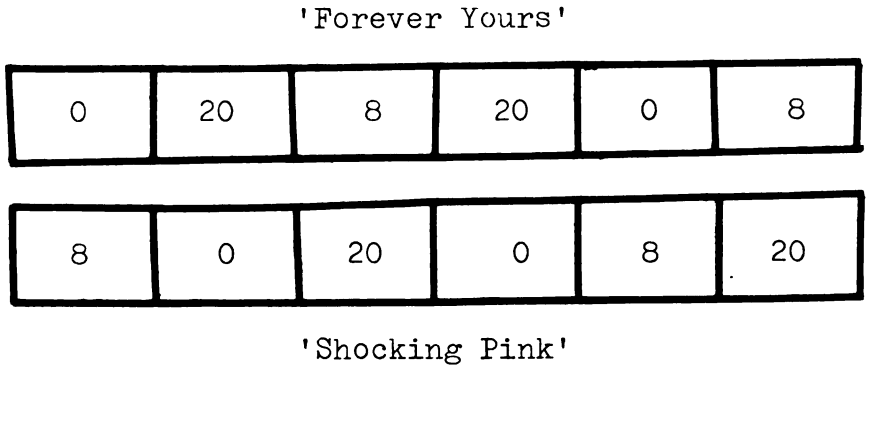


Figure 1.--Plot plan of two greenhouse benches used in the study showing number of hours daily of supplemental high intensity lighting given each plot.

Supplemental lighting was supplied by wide-spectrum Gro Lux fluorescent tubes mounted 8 inches apart in 4-foot by 8-foot metal fixtures (Figure 2).

Plants were supported by several tiers of wire and string with the lighting fixtures placed between rows 1-2 and 3-4 across the bench (Figure 3). Two fixtures were placed in each lighted plot; thus the two inside rows of plants were between the two parallel fixtures and no leaves were more than a foot from the light source.

Four-foot by 5-foot opaque partitions were placed between lighted and unlighted plots. Black sateen cloth was pulled nightly in the aisle between the two benches to prevent light contamination. There were 6 wide-spectrum Gro Lux tubes per fixture and 12 for each plot. Each tube emitted 73 lamp watts, totalling 876 lamp watts per 28 square foot plot. The tubes when lighted emitted 31.3 lamp watts per square foot of bench surface.

Light intensity measurements were made with a Weston 376 photometer at various locations in the plots during the daylight and at night. Nighttime light intensity readings in unlighted plots were insufficient to be measurable on the low light intensity scale and were therefore assumed to be less than one foot candle. Readings in foot candles for selected locations in a lighted plot are shown in Figure 4. Daytime readings were made when the greenhouse light intensity was 780 foot candles. Measurements were made in one plot of

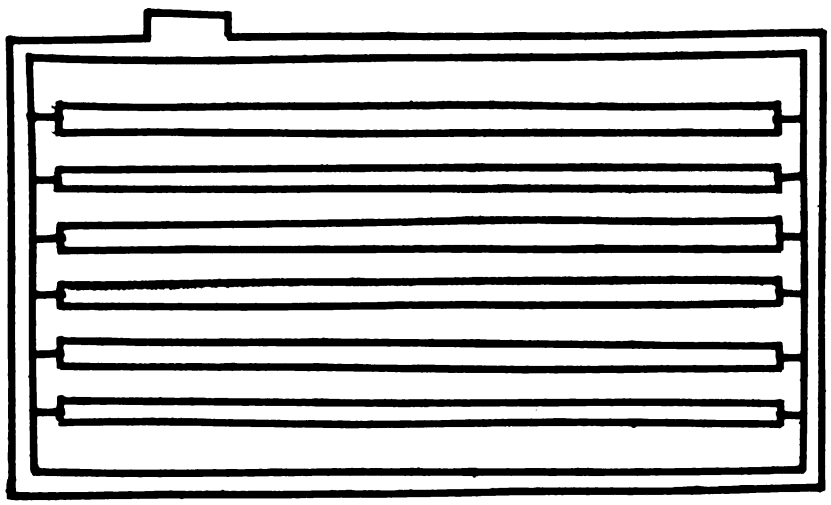
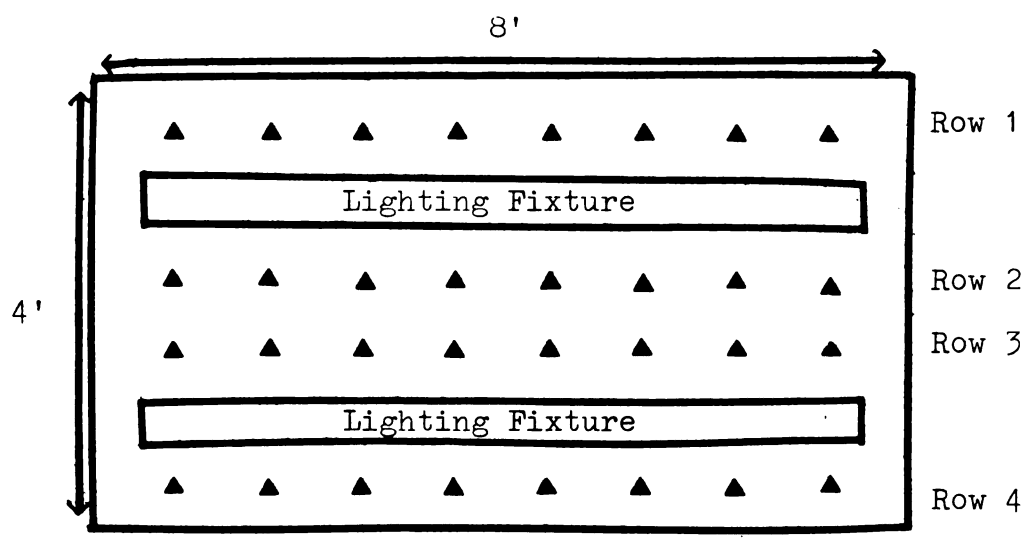


Figure 2.--Diagram of 4' by 8' metal fixture with six wide-spectrum Gro Lux lamps.



▲ = rose plant

Figure 3.--Overhead diagram of lighted plot showing rose plant spacing and placement of lighting fixtures.

Table 1.--Greenhouse cloudy day light intensity readings in lighted and unlighted plots of clone 'Forever Yours'. Values in foot candles.

Location	20 hr. Plot (lighted)	8 hr. Plot (unlighted)	0 hr. Plot (unlighted)
6 inches north of north edge of bench	450	360	200
north row, center of plants	275	100	15
between 2 northern-most rows, halfway between tubes	260	70	13
center of bench	60	40	11
between 2 southern-most rows, halfway between tubes	250	250	250
south row, center of plants	155	110	52
6 inches south of south edge of bench	220	36	28

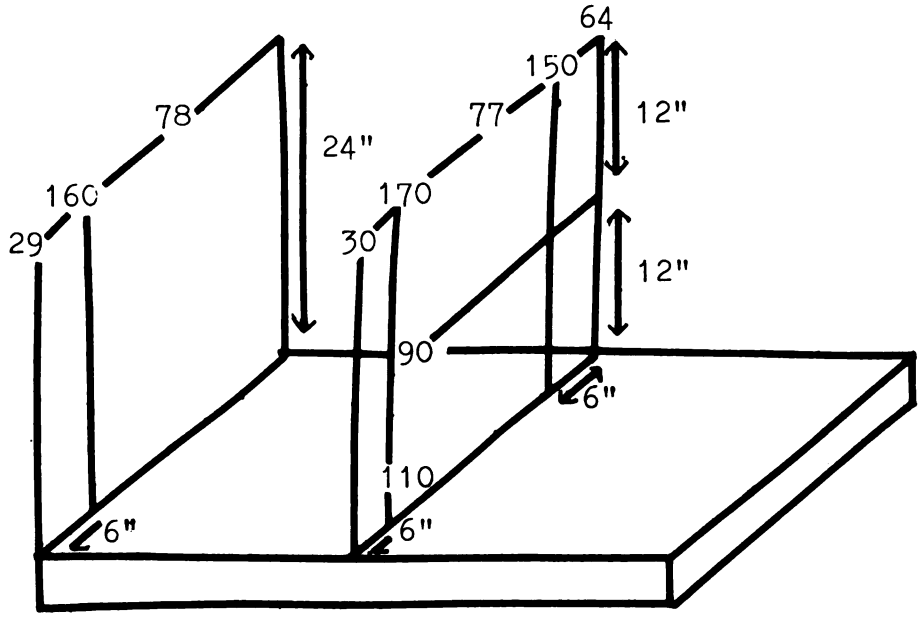


Figure 4.--Night light intensity readings in a lighted plot. Values in foot candles.

each of the three treatments (Table 1).

Lighting began December 15, 1969. The 8 hour plots were lighted from 6 p.m. to 2 a.m. nightly while the 20 hour plots were lighted from 6 a.m. to 2 a.m.. Lights were off in 20 hour plots only during a four hour period from 2 to 6 a.m..

Recommended environmental and cultural practices were maintained throughout the study. Carbon dioxide levels of 1,000 to 1,200 ppm. were maintained during the daylight hours in the greenhouse atmosphere except when certain photosynthetic studies were being carried out.

Growth and Flowering Data Collection

Beginning December 15, 1969 all canes were tagged and dated after each flower was cut, and an appropriate coding was made for identification of the plot and treatment. Rose flowers were cut at their usual commercially recommended stage, leaving the two uppermost 5-leaflet leaves on the rose canes after cutting the flower. When canes flowered again the tag was removed from the stem and tied to the cut flower. The cut cane was then tagged and dated with the identifying code. When two or more flowering shoots developed from a single cane, new tags with an appropriate code were placed on all the flowers so that they could later be identified as coming from the same cane.

Flower data were collected immediately after harvesting. These data included the date tagged, date cut, identifying

letter, number of nodes per flower, length of stem in centimeters from the base of the bud to the end of the stem, and fresh weight of each flower in grams. From these data the average monthly and average overall values were calculated for each plot. These values included: a) the number of flowers per plant, b) number of days for a stem to flower again from the time it was perviously cut, c) number of nodes per flower, d) length of the stem, e) fresh weight of the flowers, and f) number of bottom breaks per plant.

Data collections were terminated on May 1, 1970 for clone 'Shocking Pink' and May 15 for clone 'Forever Yours'.

Least significant difference values (LSD) were calculated at both the .01 and .05 levels for the growth and flowering data.

Chemical Analyses

Quantitative measurements of total reducing sugar levels in leaves were made on four different days. Leaves were collected from plants of clone 'Forever Yours' grown under the three lighting treatments of this study: a) normal greenhouse light conditions, b) lighted with Gro Lux lamps at 250 foot candles for 8 hours (6 p.m. to 2 a.m.) nightly, and c) lighted continuously with Gro Lux lamps during the daylight hours and 8 hours nightly. Leaf samples were collected only from the three uppermost "mature" 5-leaflet leaves from flowering shoots with developing buds. Leaves

approximately 6 inches from the lamps were selected in the lighted treatments. Eighteen leaves per plot were tagged and covered on both surfaces with an opaque material and clipped securely to exclude light from the leaves. Leaves were covered for 48 hours prior to exposure to the lighted and non-lighted treatments. At sunrise all leaves were uncovered. The lighting conditions given the various plots remained the same as previously described throughout the investigation. Leaf samples were collected after 24 hours of exposure to the prevailing daylight conditions or those conditions with the supplemental lighting treatments. Leaves were harvested from each treatment and taken immediately to the laboratory. Three 5 gram samples from each plot were accurately weighed out and washed. This provided 6 samples from each treatment.

Samples were homogenized in a Waring blender with 80% alcohol and then heated to extract sugars. The extract was "cleared" with lead acetate and sodium oxalate (30). After hydrolysis with hydrochloric acid and neutralization with sodium hydroxide the samples were analyzed for reducing sugars using a modified Hagedorn-Jensen procedure (16). Transmittance was read on a Bauch-Lamb Spectrophotometer 20 set at a wavelength of 420 mu. Transmittance values were converted to glucose equivalents by comparison with a standard glucose curve. Values were then expressed in Tables 6-9 as milligrams of glucose equivalents per gram of fresh leaf tissue.

Preparations for sampling were made weekly from mid-January to mid-March to measure quantitatively the benefits of lighting during:

a) a sunny day with supplemental carbon dioxide (February 23, 1970).

b) a sunny day with no supplemental carbon dioxide (February 16, 1970).

c) a cloudy day with supplemental carbon dioxide (February 9, 1970).

d) a cloudy day with no supplemental carbon dioxide (March 3, 1970).

February 16 and 23 were sunny days during which a total of 332 and 385 gram-calories of sunlight per square centimeter were recorded respectively. February 9 and March 3 were cloudy days with less than 50 gram-calories of sunlight per square centimeter recorded. On February 9 and 23 carbon dioxide levels of 1,000 to 1,200 ppm. were maintained during the daylight hours in the greenhouse atmosphere.

The analysis of variance was made using Tukey's (30) honestly significant difference (HSD) to determine significance among the treatment means for the chemical analyses.

RESULTS

The growth and flowering of Hybrid-T rose clones 'Forever Yours' and 'Shocking Pink' were significantly altered when lighted with Gro Lux lamps for 8 hours (6 p.m. to 2 a.m.) nightly and when lighted continuously with Gro Lux lamps during the daylight hours and 8 hours nightly. Variables compared were flower production, days required for a return of stems to flowering, number of flowers per cane resulting from a single cut, number of nodes, flower stem length, and fresh weight. Clonal differences were found in the study when the responses of the two clones to high intensity supplemental lighting were considered (Table 2). Rose 'Forever Yours' responded well to the supplemental lighting of high intensity while clone 'Shocking Pink' was less responsive.

Consistency in results over the entire period of the study was shown when monthly averages of the variables were plotted graphically (Figures 5-18). The seasonal effect of longer and more sunny days toward spring was superimposed upon all the lighting treatments, resulting in more flowers and a decrease in the number of days required for a return of stems to flowering.

Consistency of the results throughout the study indicated reliability of the trends observed. Combination of data from

Table 2.--Rose clonal differences in mean number of flowers per plant, days to flower, flowers per cane, number of nodes, stem length, dry weight, and basal breaks.

Variables	'Forever Yours'	'Shocking Pink'	Approx. Sig. Prob. of F Stat.
Number of Flowers per Plant	9.98	6.23	.001
Number of Days to Flower	37.58	38.51	.429
Number of Flowers per Cane	1.14	1.17	.468
Number of Nodes per Flower	6.16	5.33	.021
Length of Stem (centimeters)	37.80	36.47	.460
Fresh Weight of Flowers (grams)	14.57	15.47	.292
Number of Basal Breaks per Plant	0.77	0.50	.033

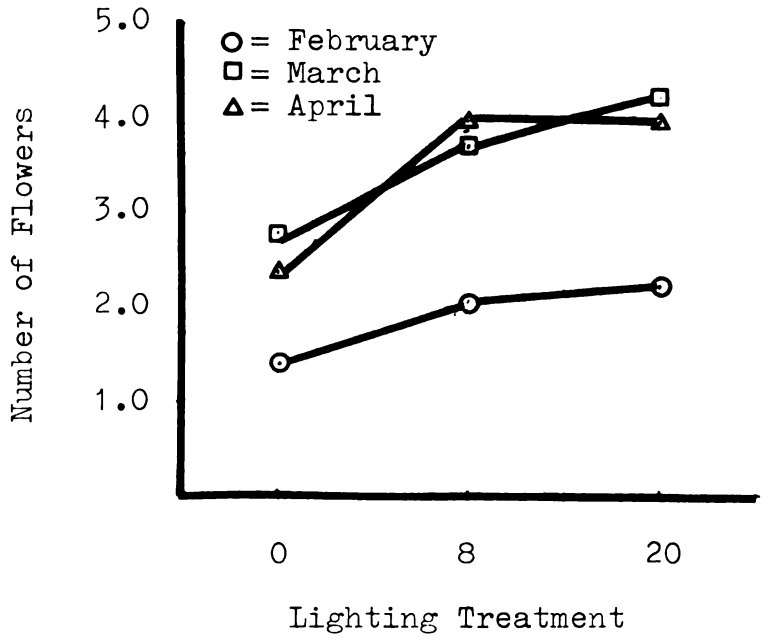


Figure 5.--Monthly means of number of flowers harvested per plant from clone 'Forever Yours'.

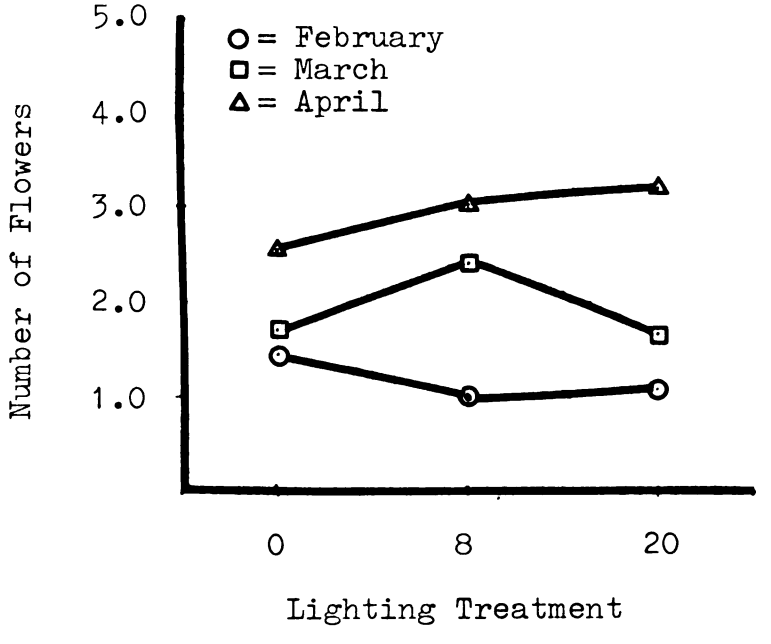


Figure 6.--Monthly means of number of flowers harvested per plant from clone 'Shocking Pink'.

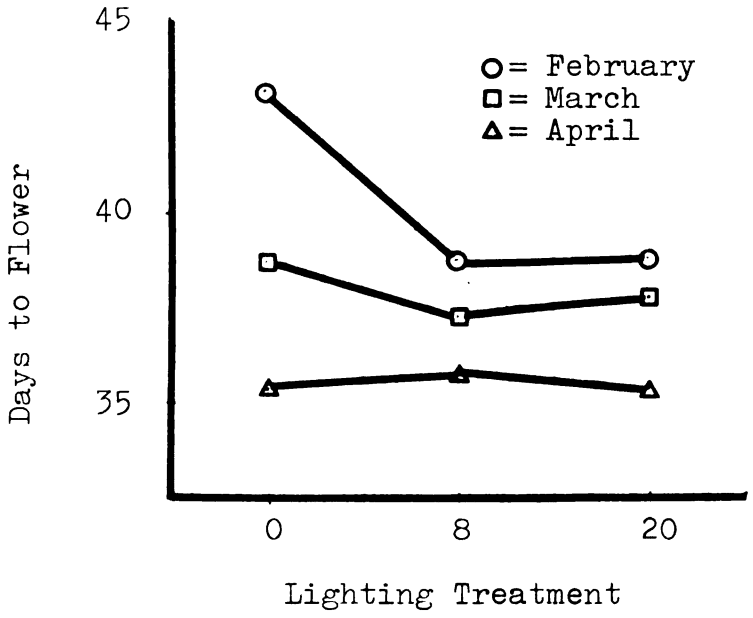


Figure 7.--Monthly means of days to flower of flowers harvested from clone 'Forever Yours'.

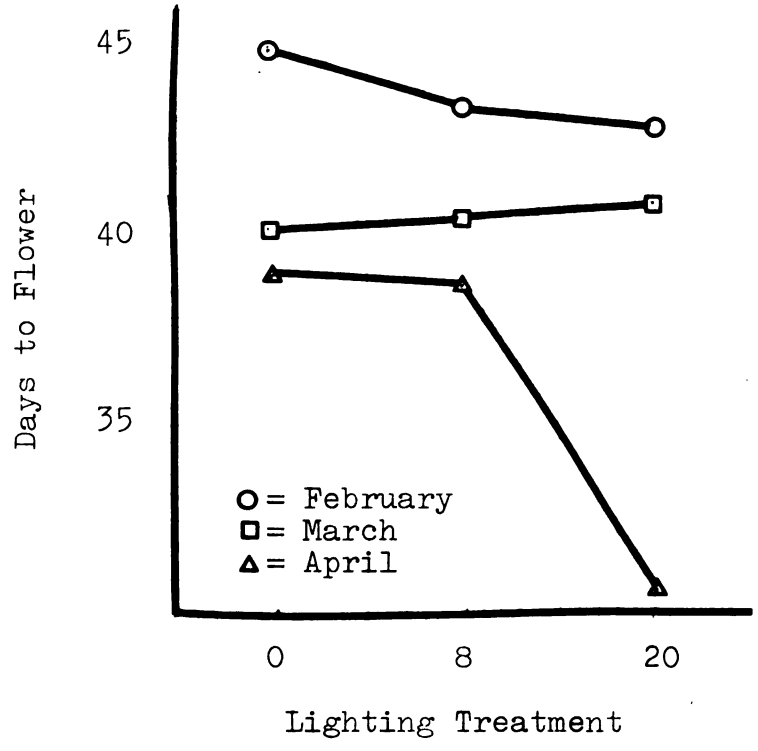


Figure 8.--Monthly means of days to flower of flowers harvested from clone 'Shocking Pink'.

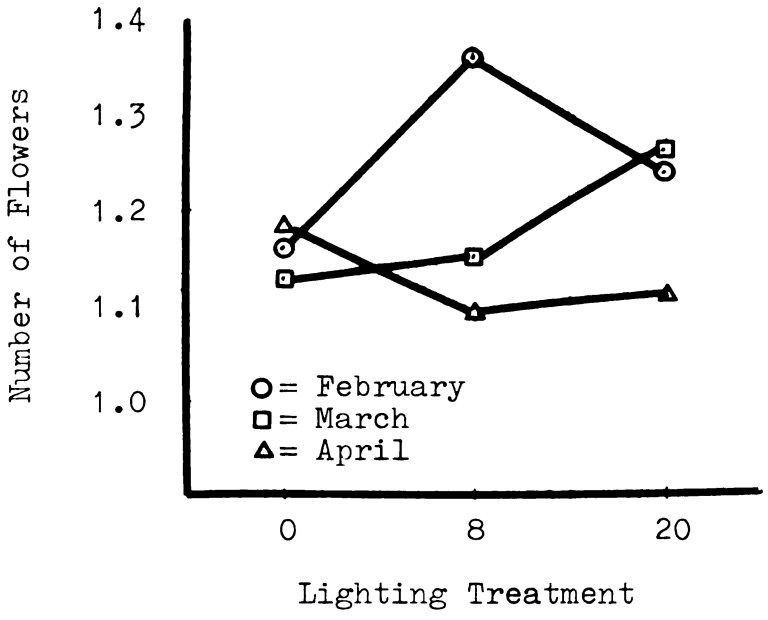


Figure 9.--Monthly means of number of flowers harvested per cane from clone 'Forever Yours'.

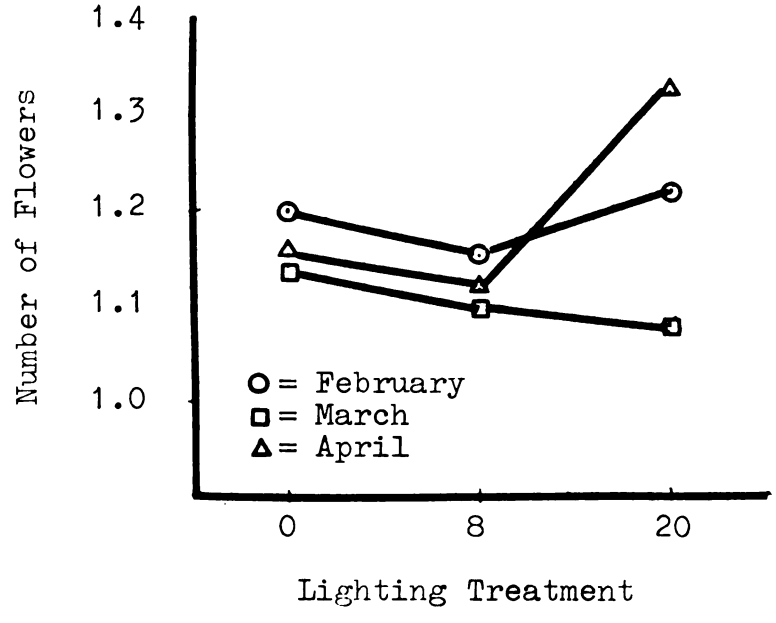


Figure 10.--Monthly means of number of flowers harvested per cane from clone 'Shooking Pink'.

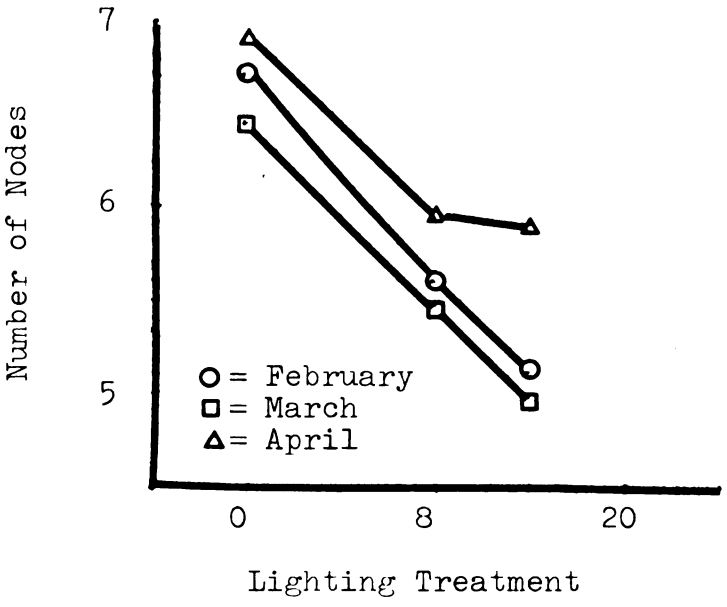


Figure 11.--Monthly means of number of nodes per flower from clone 'Forever Yours'.

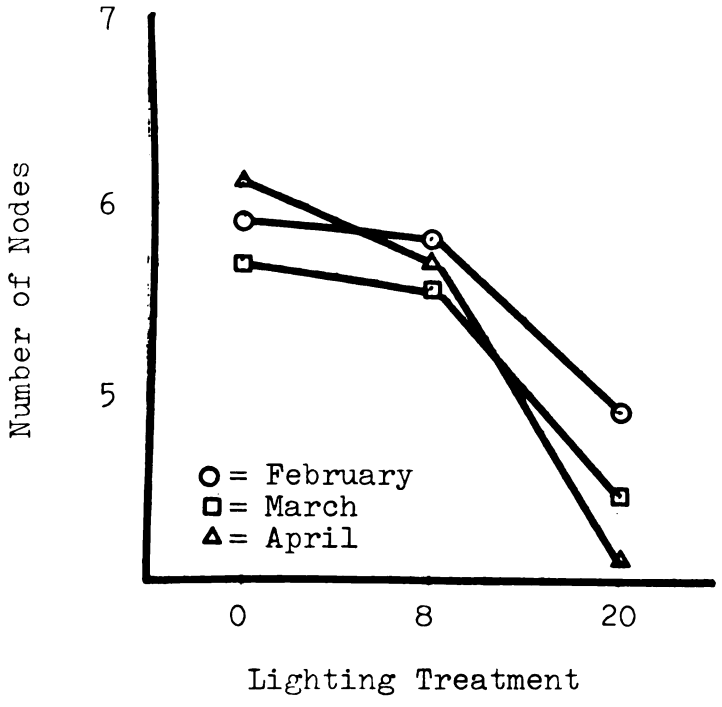


Figure 12.-- Monthly means of number of nodes per flower from clone 'Shocking Pink'.

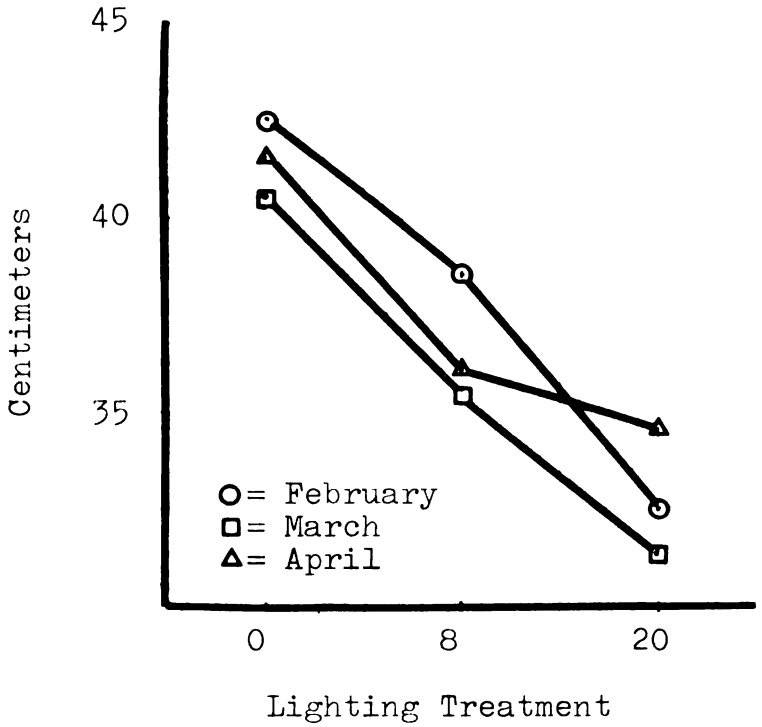


Figure 13.--Monthly means of length of stems of flowers harvested from clone 'Forever Yours'.

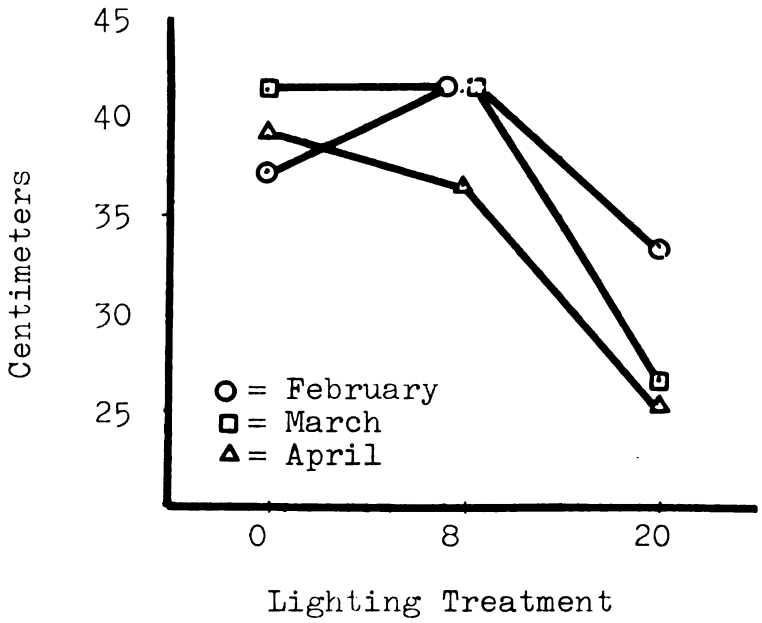


Figure 14.--Monthly means of length of stems of flowers harvested from clone 'Shocking Pink'.

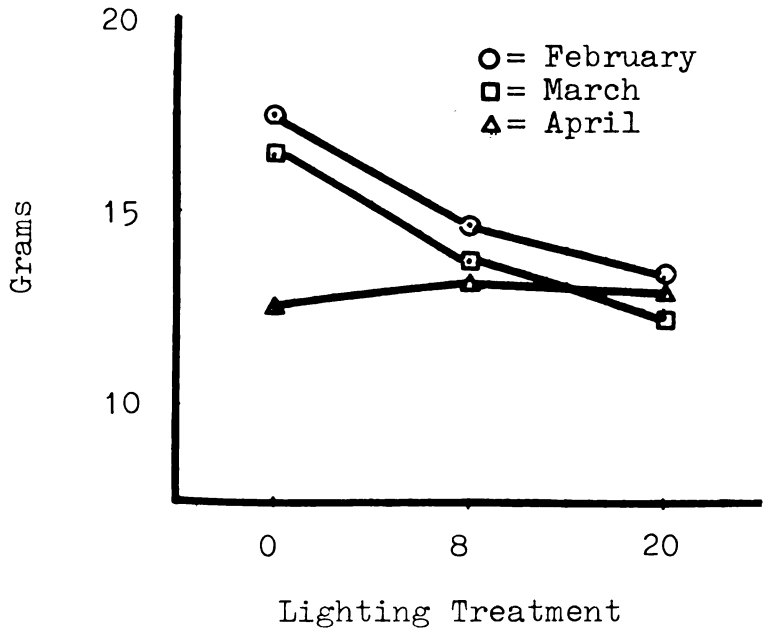


Figure 15.--Monthly means of fresh weight in grams of flowers harvested from clone 'Forever Yours'.

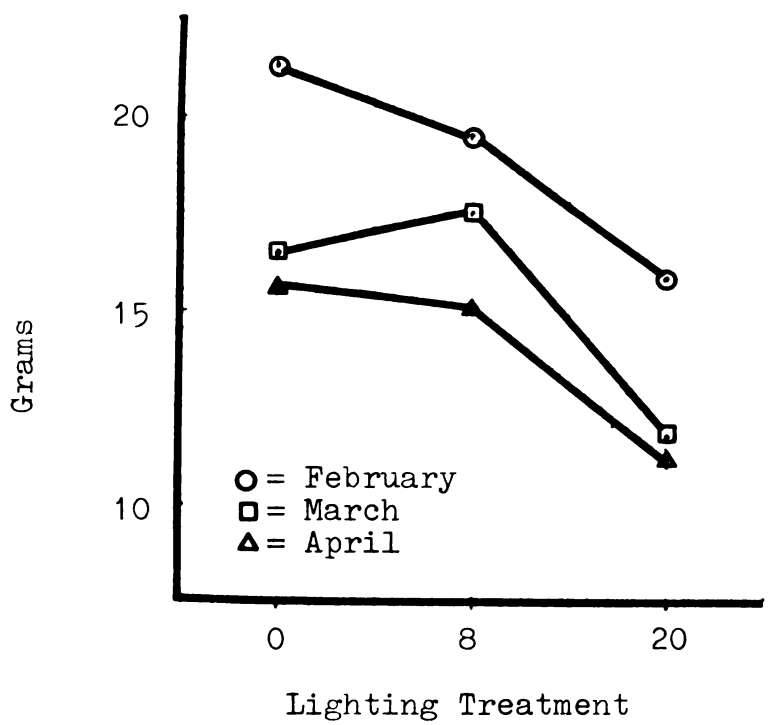


Figure 16.--Monthly means of fresh weight in grams of flowers harvested from clone 'Shocking Pink'.

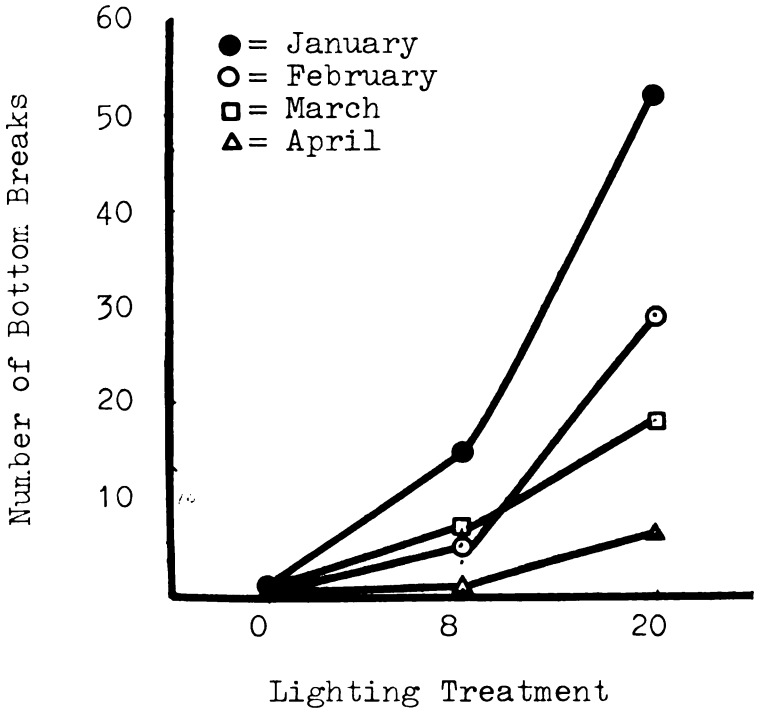


Figure 17.--Monthly means of number of bottom breaks per plant of clone 'Forever Yours'.

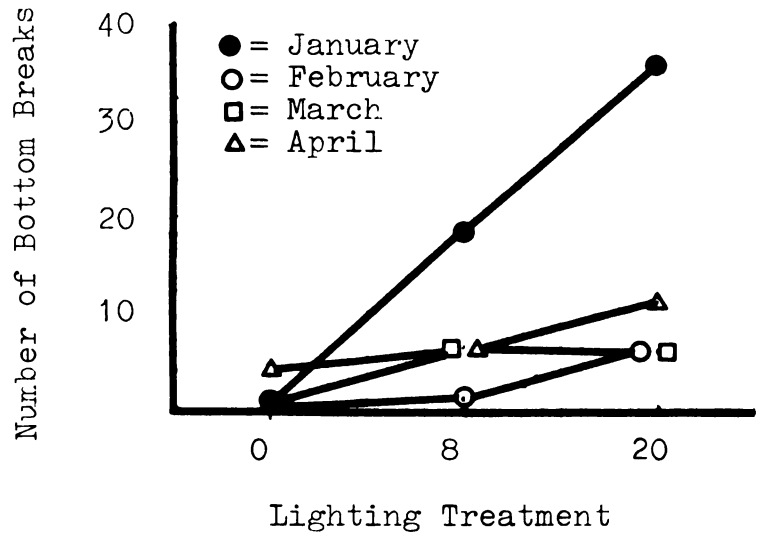


Figure 18.--Monthly means of number of bottom breaks per plant of clone 'Shocking Pink'.

Table 3.--Growth and flowering of clone 'Forever Yours'. Means for December 15, 1969 to May 15, 1970.

Treatment	Plot	Number of Flowers per Plant	Number of Days to Flower	Number of Flowers per Cane	Number of Nodes per Stem	Length of Flower (cm)	Fresh Wt. of Flower (grams)	Number of B. Breaks per Plant
Unlighted	E	6.84	37.50	1.15	6.45	39.10	14.89	0.00
	W	8.06	39.76	0.96	7.32	44.52	17.88	0.00
	$\bar{x}$	7.45	38.63	1.06	6.89	41.81	16.39	0.00
Lighted 8 hr. Daily (6 p.m. to 2 a.m.)	E	10.73	36.39	1.19	6.20	39.18	15.04	0.50
	W	10.23	37.82	1.17	5.80	36.20	13.40	0.65
	$\bar{x}$	10.48	37.11	1.18	6.00	37.69	14.22	0.55
Lighted 20 hr. Daily (6 a.m. to 2 a.m.)	E	11.50	36.85	1.19	5.52	32.66	12.18	1.90
	W	12.52	37.16	1.17	5.67	35.15	14.03	1.65
	$\bar{x}$	12.01	37.01	1.18	5.56	33.91	13.11	1.75
$LSD_{.05}$		2.82	2.98	0.30	1.94	12.95	7.36	0.63

Table 4.--Growth and flowering of clone 'Shocking Pink'. Means for December 15, 1969 to May 1, 1970.

Treatment	Plot	Number of Flowers per Plant	Number of Days to Flower	Number of Flowers per Cane	Number of Nodes per Stem (cm) Flower	Length of	Fresh Wt. of Flower (grams)	Number of B. Breaks per Plant
Unlighted	E	5.78	42.19	1.17	5.89	41.53	16.37	0.06
	W	5.81	39.60	1.14	5.98	42.31	17.77	0.03
	$\bar{x}$	5.80	40.90	1.15	5.94	41.92	17.07	0.05
Lighted 8 hr. Daily (6 p.m. to 2 a.m.)	E	6.06	40.06	1.15	5.44	36.58	15.56	0.39
	W	7.03	39.19	1.09	5.82	41.82	17.73	0.71
	$\bar{x}$	6.55	39.63	1.12	5.63	39.20	16.65	0.50
Lighted 20 hr. Daily (6 a.m. to 2 a.m.)	E	5.92	36.29	1.28	4.42	27.08	12.20	1.00
	W	6.75	33.71	1.16	4.42	29.52	13.17	1.00
	$\bar{x}$	6.34	34.98	1.22	4.42	28.32	12.69	1.00
$LSD_{.05}$		1.54	3.01	0.14	0.60	6.84	1.85	0.70

both rose clones for statistical analyses was found to obscure treatment differences since clonal variability was large. Therefore, the clones were statistically analyzed for each factor being considered. Least Significant Difference (LSD) values were used for comparisons of results (30).

Flower Production

Clone 'Forever Yours' rose plants receiving 8 or 20 hours daily of high intensity lighting had significantly higher yields of flowers per plant than unlighted control plants (Table 3). During the five month period (December 15-May 15) there was an average of 7.45, 10.48, and 12.01 flowers per plant for plots of clone 'Forever Yours' under normal greenhouse light conditions, lighted with Gro Lux lamps at about 250 foot candles for 8 hours nightly, and lighted continuously with Gro Lux lamps during the daylight hours and 8 hours nightly respectively. The increased numbers of flowers for lighted plants were found for each month of the study. Mean numbers of flowers for the entire lighting period (December 15-May 15) showed 41% and 61% increases for plots lighted 8 and 20 hours respectively over the unlighted control.

No significant increase in flower production was found from lighting clone 'Shocking Pink' (Table 4). During the four and one-half month period (December 15-May 1) there was an average of 5.81, 6.55, and 6.33 flowers per plant for

plants of clone 'Shocking Pink' under normal greenhouse light conditions, lighted with Gro Lux lamps at about 250 foot candles for 8 hours nightly and lighted continuously with Gro Lux lamps during the daylight hours and 8 hours nightly respectively. The large monthly variability in the numbers of flowers per plant produced by clone 'Shocking Pink' could not be accounted for by seasonal changes in daylength or sunlight (Figure 6).

Days to Flower

The number of days required from cutting a flower to flowering of the stem again was not significantly altered by supplemental lighting during this study. The average number of days required for the return of stems of 'Forever Yours' roses to flowering was 38.63, 37.11, and 37.01 for unlighted, 8, and 20 hour lighted plots respectively. Clone 'Forever Yours' had less than three days difference between the plot requiring the greatest and the plot requiring the least number of days to flower again (Table 3). A significant reduction in the number of days to flower in lighted plots of clone 'Forever Yours' occurred only during the first month of the study (Figure 7). This apparent effectiveness of supplemental lighting during the season of shortest days is noteworthy.

Overall, a significant reduction in days to flower for clone 'Shocking Pink' resulted only in the treatment lighted 20 hours daily (Table 4). The average number of days required

for the return of 'Shocking Pink' roses to flowering was 40.90, 39.63, and 34.94. This represents a 15% reduction in the number of days required from cutting a flower to flowering of the stem again for 'Shocking Pink' roses lighted continuously with Gro Lux lamps during the daylight hours and 8 hours nightly compared with those which were under normal greenhouse light conditions. This reduction was largely accounted for by an abnormally large decline in the number of days to flower in the treatment lighted 20 hours daily during the last month of the study (Figure 8).

Number of Flowers per Cane

Counts were taken of the number of flower buds which developed following the cutting of a flower from a cane. Usually only one flower develops from a node below the cut, but sometimes two or more lateral buds may develop and flower. These data were taken to isolate a possible source of increased production resulting from lighting. However, calculation of the number of flowers per cane resulted in virtually no differences among the lighted or unlighted treatments for either clone (Tables 3 and 4). There also was no significant difference between the two clones or among the various months during which the study was conducted (Figures 9 and 10). For both rose clones differences in the number of flowers per cane were small (less than 0.23 flower per cane). Differences between the two clones were also very

small.

Number of Nodes

Supplemental lighting consistently reduced the number of nodes per flowering stem for both clones 'Forever Yours' and 'Shocking Pink' (Tables 3 and 4). This reduction in node number occurred during all months of the study (Figures 11 and 12). Clone 'Forever Yours' averaged 6.89, 6.00, and 5.56 nodes per flowering stem for unlighted, 8 hour, and 20 hour lighted plots respectively. Clone 'Shocking Pink' averaged 5.94, 5.63, and 4.42 nodes per flowering stem for the unlighted, 8 hour, and 20 hour lighted plots respectively. During all months of the study the largest number of nodes occurred on flowers harvested from unlighted control plots. The longer the duration of supplemental lighting the greater the reduction in the number of stem nodes for flowering stems.

Both lighting durations significantly reduced the number of nodes per flowering stem for clone 'Forever Yours'. However the additional lighting during the daylight hours in 20 hour plots resulted in only a slight reduction in number of nodes beyond that found with merely 8 hours of supplemental high intensity lighting nightly. Photoperiods were the same for both lighted plots since the additional 12 hours of lighting in 20 hour plots occurred during daylight hours. Clone 'Shocking Pink' had a significant reduction in node number only when illuminated with Gro Lux lamps during the

daylight hours and 8 hours nightly. For this clone, 8 hours of supplemental lighting nightly did not significantly reduce the number of nodes per flowering stem.

Length of Stem

Stem length was reduced noticeably with high intensity supplemental lighting for clones of both 'Forever Yours' and 'Shocking Pink' (Tables 3 and 4). Comparison of monthly averages showed a consistent reduction from lighting for most of the study (Figures 13 and 14). The means for all 'Forever Yours' rose flowers harvested during the study were 42.2, 37.8, and 34.0 cm. for the unlighted, 8, and 20 hour treatments. The average stem length of 'Shocking Pink' rose flowers was 41.92, 39.20, and 28.32 for unlighted, 8, and 20 hour treatments. This represented a highly significant decrease in stem length for the plots lighted continuously during the daylight hours and 8 hours nightly. This decrease occurred during all months of the study and was consistent for both replications.

Flowers were put into grades according to flowering stem length (Table 5). Lighting 8 hours nightly with Gro Lux lamps at about 250 foot candles increased the percentage of flowers in shorter grades. Lighting continuously during the daylight hours in addition to 8 hours nightly further increased the percentage of cut roses in shorter grades and simultaneously reduced the percentage of flowers in longer grades.

Table 5.--Percentage of roses in various grades according to length of stem. Graded according to length of stem in centimeters; values equal to or greater than the number indicated but less than the next longest grade.

	'Forever Yours'			'Shocking Pink'		
Grade	0 hr.	12 hr.	20 hr.	0 hr.	12 hr.	20 hr.
>15	0	0	2	3	1	10
15	3	11	24	9	13	30
27	32	45	44	27	31	38
39	46	34	26	33	35	16
51	17	9	4	24	17	6
<63	2	1	0	4	3	0

The percentage of 'Forever Yours' roses between 51 and 63 cm. decreased from 17% to 9% to 4% in unlighted, 8, and 20 hour plots respectively. At the same time the percentage of flowers in the 15 to 27 cm. grade increased from 3% to 11% to 24% in the unlighted, 8, and 20 hour plots respectively.

Weight

Fresh weights of cut rose flowers decreased with supplemental illumination (Tables 3 and 4). The average weight of flowers from clone 'Forever Yours' was 16.39, 14.22, and 13.11 grams for unlighted, 8, and 20 hour plots respectively. Largest differences in fresh weight for the three treatments were found for roses harvested when the days were the shortest (Figure 16). However, overall treatment means for fresh

weight were not significantly different for clone 'Forever Yours'.

'Shocking Pink' flowers cut from plots of treatments lighted during the daylight hours and 8 hours nightly weighed significantly less than flowers under normal greenhouse light conditions. This decreased weight was accompanied by a significant reduction in stem length as well as a noticeable decrease in stem diameter.

Bottom Breaks

The most dramatic effect of the high intensity supplemental lighting was the stimulation of basal break development from the bud and understock union (Tables 3 and 4). Both rose clones showed a large initial response when lighting began in December (Figures 17 and 18). During the winter no bottom breaks were observed for any plant in unlighted plots. Eight hours of supplemental light nightly produced an average of 8 and 9 bottom breaks per plot for clone 'Forever Yours' and 'Shocking Pink' respectively during the first three weeks of lighting. During the same period plots of clone 'Forever Yours' lighted continuously during the daylight hours and 8 hours nightly produced an average of 26 bottom breaks per plot. Plots of clone 'Shocking Pink' lighted 8 hours during the first three weeks (an average of 18 bottom breaks for the 20 hour plot as opposed to 9 for the 8 hour plot). Data collected in subsequent months indicated that fewer bottom

breaks were formed although nearly all bottom breaks recorded were found in lighted plots. During the spring months of the study (March through April), clone 'Forever Yours' averaged 0, 8, and 14 bottom breaks for 0, 8, and 20 hour plots respectively. During the same period clone 'Shocking Pink' averaged 2, 9, and 13 bottom breaks for the 0, 8, and 20 hour plots respectively.

Chemical Analyses

Analyses of leaf tissue from clone 'Forever Yours' for total reducing sugars revealed significant increases in total sugar content of leaves from lighted plots over those from unlighted plots in all four studies (Tables 6-9). On February 16 (during which a total of 332 calories of sunlight were recorded per square centimeter) the average values for milligrams of glucose per gram of fresh leaf tissue were 0.268, 0.290, and 0.298 for leaves which had been covered for 48 hours, then exposed 24 hours to (respectively) normal greenhouse light conditions, normal greenhouse light conditions supplemented with 8 hours of high intensity lighting from 6 p.m. to 2 a.m., and normal greenhouse light conditions supplemented with 20 hours of high intensity lighting from 6 a.m. to 2 a.m.. On February 23 (during which a total of 385 calories of sunlight per square centimeter were recorded) the average values were 0.273, 0.283, and 0.284 milligram of glucose per gram of fresh leaf tissue for the unlighted, 8, and 20 hour plots

Table 6.--Milligrams of glucose per gram of fresh leaf tissue from clone 'Forever Yours' in samples taken February 23, 1970. (385 langleys of sunlight, with supplemental carbon dioxide)

Treatment	East Plot	West Plot	$\bar{x}$
No Supplemental Lighting	.275	.272	.273
8 hrs. of Supplemental Lighting Daily (6 p.m. to 2 a.m.)	.287	.279	.283
20 hrs. of Supplemental Lighting Daily (6 a.m. to 2 a.m.)	.286	.283	.284
$HSD_{.05}$			.0015

Table 7.--Milligrams of glucose per gram of fresh leaf tissue from clone 'Forever Yours' in samples taken February 16, 1970. (332 langleys of sunlight, without supplemental carbon dioxide)

Treatment	East Plot	West Plot	$\bar{x}$
No Supplemental Lighting	.266	.269	.268
8 hrs. of Supplemental Lighting Daily (6 p.m. to 2 a.m.)	.296	.284	.290
20 hrs. of Supplemental Lighting Daily (6 a.m. to 2 a.m.)	.299	.297	.298
$HSD_{.05}$			.0038

Table 8.--Milligrams of glucose per gram of fresh leaf tissue from clone 'Forever Yours' in samples taken February 9, 1970. (cloudy day, with supplemental carbon dioxide)

Treatment	East Plot	West Plot	$\bar{x}$
No Supplemental Lighting	.301	.299	.300
8 hrs. of Supplemental Lighting Daily (6 p.m. to 2 a.m.)	.303	.302	.302
20 hrs. of Supplemental Lighting Daily (6 a.m. to 2 a.m.)	.318	.344	.331
$HSD_{.05}$			.0081

Table 9.--Milligrams of glucose per gram of fresh leaf tissue from clone 'Forever Yours' in samples taken March 3, 1970. (45 langleys of sunlight, without supplemental carbon dioxide)

Treatment	East Plot	West Plot	$\bar{x}$
No Supplemental Lighting	.290	.296	.293
8 hrs. of Supplemental Lighting Daily (6 p.m. to 2 a.m.)	.332	.311	.322
20 hrs. of Supplemental Lighting Daily (6 a.m. to 2 a.m.)	.317	.310	.313
$HSD_{.05}$			.0150

respectively. On two cloudy days, February 9 and March 3 (days during which less than 50 calories of sunlight per square centimeter were recorded), there were higher sugar contents in leaves irradiated with Gro Lux lamps compared with those which were unlighted. On February 9 the average values were 0.300, 0.302, and 0.331 milligram of glucose per gram of fresh leaf tissue for the unlighted, 8, and 20 hour plots respectively. On March 3 the average values for unlighted, 8, and 20 hour plots were 0.293, 0.322, and 0.313 milligram of glucose per gram of fresh leaf tissue respectively.

DISCUSSION

The results indicate high intensity supplemental lighting influences both the vegetative growth and flowering of rose clones 'Forever Yours' and 'Shocking Pink'. A major morphological change resulting from lighting was the stimulation of bottom break development which began strongly during the first several weeks and continued at a reduced rate during the entire study. Bottom break development normally is non-existent during late December through March when days are short. As the days lengthen rose plants usually produce some basal branches from the old canes beginning in April or May. If properly pinched these new shoots develop into flowering canes and flower production from a given number of plants can be increased.

The unlighted rose plants receiving normal winter conditions had no bottom breaks develop for either clone. However, 8 hours nightly of high intensity lighting during the winter caused bottom breaks to develop (during the first three weeks of the study) on about one-fourth of the plants for both clones. Clone 'Forever Yours' had three times as many bottom breaks develop on plants lighted 20 hours daily than on plants lighted only 8 hours nightly. Clone 'Shocking Pink' was slightly less responsive, yet a two-fold increase

in bottom breaks was recorded for plants given 20 hours of supplemental lighting over those given 8 hours daily.

Carpenter, Rodriguez, and Carlson (7) lighted four rose clones nightly, including clone 'Forever Yours', using light intensities of 60 to 70 foot candles and reported no bottom breaks developed during the course of their study (September through April).

A major difference between this and previous rose lighting studies was the physical arrangement of the lamps with respect to the plants. Other workers (11,15) using fluorescent lamps placed them above the plants. In this study the 6 lamps in each fixture were arranged in tiers, one above the other between rows 1-2 and 3-4 so no part of a plant was more than one foot from a lamp. This high intensity lighting in close proximity to the basal region of the plant was a sufficient stimulus to induce bottom break development. This response was evidently influenced by the duration of the high intensity irradiation and not merely daylength. Thus two to three times as many bottom breaks were produced on plants given 20 hours of supplemental illumination daily compared with those given 8 hours daily.

High intensity supplemental illumination (20 hours) daily produced an average of less than one bottom break per plant for clone 'Shocking Pink' and 1.5 for clone 'Forever Yours' during the first three weeks of lighting. During the months of February through April fewer bottom breaks

were produced monthly in lighted plots than were produced in the same plots during the initial month of the study. Monthly counts in lighted plots from February through April recorded only one-fourth as many bottom breaks as were counted in the same lighted plots after the first three weeks of lighting. No bottom breaks were observed in unlighted plots of clone 'Forever Yours' at any time during the study. Only three bottom breaks developed in unlighted plots of clone 'Shocking Pink' during the course of the study. Initial bottom break development in lighted plots probably was made possible by increased sugar levels in the plant resulting from high intensity lighting. With the development of the initial bottom breaks into flowering canes, the total number of flowers harvested per plant was increased. Thus high intensity supplemental lighting can influence the yield of greenhouse roses.

The flower production of other florist crops has been increased with supplemental illumination. Lighting has been found to significantly increase flower yields of carnation, a nonphotoperiodic crop (5). During the course of this study the number of rose flowers harvested per plant was significantly increased for clone 'Forever Yours' when supplemental high intensity lighting was supplied to the plants. Lighting day and night (20 hour treatment) did not significantly increase production over that attained when plants were lighted 8 hours nightly. On this basis the value of lighting

the plants from 6 a.m. to 6 p.m. in addition to lighting them from 6 p.m. to 2 a.m. might be legitimately questioned.

The yield of flowers per plant is influenced by the number of flowering canes per plant and the days required from cutting a flower to flowering of the stem again. Carpenter, Rodriguez, and Carlson (7) reported that 'Forever Yours' rose plants given longer photoperiods of low intensity supplemental lighting showed a higher ratio of flowering to non-flowering branches than plants which were given shorter photoperiods. Bickford (3) found no differences among lighted treatments in the number of flowers produced per cane for 'Colorado # 6' roses. He postulated that the production of flowers per cane was under a constant genetic rate control that was unaffected by differences in light treatment. In this study the number of flowering shoots produced following the cutting of a single flower from a cane was recorded. Data showed virtually no differences between the lighted and unlighted plots with respect to this factor. The average number of flowers cut from a single cane was just slightly over one. This deviated less than 0.23 flower per cane for any plot in the study. These findings tend to substantiate Bickford's hypothesis that production of flowers per cane is a fairly constant genetic characteristic. This indicated that light has little or no effect on this particular aspect of rose growth.

The other factor influencing flower production is the time required for rose stems to flower again from the time they are cut. Post (25) reported that extension of the day-length with supplemental illumination reduced the number of days for several greenhouse crops to mature. Carpenter, Rodriguez, and Carlson (7) were able to demonstrate only a 6¼% reduction in days to flower for four rose clones grown under normal winter days with low intensity supplemental lighting to create a 16 hour daylength compared with 9 hour winter days without lighting.

In this study, reduction in the number of days to flower was also observed with increased periods of supplemental high intensity irradiation. However clone 'Forever Yours' showed only a 4% reduction in number of days to flower when comparing plots lighted 20 hours daily with unlighted plots. Plants of clone 'Shocking Pink' lighted daily and 8 hours nightly flowered in 14% fewer days than non-lighted plants. High intensity supplemental lighting increased the yield of both clones tested by reducing the days required for rose stems to flower again from the time they were cut.

Since neither increases in number of flowers developing from a single cane nor reduction in number of days required to flower could totally account for significant increases in number of flowers harvested per plant from clone 'Forever Yours', there must be some other factor to consider. The difference between treatments possibly resulted from the

ratio of flowering to non-flowering branches. Normally 30-40% of the rose shoots are blind (22). It is likely that a number of branches which would not normally produce flowers are induced to flower by the high intensity lighting. It is difficult to quantitatively determine this effect since the same cane cannot be lighted and unlighted at the same time. The supplemental lighting of rose plants probably acts by increasing the carbohydrate levels within the plant. Translocation of the carbohydrates throughout the plant may then raise carbohydrate concentrations in these canes to levels necessary for flower development to proceed.

Supplemental high intensity lighting had an impact on the morphology of the flowers produced from both clone 'Forever Yours' and clone 'Shocking Pink'. Lighted plots showed consistent reductions in number of nodes, length of stem and weight of flowers. Blake (5) reported a 37-44% reduction in the number of nodes for carnation stems by increasing the daylength from 8 to 17 hours. However, Carpenter, Rodriguez, and Carlson (7) found no differences in the number of nodes for rose stems developed under 9 to 16 hour daylengths using low intensity lighting. In this study 20 hours of high intensity lighting daily resulted in 18% and 25% reductions in number of nodes per flower for clones of 'Forever Yours' and 'Shocking Pink' respectively. The accompanying decrease in stem length with increased supplemental photoperiods resulted in little change in internode length for the various

treatments. 'Forever Yours' roses lighted 20 hours were 19% shorter than those which were unlighted. This reduction is undesirable commercially since longer stemmed roses generally bring a higher price than shorter ones.

In this study the fresh weight of cut rose flowers decreased as the duration of supplemental high intensity illumination increased. This resulted from shortened stems and fewer leaves per stem. There also was a noticeable weakening of the stems of flowers from plots lighted 20 hours. Perhaps these flowers were from stems which would not have developed without the supplemental lighting. High intensity light stimulated their flowering, but resulted in poor blooms with abnormally short and weak stems. The occurrence of this condition was more frequent in plots lighted 20 hours daily than those lighted 8 hours daily. Thus some of the additional flowers which were promoted by the supplemental lighting would be of little benefit to the commercial grower since they are of inferior quality. Therefore the increases in total numbers of flowers were not as significant as the data showed. However, these low quality flowers were a factor in the reduction of the number of nodes, length of stems, and weight of flowers from lighted plots. The fact that there were probably as many normal flowers in lighted as unlighted plots was probably obscured by these extra flowers of lower quality (Figure 18).

Taking into consideration all the factors measured in this study, the most satisfactory results for both clones 'Forever Yours' and 'Shocking Pink' were obtained from plots given 8 hours of high intensity supplemental light daily. In these plots a significant increase in flower production over unlighted plots was demonstrated with a relatively small decrease in overall quality of flowers harvested. Twenty hours of light daily seemed to increase the number of abnormal flowers with only a slight increase in flower production compared with plots lighted 8 hours daily.

Light has a profound effect on the production of sugar in plants. Assuming that plant turgidity and carbon dioxide are not limiting, the rate of photosynthesis should depend on the amount of light striking the leaf surface. In this study the amount of natural light reaching the leaves was greatly augmented by the supplemental high light intensity emitted by the wide-spectrum Gro Lux lamps in close proximity to the leaf surface. The light emitted from these tubes contained a spectral distribution approximating that needed by plants for photosynthesis (15).

Rose plants in lighted plots received a much greater total of light energy each day than plants in unlighted plots. Yet the plant response observed in the lighted plots was not a satisfactory index of the additional light received. This probably reflects the interaction of various limiting mechanisms which occur when high rates of photosynthesis are

attained. Burkholder (6) mentions that daily light period not only affects the quantity of photosynthetic materials formed but also affects the way in which the plant can use them. Lockhart reported that beans given higher light intensities, in excess of 40,000 lux, showed a reduction in internode length (21).

The carbohydrate content in leaf tissue has been used as an indicator of the amount of photosynthesis which has occurred (1,8,9,18). In this study it was hypothesized that various durations of high intensity supplemental lighting would result in differing photosynthetic rates. These photosynthetic rates were to be compared by determination of the total sugar content of the leaves under the experimental conditions. It was anticipated that sugar contents could be correlated with growth and flowering data from the various treatments.

A comparison of total reducing sugars in leaves at any one time would not be a satisfactory measurement of the photosynthetic material being produced by the plant, since the processes utilizing the photosynthetic material occur concurrently with synthesis of the material. Therefore any attempt to measure rates of photosynthesis by analyzing for total reducing sugars in the leaves must be preceeded by a reduction in the reserve of reducing sugars. After the carbohydrates in the rose leaves have been used, the accumulation of reducing sugars in the leaves is an index of the amount of photosynthesis that has occurred. In this study

rose leaves were covered with an opaque material 48 hours prior to the day when they were given the various lighting treatments. According to Arthur, Guthrie, and Newell (1) and Chandler and Watson (8) this should have been sufficient time to significantly decrease the carbohydrates in the leaves. However, chemical analyses of rose leaves covered 48 hours with an opaque material did not show large decreases in total reducing sugar levels.

Because lighting continued during the time selected leaf samples were covered, uncovered leaves were able to continue photosynthesis. Photosynthesis was arrested only in leaves from which light was excluded. It is possible that as the available food supply was reduced in the covered leaves, sugars from the lighted leaves were translocated to the unlighted leaves. Redistribution of sugars within the plant would thus prevent great decreases in sugar levels during the given 48 hour period. Furthermore the rose plant contains a reserve food supply in addition to the readily available reducing sugars. When reducing sugar levels cannot meet the metabolic demands of the plant, the reserve materials, such as starch, are converted to sugars. Therefore conversion mechanisms within plants with large food reserves act to prevent depletion of available sugars.

Darkening of the entire rose plant for several days in order to lower reducing sugar levels was not possible in this study. Radical changes in the environment, such as

exclusion of light for several days, are known to alter the metabolic functions of the plant and perhaps induce conditioning responses. Barua (2) reports that leaves adapt readily to specific conditions and rates of photosynthesis are affected by the previous conditioning of the leaf.

Leaves from 'Forever Yours' roses which had been exposed to the conditions of this study for 24 hours after having been covered for the previous 48 hours did show significant differences in the levels of total reducing sugars in their leaf tissue. The three treatments being compared were a) no supplemental lighting, b) 8 hours of high intensity supplemental lighting daily, and c) 20 hours of supplemental high intensity lighting daily. Lighting was from 6 p.m. to 2 a.m. in 8 hour plots and from 6 a.m. to 2 a.m. in 20 hour plots. Therefore both lighted plots received approximately the same photoperiod. After exposure to these conditions on February 16, 1970 (a sunny day during which no supplemental carbon dioxide was added to the greenhouse atmosphere) selected leaves contained 0.268, 0.290, and 0.298 milligram of glucose equivalents per gram of fresh tissue for the unlighted, 8 hour, and 20 hour plots respectively. After exposure to other climatic conditions on different days the same trend was observed. Leaves from lighted plots contained significantly higher sugar levels than unlighted plots. There was also more sugar in leaves lighted 20 hours daily with high intensity lighting than in those lighted only 8 hours with

the same light source. These data indicate that high intensity supplemental lighting increases the total reducing sugar level in rose leaves. It appears that the responses observed in the rose plants studied result from differences in light energy. The effects are not merely ones of photoperiod since both 8 and 20 hour plots received approximately the same photoperiod.

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