THE EFFECT OF LIGHT INTENSITY ON THE PHOTOSYNTHETIC EFFICIENCY OF CARNATION VARIETIES

Thesis for the Degree of M. S.

MICHIGAN STATE COLLEGE

Winfred D. Holley

1940

THE EFFECT OF LIGHT INTENSITY ON THE PHOTOSYNTHETIC EFFICIENCY OF CARNATION VARIETIES

By

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A THESIS

Submitted to the Graduate School of Michigan State College of Agriculture and Applied Science in partial fulfilment of the requirements for the degree of

MASTER OF SCIENCE

Department of Horticulture

1940

Approved May 27, 1940

V. R. Gardner

THESIS

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Introduction

The greenhouse carnation is one of the most widely grown of florists' crops. Although methods of culture have been rather generally agreed upon, many carnations of poor quality are found on the markets during the winter months. Flowers produced in sections where cloudy weather prevails are noticeably weaker of stem than those produced under more favorable light conditions.

It has been a common practice to grow all varieties of carnations under whatever conditions may prevail. Possibly these conditions are most favorable only for the most prolific varieties. Certain varieties consistently produce more flowers per season, including a higher production during the cloudy months from December to February. Production is undoubtably tied up with heredity, but it may be directly due to photosynthetic efficiency. Are these more prolific varieties capable of utilizing lower light intensities more efficiently? Presumably, the accumulation of the products of photosynthesis over and above those used in respiration determines largely the production. How do different varieties respond to different intensities of light? Experiments were designed and carried out to secure results that might serve in giving an answer to that question.

Review of Literature

Light is only one of the many factors that influence the rate of photosynthesis in green plants. Blackman and Matthaei (2), under properly controlled conditions, concluded that if the temperature and carbon dioxide are in excess, the rate of photosynthesis is proportional to the intensity of incident light. For every temperature there is a maximum light intensity which will produce a maximum rate of photosynthesis at that temperature.

Combes (3) grew potatoes and other tuber-forming species under different light intensities. He concluded that the higher the light intensity, the greater the accumulation of elaborated organic compounds in the storage parts of the plants. Apparently, at lower intensities the storage function ceased and the entire amount of the products of photosynthesis was consumed in the growth of parts of the plants other than storage organs. Combes also found, for a majority of species studied, that optimum light intensity varied with the growth stage of the plant. Higher light intensities were required during the period from flowering to maturity than were necessary for optimum dry weight increase in the earlier stages of growth.

Tincker (13) made similar conclusions, working with Dahlia and several other tuberous rooted and root-storing species. He obtained taller plants by supplementing 12 hours of daylight with weak electric lights, but there was very little storage under such conditions. Plants receiving only 12 hours of daylight were shorter but had good storage root systems. Apparently the weak electric lights stimulated top growth at the ex-

pense of the storage function. Tincker also found that the average storage under 5 to 6 hours of daylight was only 17 percent of that under 10 to 12 hours of daylight. The shorter period of light produced only enough food materials for top growth.

Working with the garden pea, De Besteriro and Durand (6) found a dry-weight increase in direct proportion to the intensity employed for its irradiation.

Porter (10), working with greenhouse tomatoes under different light intensities, found the percentages of dry matter, ash material, fresh weight and elaborated food materials to correlate rather closely with the light intensity received by the plants. He concluded that light intensity variation is the chief cause of differences in plant efficiency.

Popp (9) grew four varieties of soybeans for 7 days at a temperature of 19 to 23° C. under light intensities of 4,285, 1,538, 560, 390, 250, and 26 foot-candles, respectively. He observed that the lower the light intensity the more rapid was the rate of stem elongation during the period of initial growth. The greatest general height was attained by plants under a light intensity averaging 560 foot-candles and the lowest under 26 foot-candles. The thickness of the stem was directly proportional to the light intensity, and there was a gradual decrease in vigor with decreasing light intensity.

Dastur and Samant (5), working under artificial and natural light conditions, reported that the production of starch, total carbohydrates, and total sugars is much greater in diffuse daylight than in artificial light. They attributed these differences not to any variations in intensity but to a difference in

the quality of the light. Dastur and Mehta (4) concluded that in using artificial light, photosynthetic activity is highest in white light, intermediate in red light and very feeble in the blue-violet region of the spectrum.

The foregoing are only a few of the numerous investigators who have worked with light and its relation to plant growth. Artificial light has been used in many instances as a method of forcing greenhouse plants. Tjebbes (14) and Hostermann (8) obtained earlier and larger yields of various greenhouse crops by supplementing winter daylight with eight hours of electric light.

Literature on the use of light on carnations is not plentiful. Arthur et. al. (1) grew various greenhouse plants under artificial climatic conditions. Additional light and carbon dioxide gave no response with carnations; however, some ornamentals, such as roses, sweet peas, snapdragons, petunias and nasturtiums, grew and flowered remarkably well. Their results with carnations may have been due to the comparatively high temperature used (78°F), since carnations grow best at cooler temperatures.

Ramaley (12), working with carnations, and other caryophyllaceous plants, found that continuous illumination caused carnations to bloom appreciably earlier than check plants. There was no difference in appearance between treated and untreated plants. Light intensities of 10-20 foot-candles were used during the night. Withrow and Richman (15) grew the Pink Abundance variety of carnation, using 16 foot-candles of light for 10

hours as a supplement to winter daylight. The additional light increased both flower production and length of stem, but the variety produced fewer new shoots than control plants. Recent work on the carnation at Cornell University (11) yielded similar results. Low intensity lights were not beneficial when used 6 hours or less. High intensity lights hastened production considerably but at cost too great to be profitable. This work and the work by Withrow and Richman (15) indicate that supplementing daylight with artificial light is not a profitable method of increasing carnation production, since high intensities of light are necessary. Perhaps it would be possible to select certain varieties that are more efficient in using lower intensities of light. A comparison of the leaf efficiency of several varieties should furnish needed information.

General Procedure

The three varieties of carnations used in this experiment were: Morning Glow, a good producer from the standpoint of number of blooms; Maine Sunshine, an average producer; and Pelargonium, a poor producer under local conditions.

It was first necessary to determine as accurately as possible the relative growth rates for the three varieties under natural daylight conditions. On May 31, 150 plants of each variety were selected and potted in 5 inch pots. These plants had been propagated by cuttings the previous winter and had been grown under identical conditions for one month previous to potting.

The soil used in potting consisted of 2 parts of heavy loam compost, 1 part leaf mold and a small amount of sand. Super-phosphate was added at the rate of one 3 inch potful to 2 bushels of soil. The soil was mixed by thorough shovelling-over and was as uniform as could be obtained.

Water was applied sparingly for the first month, since the plants were over-potted at the outset to avoid shifting at anytime during the experiment. The leaf area on all plants was made as uniform as possible by pinching some plants and partial defoliation of others. The plants were placed on moist sand, in a sunny house on June 1. The varieties were arranged in alternating rows as follows: a row of 10 of the Morning Glow variety, then a row of 10 of Pelargonium, followed by 10 of the variety Maine Sunshine, after which the sequence was repeated.

On June 15, 35 whole plants of each variety were taken; washed; dried to constant weight in an oven at 70°C., then weighed individually. In taking them from the bench, every fourth plant of each variety was taken. Dry weights of 35 plants of each variety were obtained later, on each of three days--July 15, August 15, and September 15.

On September 16, 200 rooted cuttings of each variety were potted in 3 inch pots in the same soil mixture as used previously. They were placed in a coldframe and given partial shade for about one month. On November 25, 150 of the most uniform plants of each variety were selected out and given a uniform pinching. Thirty-five plants of each variety, sel-

ected at random, were washed and dried to constant weight. The remainder of the plants was arranged in a manner previously mentioned on a well lighted bench. The temperature throughout the rest of this particular experiment was maintained at approximately 50°F. during the night, with slightly higher day temperatures. Thirty-five plants of each variety were dried December 27, January 27, and March 1, which concluded this particular phase of the experiment. The plants received the natural daylight during this period which was predominately cloudy, as shown in Table 8.

The second part of this experiment was an attempt to determine the comparative leaf efficiency of the three varieties by using the "twin- or opposite-leaf" method of sampling described by Denny (7). Carnations were found to have identical opposite leaves.

In August, the three varieties were planted in alternating rows in a 21 foot bench on the east side of a carnation house. They were planted in the same soil mixture used for commercial production.

In adapting the "twin-leaf" method of sampling to carnations, it was first necessary to find some method of measuring the leaf area. This was done by blueprinting 160 leaves of each variety and measuring them with a planimeter. The area (y) of each of these leaves was then plotted against the length (x) and the curve of best fit derived by the method of least squares. The resultant relationship was parabolic in type. The derived equations for the three varieties were as follows:

leaf efficiency. Samples were taken under various light intensities throughout January, February, and March.

Experimental Results

The average dry weights for the three varieties were obtained on the dates shown in Table 1. The weights presented are averages of 35 plants weighed individually on each date.

The dry weights were not taken at regular intervals of time. However, as shown by Tables 2, 3, 4, 5, 6, and 7, they were calculated to a weekly basis, in order properly to derive and compare the relative growth rates of the three varieties. For this procedure use was made of the familiar equation:

$$R / 100 = \log_e W_2 - \log_e W_1.$$

For convenience of calculation, this equation was given the form:

$$R / 100 = 2.302585 \log W_2 / W_1.$$

These symbols, with their corresponding values, were used in the composition of the tables mentioned above.

Morning Glow $y = -4.8888 + 6.476x - 0.6882x^2$

Maine Sunshine $y = 0.0169 + 0.327x + 0.0161x^2$

Pelargonium $y = -0.0081 + 0.388x + 0.0056x^2$

This made it possible accurately to determine areas on the simple basis of measurements of leaf lengths.

Since the "twin-leaf" method of sampling on carnations involves pulling the leaves from the stems with a downward motion, it was necessary to calculate the approximate error in sampling. Duplicate samples of 50 opposite leaves were dried to constant weight and their weights compared. Five replications were made for each variety. The maximum error involved in sampling was $\pm 1.67\%$ for the Pelargonium variety, $\pm 0.77\%$ for Morning Glow, and $\pm 0.44\%$ for Maine Sunshine.

Samples were taken under different intensities of light, which were obtained by using natural daylight, 500 watt, and 1000 watt Mazda bulbs, during cloudy weather. The lowest light intensities were obtained by shading with black cloth. Light intensity readings were taken every hour by means of a General Electric photoelectric galvanometer and an average of these readings used as the light intensity for the daily period. Temperature readings were also taken and averaged in the same manner.

In sampling, one of a pair of opposite leaves was taken at 8 A.M. and the other taken at 5 P.M. Approximately 50 leaves were taken in each sample. After lengths of leaves were measured for each variety, the samples were dried to constant weight in an oven at 70°C. The increase in dry weight over the 9 hour period was used as a basis for comparison of

Table 1: Dry Weight Averages of Thirty-five Plants Weighed Individually

Variety	Date			
	6/15	7/15	8/15	9/15
Morning Glow	1.059	1.854	3.295	5.054
Maine Sunshine	1.404	2.207	3.630	5.252
Pelargonium	0.963	1.824	3.164	4.553

Variety	Date			
	11/24	12/27	1/27	3/1
Morning Glow	0.484	0.637	0.991	1.592
Maine Sunshine	0.601	0.652	0.943	1.579
Pelargonium	0.663	0.703	1.026	1.580

Table 2: Summer Increase in Dry Weight for Morning Glow Variety of Carnation

Date	Ave. dry wt. in grms.	W_2/W_1	Log W_2/W_1	$R/100$	R* (Rate)
6/15	1.059				
6/22	1.245	1.1756	0.07041	.1621	16.21
6/29	1.431	1.1494	0.06032	.1389	13.89
7/6	1.617	1.1300	0.05308	.1222	12.22
7/13	1.803	1.1150	0.04727	.1088	10.88
7/20	2.088	1.1581	0.06371	.1467	14.67
7/27	2.413	1.1643	0.06595	.1519	15.19
8/3	2.738	1.1347	0.05500	.1266	12.66
8/10	3.063	1.1187	0.04883	.1124	11.24
8/17	3.408	1.1126	0.04650	.1071	10.71
8/24	3.805	1.1165	0.04766	.1097	10.97
8/31	4.202	1.1043	0.04297	.0989	9.89
9/7	4.599	1.0945	0.03941	.0907	9.07
9/15	4.996	1.0863	0.03583	.0825	8.25

* Weekly increase in dry weight in percentage.

Table 3: Summer Increase in Dry Weight for Maine Sunshine Variety of Carnation

Date	Ave. dry wt. in grms.	W_2/W_1	Log W_2/W_1	$R/100$	R* (Rate)
6/15	1.404				
6/22	1.592	1.1339	0.05461	.1257	12.57
6/29	1.780	1.1181	0.04844	.1115	11.15
7/6	1.968	1.1056	0.04376	.1008	10.08
7/13	2.156	1.0955	0.03981	.0917	9.17
7/20	2.436	1.1299	0.05308	.1222	12.22
7/27	2.757	1.1318	0.05385	.1240	12.40
8/3	3.078	1.1164	0.04766	.1097	10.97
8/10	3.399	1.1043	0.04297	.0989	9.89
8/17	3.735	1.0988	0.04100	.0944	9.44
8/24	4.101	1.0980	0.04060	.0935	9.35
8/31	4.467	1.0892	0.03703	.0853	8.53
9/7	4.833	1.0819	0.03383	.0779	7.79
9/14	5.199	1.0757	0.03181	.0732	7.32

* Weekly increase in dry weight in percentage.

Table 4: Summer Increase in Dry Weight for Pelargonium Variety of Carnation

Date	Ave. dry wt. in grms.	W_2/W_1	Log W_2/W_1	$R/100$	R* (Rate)
6/15	0.963				
6/22	1.164	1.2087	0.08243	.1898	18.98
6/29	1.365	1.1727	0.06930	.1596	15.96
7/6	1.566	1.1473	0.05956	.1371	13.71
7/13	1.767	1.1284	0.05231	.1204	12.04
7/20	2.039	1.1539	0.06221	.1432	14.32
7/27	2.342	1.1486	0.06032	.1389	13.89
8/3	2.645	1.1294	0.05269	.1213	12.13
8/10	2.948	1.1146	0.04727	.1088	10.88
8/17	3.254	1.1038	0.04297	.0989	9.89
8/24	3.568	1.0965	0.04021	.0926	9.26
8/31	3.882	1.0880	0.03663	.0843	8.43
9/7	4.196	1.0809	0.03342	.0770	7.70
9/14	4.510	1.0748	0.03141	.0723	7.23

* Weekly increase in dry weight in percentage.

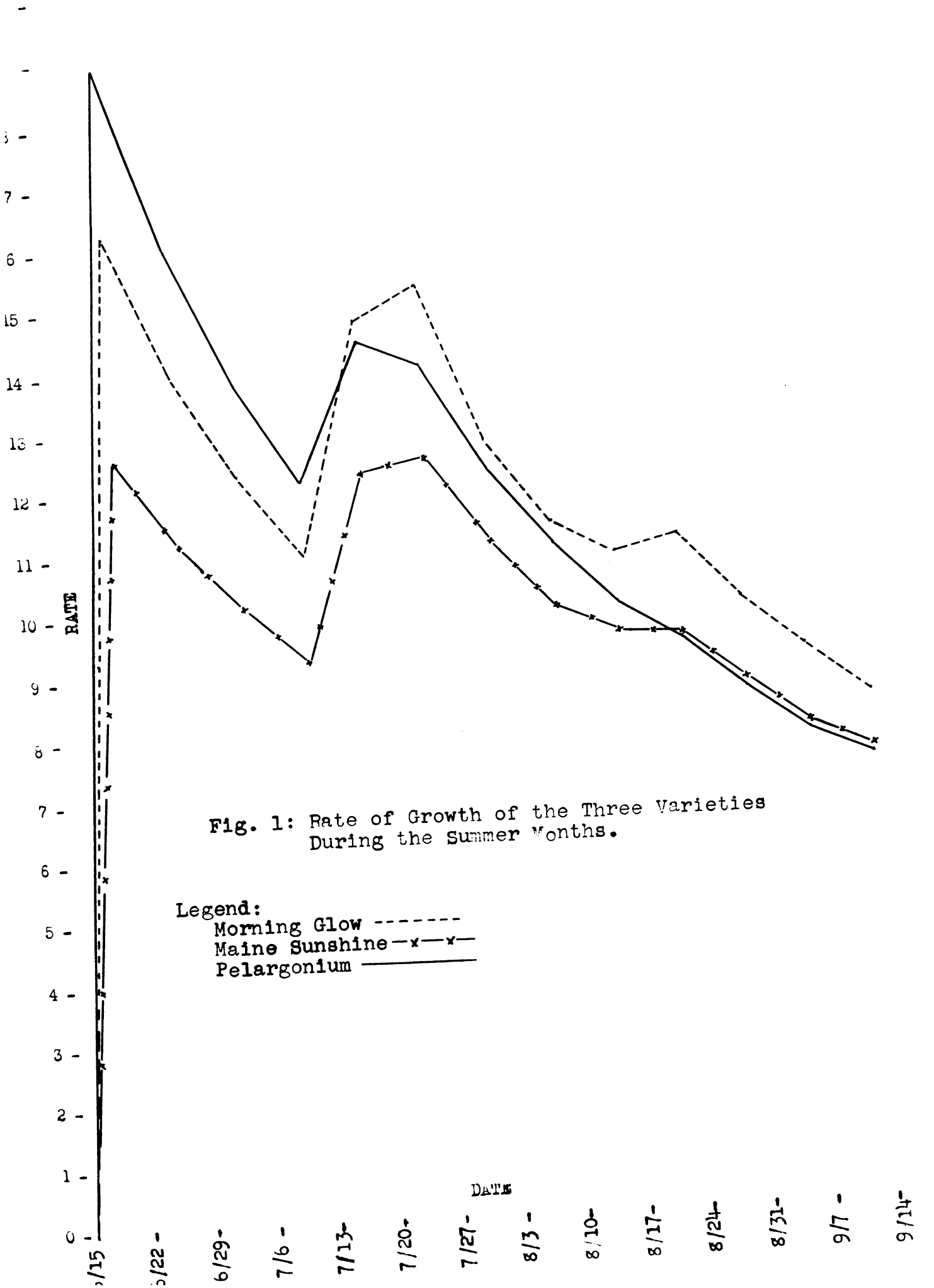


Fig. 1: Rate of Growth of the Three Varieties During the Summer Months.

The three graphs in Figure 1 have much the same characteristics. All three varieties showed a rapid growth rate, reaching a maximum the first week, then decreasing for 3 weeks, then rising again during the sixth and seventh weeks, and finally showing a downward trend for the remaining 7 weeks. The initial growth rate of the Pelargonium variety is significantly higher than that of Morning Glow. However, beginning with the sixth week, and throughout the remainder of the period, Morning Glow exceeded Pelargonium. Throughout the experiment the growth rate of the variety Maine Sunshine was significantly lower than that of the other varieties, with the exception of the last four weeks, when it slightly exceeded the growth rate of Pelargonium. This may be explained by the fact that plants of the Maine Sunshine variety were in a somewhat hardened condition when received, one month before the experiment was started. For the entire period of 13 weeks, Morning Glow increased 477 per cent, and Pelargonium increased 473 per cent, against 374 per cent for Maine Sunshine. The light conditions prevailing during the 13 weeks were sunny, as shown in Table 8.

Table 5: Winter Increase in Dry Weight for Morning Glow Variety of Carnation

Date	Ave. dry wt. in grms.	W_2/W_1	Log W_2/W_1	$R/100$	R* (Rate)
11/24	0.484				
12/1	0.516	1.0661	0.02776	.0639	6.39
12/8	0.548	1.0620	0.02612	.0601	6.01
12/15	0.580	1.0584	0.02449	.0564	5.64
12/22	0.612	1.0552	0.02325	.0535	5.35
12/29	0.660	1.0784	0.03262	.0751	7.51
1/5	0.740	1.1212	0.04961	.1142	11.42
1/12	0.820	1.1081	0.04454	.1026	10.26
1/19	0.900	1.0976	0.04060	.0935	9.35
1/26	0.980	1.0888	0.03703	.0853	8.53
2/2	1.097	1.1193	0.04883	.1124	11.24
2/9	1.221	1.1130	0.04650	.1071	10.71
2/16	1.345	1.1015	0.04218	.0971	9.71
2/23	1.469	1.0922	0.03822	.0880	8.80
3/1	1.592	1.0837	0.03503	.0807	8.07

* Weekly increase in dry weight in percentage.

Table 6: Winter Increase in Dry Weight for Maine Sunshine Variety of Carnation

Date	Ave. dry wt. in grms.	W_2/W_1	Log W_2/W_1	R /100	R* (Rate)
11/24	0.601				
12/1	0.612	1.0183	0.00787	.0181	1.81
12/8	0.623	1.0180	0.00775	.0178	1.78
12/15	0.634	1.0176	0.00760	.0175	1.75
12/22	0.645	1.0173	0.00745	.0172	1.72
12/29	0.671	1.0403	0.01703	.0392	3.92
1/5	0.737	1.0984	0.04060	.0935	9.35
1/12	0.803	1.0895	0.03724	.0857	8.57
1/19	0.869	1.0822	0.03423	.0788	7.88
1/26	0.935	1.0759	0.03181	.0732	7.32
2/2	1.055	1.1283	0.05231	.1204	12.04
2/9	1.186	1.1242	0.05077	.1169	11.69
2/16	1.317	1.1104	0.04532	.1044	10.44
2/23	1.448	1.0994	0.04100	.0944	9.44
3/1	1.579	1.0904	0.03743	.0862	8.62

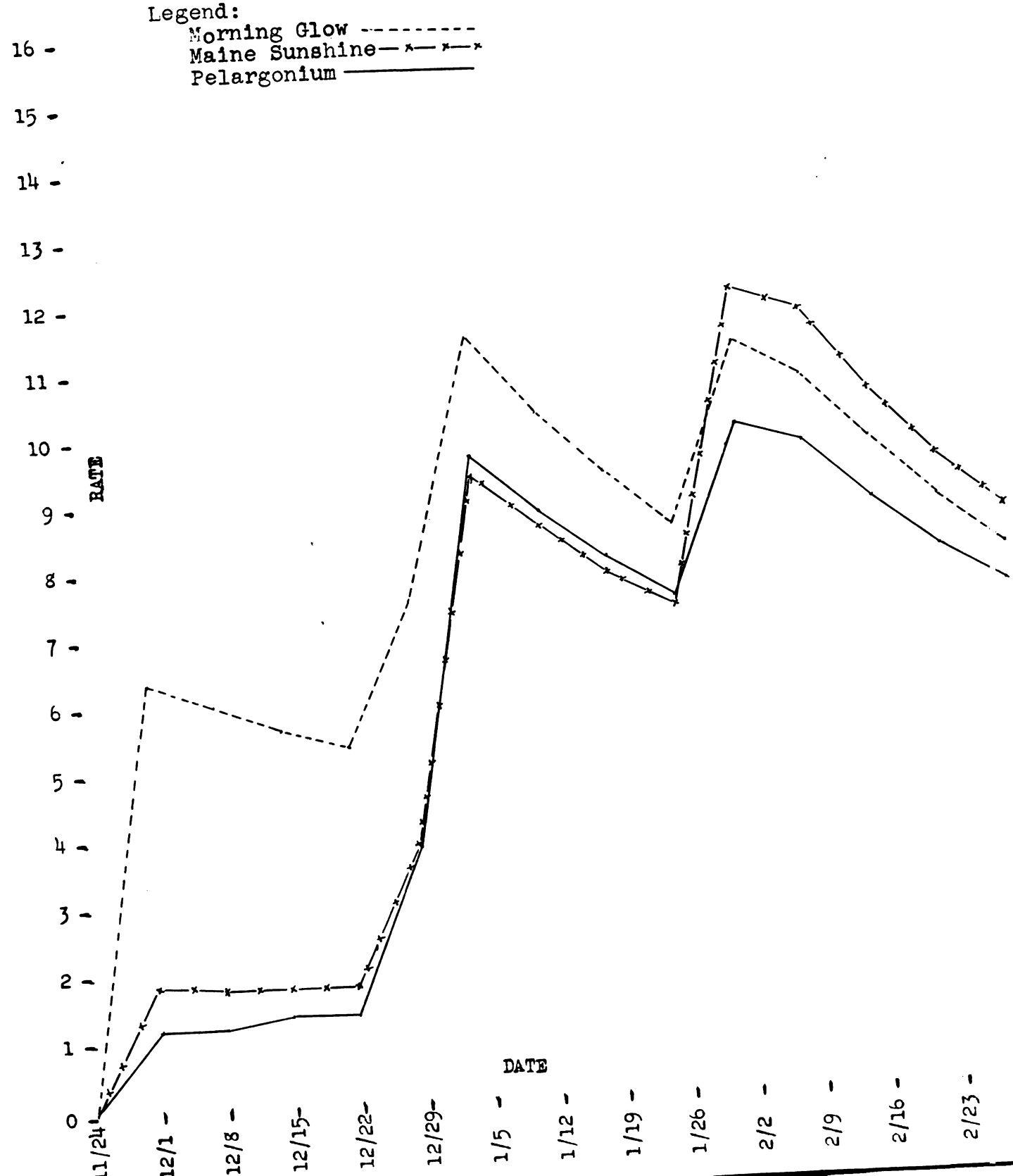
* Weekly increase in dry weight in percentage.

Table 7: Winter Increase in Dry Weight for Pelargonium Variety of Carnation

Date	Ave. dry wt. in grms.	W_2/W_1	Log W_2/W_1	$R/100$	R* (Rate)
11/24	0.663				
12/1	0.671	1.0121	0.00522	.0120	1.20
12/8	0.679	1.0119	0.00514	.0118	1.18
12/15	0.688	1.0133	0.00573	.0132	1.32
12/22	0.697	1.0131	0.00565	.0130	1.30
12/29	0.724	1.0387	0.01662	.0383	3.83
1/5	0.797	1.1008	0.04179	.0962	9.62
1/12	0.870	1.0915	0.03822	.0880	8.80
1/19	0.943	1.0839	0.03503	.0807	8.07
1/26	1.016	1.0774	0.03222	.0742	7.42
2/2	1.123	1.1053	0.04336	.0998	9.98
2/9	1.237	1.1015	0.04218	.0971	9.71
2/16	1.351	1.0922	0.03822	.0880	8.80
2/23	1.465	1.0844	0.03503	.0807	8.07
3/1	1.580	1.0784	0.03262	.0751	7.51

* Weekly increase in dry weight in percentage.

Fig. 2: Rate of Growth of the Three Varieties During the Winter Months.



Much less favorable light conditions prevailed when samples were taken during the winter months. The results are presented graphically in Figure 2. The growth rate of Morning Glow increased rapidly, beginning with the first week and reaching a maximum on the sixth week. Pelargonium and Maine Sunshine grew very slowly until the beginning of the fifth week, when they increased rapidly for two weeks. From the sixth week on, Pelargonium followed the growth curve of Morning Glow, but was significantly lower. However, the growth rate of Maine Sunshine increased rapidly during the tenth week until it exceeded that of Morning Glow for the last 5 weeks of the period. All three varieties began a gradual decrease in growth rate during the last 5 weeks. For the entire period of 14 weeks, Morning Glow increased 329 per cent, compared to 263 per cent for Main Sunshine and 238 per cent for Pelargonium.

Since the plants were the same age and had identical treatment, Figure 2 shows Morning Glow to be either a more rapid starter, or else it was able to use more efficiently the lower light intensities during the first 9 weeks of the period. The more rapid rate of growth of the Maine Sunshine variety, during the last 5 weeks, corresponds to an increase in average light intensity during that time.

Table 8: Weather Data for Periods Covering Growth Experiments*

Month	Days Clear	Partly Cloudy	Cloudy	Hours of Sunshine	Per Cent of Possible
June, 1939	6	13	11	302	66
July	14	11	6	361	78
August	15	13	3	316	73
September	14	9	7	265	71
November	11	7	12	146	50
December	3	8	20	65	23
January, 1940	0	7	24	42	14
February	7	2	20	95	31

Sunshine data for the periods June to September, 1939, and November, 1939, to February, 1940, are presented in Table 8. Only the last 6 days of November were included in the second period.

That there were comparatively few hours of sunshine in December and January is easily seen. Not only was there an increase in number of hours of sunshine in February over the two previous months, but also an increase in light intensity during the cloudy days. Mid-day light intensity frequently dropped to 100-200 foot-candles during December and January. The lowest corresponding intensity for February was 315 foot-candles.

* Obtained from the United States Weather Bureau Station at East Lansing, Michigan.

Table 9: Photosynthate Produced Under Different Conditions of Light and Temperature

Low Light Intensities (in foot-candles)

Variety	Light 35 Temp.* 56.6	46 57.1	59 64.2	64 69.0	98 72.5	Total
Morning Glow	-0.655	1.454	0.988	0.898	-0.864	1.821
Maine Sunshine	-0.382	0.483	1.452	-0.136	-1.607	-0.190
Pelargonium	0.180	-0.624	-0.883	0.876	-4.143	-4.594

Medium Light Intensities (in foot-candles)

Variety	Light 546 Temp.* 55.0	640 58.0	765 58.0	850 62.0	970 66.3	Total
Morning Glow	1.557	1.545	2.775	1.046	3.109	10.030
Maine Sunshine	0.878	0.980	2.185	2.656	1.555	8.254
Pelargonium	0.918	3.065	2.813	1.676	4.313	12.785

Higher Light Intensities (in foot-candles)

Variety	Light 1502 Temp.* 62.2	1615 59.0	2043 67.0	2043 67.0	Total
Morning Glow	3.982	6.082	6.256	7.423	23.723
Maine Sunshine	7.260	3.695	12.991	10.487	34.433
Pelargonium	7.576	6.395	10.132	9.365	33.468

* Temperature in degrees F.

The amount of photosynthate in grams per square meter of leaf area, over 9 hour periods, is presented in Table 9. It is at once apparent that temperature plays an important role in photosynthate accumulation. Since it was not possible to keep the temperature constant, samples were taken under different temperatures as well as different intensities of light. The low light intensities were obtained by shading with black cloth, medium light intensities were obtained by use of 1000 and 500 watt Mazda lamps, and higher light intensities occurred during partially cloudy weather in early March.

The total amount of photosynthate produced by a variety under a series of light intensities, as presented in Table 9, is of little significance, since each set of conditions within the series is different. However, the efficiency of a variety under a given set of conditions is exemplified somewhat in the totals.

Under low light intensities, Morning Glow was the most efficient under almost every set of conditions. Pelargonium seems to be least efficient under the majority of light intensities and temperatures tried. Temperature played a much more important part when light was limited; its effect being most pronounced on the Pelargonium variety. With 98 foot-candles average light intensity and 72.5°F. temperature, respiration exceeded photosynthate production 0.864 grams for Morning Glow, 1.607 grams for Maine Sunshine, and 4.143 grams for Pelargonium.

Under medium light intensities of 546-970 foot-candles Pelargonium produced the largest amount of photosynthate.

Maine Sunshine produced the least amount under all conditions tried, with one exception. With 850 foot-candles of light and 62 • temperature, Maine Sunshine produced 2.656 grams of dry material per square meter of leaf area, compared to 1.676 grams for Pelargonium, and 1.046 grams for Morning Glow.

Both Maine Sunshine and Pelargonium accumulated significantly more photosynthate at higher intensities than did Morning Glow.

A close scrutiny of Table 9 reveals occasional errors, which are difficult to eliminate entirely. The "twin-leaf method" of sampling, while adaptable to carnations, is one in which many errors may be involved. The increase in dry weight is so small over a 9 hour period that even the smallest error may be accentuated.

Discussion

The growth curves for the three varieties of carnations used in this experiment correspond favorably to their production records. During the summer months, when light is not a limiting factor, relative growth rates were similar.

The relative growth rates for the three varieties during the darker months were in the order of their productive ability. Morning Glow showed a much higher growth rate than the other two varieties and had a tendency to produce more new shoots in both summer and winter. This higher growth rate for Morning Glow may indicate only that the conditions of this experiment were more suitable to the variety. It does not necessarily mean that limited light was the sole cause of the slower growth

rates in the other two varieties. However, since growing conditions of the experiment were those ordinarily given in commercial production, it is possible to say that Morning Glow exhibited the highest photosynthetic efficiency under these conditions.

Evidence obtained from this experiment indicates that in production of carnations, temperature becomes increasingly important when light intensity decreases. Under low light intensities of 100 to 200 foot-candles, photosynthate production may be so low that the amount of material respired easily exceeds that manufactured. This, in itself, may account for the poor production and quality of flowers obtained by careless growers.

Porter (11) found that some tomato plants accumulated more food than others under low light intensities. This is also true of carnation varieties. The varietal differences in amount of accumulated dry materials are probably due to differences both in the rate of respiration and in rate of photosynthesis.

The response of the Pelargonium variety to temperature under low light intensities indicates that it may be possible to increase the quantity and quality of flowers on many low producing varieties by growing them at still cooler temperatures. Perhaps Pelargonium, and many other similar varieties, should be grown at 45°F. during the cloudy months, while Morning Glow, and similar varieties, may grow most favorably at 50 to 55°F.

Summary

A study of three typical varieties of carnations under different light intensities reveals that:

1. Varietal differences in dry weight accumulation occur in carnations during periods when low light intensity prevails.
2. During periods of higher light intensities, this difference in photosynthetic efficiency is less pronounced.
3. Varieties showing a relatively high leaf efficiency under low light intensities may be relatively less efficient under higher intensities.
4. Carnations respond most favorably to light intensities of 1500 foot-candles or more.
5. Growing temperatures become increasingly important with decreasing light intensities. When light intensity drops to a certain point, respiration begins to exceed carbohydrate accumulation. A decrease in temperature tends to counteract the ill effects of lower light intensities.
6. Some varieties may need cooler growing temperatures than others when light intensity is limited.

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Acknowledgments

The writer wishes to acknowledge the helpful assistance of Professor C. E. Wildon in translating certain French articles and to express his appreciation of helpful suggestions and criticisms offered by Professor V. R. Gardner, Professor J. W. Crist, and Professor Wildon.