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Effect of daylength on rooting of gardenia cuttings.

J. L. Creech
University of Massachusetts Amherst

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ON ROOTING OF GARDENIA CUTTINGS

BY

JOHN L. CREECH

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I. Introduction

The literature regarding the propagation of plants yields numerous reports on the effects of medium (14, 3) growth regulators (7, 15) temperature (6, 4) age of cutting material (16) time of year of propagation (38, 8) and type of cutting (16, 28) on the resulting ability or failure of cuttings to root. However, little mention has been made of the effect of daylength on the rooting of cuttings until very recently (32, 22). It would seem that the variations in daylength such as are associated with the northern part of this hemisphere might influence the time required and number of cuttings to root as much as any other factor, and furthermore, as in the case of the other influencing factors mentioned, there undoubtedly would be a variation between the response of individual species to daylength.

Species which require considerable time to root might also vary in rooting due to the number of hours of daylight the cuttings received while in the process of rooting.

These are the two questions to which the writer was seeking the answer when he began to work on this problem: (1) Does the length of day under which the parent plant was growing at the time of propagation have any effect on the rooting of the cuttings? (2) Is there any variation in the rooting of cuttings of a species when the length of day in the propagating house is varied?

The basic theory of photoperiodism by Garner and Allard (10) has been expanded greatly since its publication and a regulatory effect has been shown on various phases of plant growth (11). Therefore, should not the "regulating effect" of photoperiod on the rooting of cuttings also be studied?

Post (26) pointed out that there are seven distinct phases of plant growth, one of which is the propagation of the plant, either by seed, rooting of the cutting or other vegetative means. He suggests that a study of all the environmental factors in each of these phases of growth would be desirable. Photoperiod being such a factor should be studied for the propagation phase of plant growth.

The writer spent a week at the United States Plant Introduction Gardens, Glendale, Maryland, where he discussed the problem with Stoutemyer (32) who was working along the same lines. At this station, work was being carried on using fluorescent light to propagate cuttings and as the literature will show, there was considerable variation in the results.

The studies here described were begun in June, 1946, and represent work done under the conditions set forth in the procedure until April, 1947. This is regarded as a preliminary investigation into the study of photoperiod and the rooting of cuttings; undoubtedly there is much more work to be done on the subject. It does, however, represent a beginning to which it is hoped more work will be added.

It should further be understood that the results obtained apply to the rooting of *Gardenia jasminoides* Ellis, var. Hadley. They would not necessarily agree with the effects of daylength on cuttings of other species. This variation in the response of cuttings of different species to daylength is also brought out in the literature.

II. Review of the Literature

The literature on the effects of environmental conditions on the rooting of cuttings reveals few papers which discuss the effect of the photoperiod on the rooting of cuttings.

Daylength as a factor in rooting cuttings

The earliest work in which the photoperiod is connected with rooting of cuttings is by Zimmerman and Hitchcock (41). This paper clearly shows that, in the case of dahlia, the length of day determines the type of root system formed on the cuttings of six varieties. A heavy storage root system is produced when the cuttings are taken during the shorter days of the year while a fibrous root system results when the cuttings are taken under long days.

The authors feel that, in the case of dahlia, vegetative growth is so limited by short days that normal fibrous roots form only in small amounts. The roots that form are of the storage type. Since nitrates accumulate under short days, according to Nightingale (23), the storage of the nitrates and change from vegetative growth to flowering in dahlias results in formation of tuberous, fleshy roots and eventually dormancy. With the approach of long days, vegetative growth again commences and any cuttings taken will have fibrous roots.

"Evidently", the authors report, "there is a certain day length at which both vegetative growth and storage can proceed at an even rate."

In the same year the same authors (42) published a paper about the vegetative propagation of holly. It deals with factors affecting the rooting of cuttings of one deciduous and five evergreen species of holly, i.e. Ilex verticillata, I. opaca, I. crenata, I. glabra, and I. aquifolium.

Among the environmental effects is a small section on the effect of light requirements. Six hours of extra light at night, when cuttings were taken during the month of November, gave better root growth and a higher percentage of rooting in the case of I. crenata. I. opaca received added light, which resulted in an increase in size of roots only, while in the case of I. glabra, winterberry, both an increase in per cent of rooting and in root growth also was noted. These experiments were repeated twice with similar results.

Cuttings of hollies taken in late fall and early winter rooted well. Cuttings taken in late spring are worthless, being very succulent and seldom root. Cuttings taken after January 1 rooted poorly because of winter injury and lack of stored food. It was also noted that an after-ripening of the buds is necessary because if cuttings are taken after December 1, the cool weather in October and November caused an after-ripening of the buds which stimulated the rooting and the top growth began to grow during the following spring. Cuttings taken before the cool fall, however, produced roots but failed to produce top growth until the plants passed a winter in a cool house. These cuttings began vegetative growth the following spring.

Hollies, then, show both an effect on rooting of the cuttings due to the time of year for propagation and also there is a variation in the rooting when the cuttings are rooted under different day lengths. A long photoperiod aided root growth when applied to the cutting bench.

It is worth noting that in the case of the growth of leaf buds after rooting of I. opaca, there is definitely an after-ripening effect which is due to low temperature and the shortening of the day length, which come at the same time.

Skinner (29) reported that extra light on the leafbud cuttings of rhododendrons and azaleas increased the percentage of rooting by 10 per cent. The cuttings were given 18 hours of daylight while those receiving normal daylight had only 10 hours.

The most recent work which parallels that of the author is a contribution from Russia by B. S. Moskov and I. E. Kocherzhenko (22). This paper is a translation of the work done by these authors on the rooting of woody cuttings as affected by the photoperiod of both the parent plants and the cuttings themselves. The results were most interesting in that all cuttings did not root best under long days. To explain these results more thoroughly, the writer has incorporated the table presented by these authors.

Table I

Variations in Response of Salix to Daylength

Species and Origin of Parent	Photoperiodic treatment of parent	Long Day (18 hrs.) % rooting increment	Short Day (10 hrs.) % rooting increment
Salix undulata	18 hours	100	100
near Leningrad	10 hours	0	0
Salix Pierotii	18 hours	42	70
Japan	10 hours	75	90
Salix Babylonica	18 hours	60	55
Sukhumi	14 hours	95	65
	10 hours	70	35

From this table, it would appear that Salix undulata cuttings, when taken from long-day parents, root well with either 18 hours or 10 hours of day light. But when parent plants received only 10 hours of daylight, the cuttings would not root under any day length. With Salix Pierotti, it is quite clear that the cuttings rooted better when both the parent plants and the cuttings themselves were given short days. Salix Babylonica rooted better when the parent plants had 14 hours day length and the cuttings, 18 hours.

From the variations shown in this table it is obvious that no one photoperiod is optimum for all species. Furthermore, the day length under which the parent plant is growing has a greater effect on the subsequent rooting of cuttings than does the photoperiod which the cuttings receive. Obviously the culmination of months of a long photoperiod would be more effective than the six weeks of photoperiod which the cuttings receive.

To explain these responses to the hours of daylight the authors postulate that cuttings taken from parent plants which receive short days are better provided with "plastic substances" (just what these "plastic substances" are is left to the discretion of the reader). The reason why many southern species examined by these workers rooted poorly is that these plants

> "failed to complete their growth and reach a physiological state indispensable for rooting."

The authors recommend that

> "the way to prepare plants that normally strike cuttings in the summer is to grow them on short days and thus enhance the rooting ability of their shoots."

Stoutemyer (32) recently completed a study at the United States Plant Introduction Gardens, Glendale, Maryland, on the rooting of cuttings under fluorescent light. He found that the reactions of cuttings differed when they received continuous illumination. For example, cuttings of Acalypha wilkesiana, Muell. rooted more heavily under 16 hours light than when they received continuous illumination. When cuttings of this plant were treated with growth substances, the rooting was similar under both photoperiods. This might indicate an interaction between daylength and root-inducing hormones.

Cuttings of Carissa bispinosa, Desf., when rooted under eight hours of daylight, rooted more rapidly than those which received 16 and 24 hours. The cuttings were taken in February and were heavily rooted in August. Generally this tropical species is difficult to root.

Citrus cuttings were rooted under 16 and 24 hours daylight with no difference in the rooting. However, cuttings of Citrus aurantium Linn. var. myrtifolia, when treated with growth substances, namely potassium indole butyrate, rooted heavily under 16 hours daylength in two weeks but under continuous daylight, only slight and greatly delayed rooting was observed.

It has been reported by many própagators that the "time of year" is important in the successful propagation of many of our more difficult species. Gardner (9) found that Ilex opaca varied considerably when propagated at different times of the year. Cuttings were taken from the 19th of June to the 6th of April. The accompanying table will indicate the great variation in the cuttings.

Table II

Variations in Holly Propagation Due to Time of Year

Time of Year	Per Cent	Time of Year	Per Cent	Time of Year	Per Cent
June 19	2%	Sept. 9	100%	March 2	26%
July 9	4%	Nov. 1	56%	April 6	28%
July 30	26%	Jan. 23	50%		
Aug. 20	88%	Feb. 7	42%		

It will be seen from these results that as the day length decreases and temperature lowers, the success in rooting increases. As the days become very short, the cuttings continue to root poorly and as day length increases and temperature increases in the spring, the amount of rooting still continues to decrease. Undoubtedly, the author points out, there is a "physiological" conditioning due to the changes in condition of the growing wood. As the days become shorter, the amount of growth decreases and wood "hardens" with the result that food materials are stored in greater amounts. It would seem that the hardness of the wood is ideal for propagation by the first of September but as winter approaches the wood is in a dormant condition and the stored materials are unavailable for root growth.

Kemp (19) arrived at a different conclusion in the case of the hybrid lilac, Ludwig Spaeth. The cuttings rooted best when taken in June and July. At this time, the leaves are expanded and any stored food can be used in the production of callus and new roots. If cuttings are taken between September and December, during which time the buds are in a state of dormancy, the cuttings will not root or even callus. Such cuttings, being in a condition of early dormancy, utilize the stored food to initiate bud growth, leaving no available foods for callusing and root growth. If the cuttings are taken between December and March, the buds are in a condition of late dormancy and require less stored food to initiate bud growth. These cuttings will callus but will not root. When cuttings are taken in June, the leafbuds have already developed and enlarged so that callusing and rooting will result.

Doran (4, 5) reports that softwood cuttings of some species root well if taken in the late summer after growth has stopped. Others do best if taken in later spring or early summer.

Wyman (38) also reported on the influence of time of year on the rooting of cuttings of narrow leaf evergreens. For most species, including the following, Chamaecyparis pisifera, Juniperus chinensis pfitzeriana, J. horizontalis, and Taxus cuspidata, cuttings taken between October and February gave the best results. He noted a sharp decline in the percentage of rooting after February and finally a very high rate of mortality in the cuttings when taken in June.

Stevens (31) reported the following in the propagation of camellia:

> "Camellia cuttings may be taken at any time during the year although it is not advisable to take cuttings between February and July as the new growth produced at this time seems to delay root production."

The term "time of year" appears in a paper by Zimmerman (39) regarding the rooting response of cuttings as affected by the age of the tissue at the base of the cuttings. In the case of Lilac, he states that if cuttings are taken in May, they will root readily when a heel or current-growth cutting is used. If cuttings are taken after June 15, rooting is slow and no top growth is obtained during the season.

Doran (5) again refers to the influence of time of year on the rooting of cuttings of white pine. When cuttings are taken in midsummer they require a longer time to root than do cuttings which are taken in the winter months.

In summarizing this portion of the review of the literature, the writer wishes to point out the lack of information until recently about the effect of photoperiod on the rooting of cuttings. These recent papers agree in the sense that there is a great variation in the response of cuttings to the photoperiod.

The other obvious factor mentioned in these several papers is "the time of year." There are several factors involved in the phrase "time of year", both environmental and physiological. The environmental factors might include the following: daylength, temperature, moisture, humidity, soil conditions and light intensity. Parker and Borthwick (24) point out that no other factor varies any more than the length of day. And yet it is such a consistent, recurrent factor. Although the length of day varies from day to day throughout the year, the corresponding length of day is the same in a given locality over a successive period of years. It can be predicted more accurately than any one other factor. Since the length of day is the most consistent of these factors, it is easy to understand its importance in the growth of plants.

The literature which covers daylength is enormous and it has been well presented in the review published by the United States Department of Agriculture (24). This may be summarized briefly. The photoperiod may generally be referred to as the relative length of day and night, and "photoperiodism" then would be merely the response of the plant to the relative length of day and night. In connection with photoperiod, it is pointed out, there is a definite temperature correlation.

The response of plants to the length of day shows itself in various forms (12). Though generally it has been most marked in the change from vegetative growth to reproductive growth. However, photoperiod is also reflected in the formation of bulbs and tubers, the growth of roots and the rooting of cuttings.

Since this paper presents only the procedure for changing the daylength by artificial means, the writer feels that it would be of no particular value to go any further into the subject. It is discussed at length in the section on experimental procedure.

2. Gardenia Propagation

The oldest English report (1) available regarding the propagation of gardenias, appeared in 1853. It was reported that half-ripened shoots are easiest to propagate from if a "gentle bottom heat" is applied. However, in 1848, a German propagator (2) reported that *Gardenia radicans* might be grafted onto G. *florida* at any season of the year. The plants form beautiful crowns and blossom richly. With other species as a stock, *G. radicans* does not succeed so easily.

It is interesting to note, however, that *G. florida*, *G. radicans*, and *G. jasminoides* are synonymous, thus accounting for the ease with which such grafts were made.

Jadoul (17) in 1885 observed that both cuttings and grafting were used successfully. The cuttings are taken at the node and put in a mixture of "terre de bruyere" and river sand, but that "the plants were rarely good." He was in favor of grafting onto stocks of G. citriodora* in April or May with a cleft graft or "greffe en placage." The grafts should be kept under a bell jar or in a frame in a temperate greenhouse. G. citriodora is vigorous and easily reproduced by cuttings.

Van Houtte (35) reported that cuttings might be used but that the grafting onto Gardenia florida was a very successful method of propagation.

Gardenias can also be propagated successfully by the use of root cuttings according to a German horticulturist, Katzer (18).

Stewart (33) discussed the peculiarities involved in the propagation of Gardenia spp. Apparently when cuttings are taken from perpendicular shoots, growth will continue vegetatively and there will be no flowering.

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* This is a "trade name", not a true botanical species; it refers to Mitriostigma axillare, R. Brown, 1820.

> "A plant of Gardenia sp. has been growing in the Royal Botanic Garden for over twenty years, to my knowledge, and it has not flowered."

Cuttings taken from branch shoots, however, will develop quite a number of flowers each year.

Weinard (36) discussed the propagation of the gardenia. Cuttings were taken between November and January. There was no apparent difference in rooting caused by the medium used. Sand, or mixtures of sand and micolite, sand and peat, and micolite and peat, were used. After two months, approximately the same percentage (33 per cent) had callused in each case. Growth regulators had some effect on the rooting of the cuttings in that they increased the rooting about 25 per cent.

White (37) gave a brief account of the rooting of gardenia cuttings. He stated that there was no variation in rooting, when cuttings were taken above or below the node. It required from six to eight weeks for the cuttings to root. He stressed the fact that a high relative humidity is essential, a fact also considered of great importance by the present writer.

III. Experimental Procedure

The procedure used in this work was designed to fulfill two requirements; that of studying the effect of the daylength received by the parent plant on the subsequent rooting of cuttings and the rooting when the cuttings themselves received different daylengths.

1. Method of obtaining cuttings from plants receiving different daylength

To carry out the first phase of the work involved the taking of cuttings at regular intervals from the longest day of the year through the shortest day. This required a plant which would be growing under almost constant conditions of temperature, moisture, and other environmental factors. The commercial gardenia, Gardenia jasminoides, Ellis, var. Hadley was selected as an ideal plant. Since the gardenia is grown under glass in the north under stable conditions and the plants are kept for two or three years, it was possible to take cuttings from the same plants throughout the entire experiment. While it is not a difficult subject to propagate, no set rules have been established as to the exact requirements of daylength for the propagation of the gardenia. Generally the cuttings are taken between November and January, mainly because this allows sufficient growth of the new plants before they are set out in the benches in May or June.

Gardenias are grown at a temperature above 60° F. throughout the year and in large ranges this temperature is accurately maintained (21). It would seem then that the only factor which varied enough throughout the year to affect the rooting of the cuttings would be the daylength.

With this factor in mind the writer began to take cuttings from a group of one-year old plants on June 24, 1946. At three week intervals, one hundred and fifty cuttings were obtained from the plants. The selection of cuttings followed the procedure recommended by the grower at the Butler and Ullman establishment in Hadley where all material was obtained.

The cuttings were prepared so that the basal cut was made above the nodes. This method is preferred by commercial propagators in the belief that a small cut is less harmful in permitting infection by *Phomopsis gardeniae*, Budd and Wake, the fungus which causes stem canker. Laurie (20) reported to the author that there was no variation in the rooting of cuttings when the basal cut was made above or below the node.

The selection of propagation wood is most important in the propagation of gardenias (21). Immature wood is taken at a stage when the stems are just beginning to harden. This wood begins to take on a gray-green roughness and will snap cleanly when cut with a sharp knife.

The cuttings when taken were divided into three groups of fifty cuttings and placed immediately in sand, the rooting medium. A temperature of 72° F. bottom heat was maintained in the propagating case. The relative humidity was kept above 80 by using a very fine mist on the steam pipes. This method was so successful that the humidity remained constantly above 80% at all times. It requires between six and eight weeks in the propagating bed to root the cuttings. At the end of this time the cuttings are generally potted in 3" pots until they are transplanted to the permanent bed.

In connection with the effect of daylength received by the parent plants the following daylength variations at this latitude are presented. Amherst, Mass., is located at Lat. 42° 23' N. The daylength here varies considerably throughout the year. The longest day of the year, June 21, is 15 hours, 20 minutes and the shortest day, December 21, is only 9 hours. Here is a difference of 6 hours, 20 minutes between the daylength on these two dates, (Table III).

Table III

Dates of Taking Cuttings and the Corresponding Daylengths

Group	No. of Cuttings	Dates of Taking Cuttings	Daylength at Time of Taking Cuttings	Date Examined	Daylength at time of Examination
I	150	June 24	15.4 hrs.	July 28	14.6 hrs.
II	150	July 15	15.0 "	Aug. 25	13.5 "
III	150	Aug. 5	14.3 "	Sept. 16	12.4 "
IV	150	Aug. 26	13.5 "	Oct. 9	11.4 "
V	150	Sept. 16	12.5 "	Oct. 30	10.4 "
VI	150	Oct. 9	11.4 "	Nov. 26	9.4 "
VII	150	Nov. 8	10.0 "	Dec. 24	9.1 "
VIII	150	Nov. 30	9.3 "	Jan. 11	9.3 "
IX	150	Dec. 26	9.1 "	Feb. 8	10.2 "
X	150	Jan. 22	9.6 "	Mar. 5	11.4 "
XI	150	Feb. 17	10.6 "	April 1	12.7 "
XII	150	Mar. 5	11.4 "	April 19	13.5 "

1. Method of Varying the Daylength on Cuttings

The cuttings which were collected at each of the above mentioned dates (see Table III) were divided into three groups of 50 cuttings each. The groups of cuttings were placed in adjacent sections of the propagation bench. All cuttings were watered at the same time and in general received similar treatment, with the exception of the duration of daylight.

The attempt was made to vary the daylength in the propagating bed so as to observe any effects such variations might have on the rooting. Hamner and Bonner (13) have described a practical method of shortening and extending the normal daylength. When it is desired to shorten the daylength, a shade of black sateen of double thickness is put over those cuttings receiving such a treatment. In the work here described the short day is nine hours, which corresponds to the daylength on the shortest day of the year. The shade was applied in the afternoon so that the nine-hour photoperiod began at sunrise.

To extend the daylength it has been reported (25) that the light supplied by Mazda lamps is sufficient to carry on photosynthesis. Post (26) reports that the light, when the sun is five degrees below the horizon, is sufficient for plants to carry on photosynthesis. This amount of light is as low as one foot candle*. The method is to suspend a bulb of sufficient wattage to give 15 to 25 f.c. above the plants where an extended daylength is desired.

In this work a 40 watt lamp was suspended two feet above the cuttings. The lights were turned on at sunset and left on until the desired daylength was obtained. The long day was 18 hours and the lights were regulated by a time clock which turned the light on at sunset and off again when the 18 hour period was completed.

To measure the foot candles, a G.E. Light Meter was placed on the sand and the light either raised or lowered until the 15 f.c. range was reached (25). A cloth screen was suspended between the cuttings receiving extra light and those where no extra light was desired. This screen was necessary since the light from the lamp used to extend the daylength, measured over the adjoining propagating units, was between three and five foot candles and this would have undoubtedly affected the results. It was suggested

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* A foot candle is the amount of light falling on a surface one foot from a standard candle.

that such a lamp suspended above the cutting bed might have an effect by raising the temperature of the cuttings. But when checked with an accurate thermometer, there was no variation between the temperature at the level of the cuttings under the light and in other sections of the propagation bench.

The cuttings which received the normal daylength during rooting had the daylength varied in no way. The accompanying chart (Fig. 1) shows how the daylight varies from the longest day through the shortest day of the year (26).

In order to submit the results to statistical treatment, each lot of 50 cuttings was divided into five replicates of ten cuttings, placed at random in the block of cuttings.

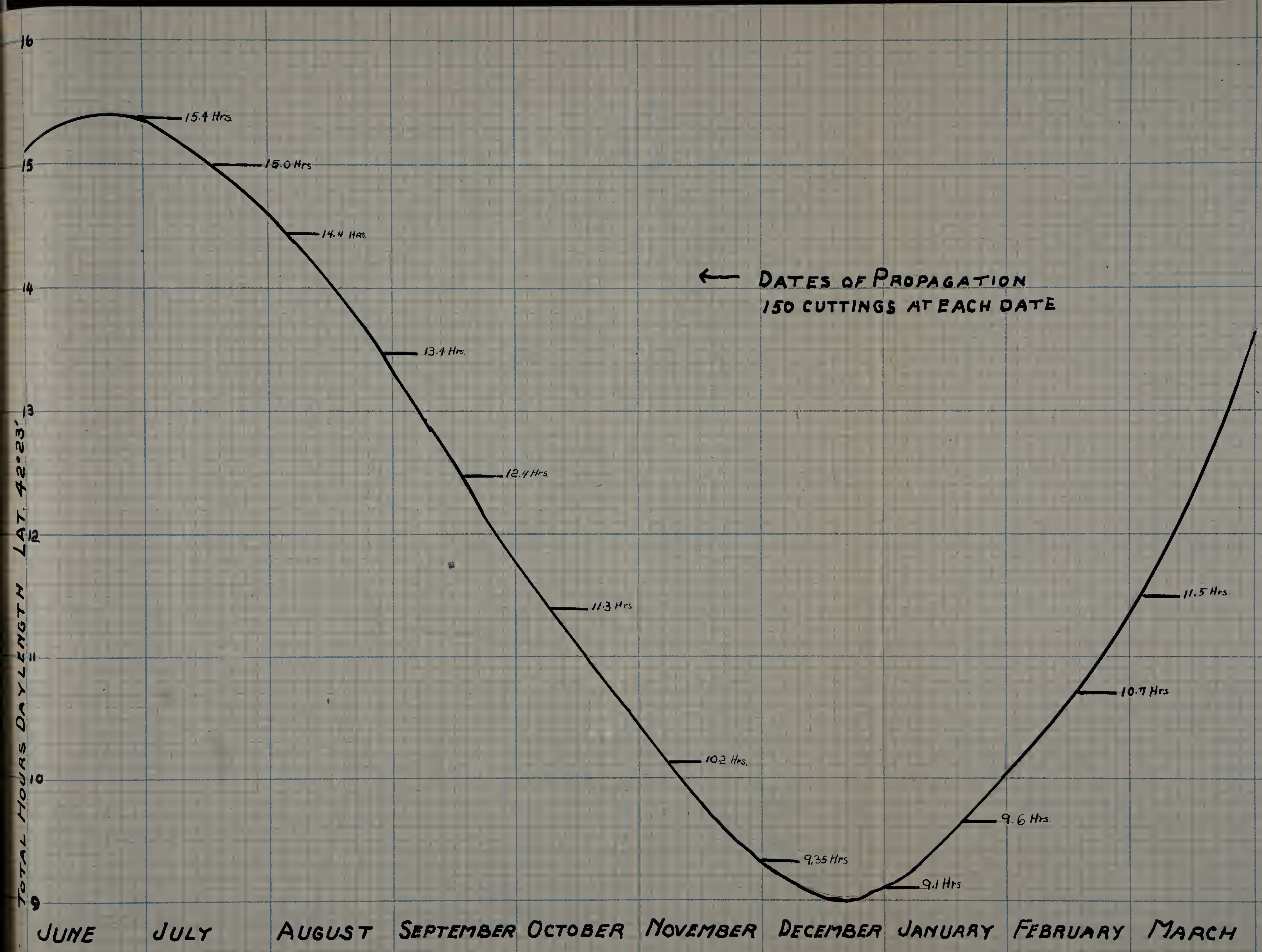
There was room for three lots of cuttings at one time in each section of the bench. By removing the cuttings for examination at the end of six weeks there was ample room for all the cuttings.

The table following (Table IV) shows the arrangement of treatments, replicates and numbers of cuttings used. This is the basis for the analysis of the results.

Table IV

Arrangement to show treatments and number of replicates used

Treatment of Cuttings	Replicates and No. of Cuttings				
	I	II	III	IV	V
Long Day (18 hours)	10	10	10	10	10
Normal Day (Varies with date of propagation)	10	10	10	10	10
Short Day (9 hours)	10	10	10	10	10



DAYLENGTH VARIATIONS - JUNE 1946 TO MARCH - 1947

FIG. 1

(ADAPTED - POST (26))

IV. Results and Discussion

In order to use a statistical treatment it is obvious that the only distinction that can be made is between the number of cuttings which root and the number that failed to root, regardless of cause. It was found that if the cuttings were disturbed frequently there was a discrepancy in the results as the roots were damaged easily. The writer therefore observed the rooting of the first lot of cuttings taken and decided to remove and examine all cuttings after a period of six weeks.

It would be impossible to measure the number of roots per cutting statistically and as this was not the concern of the writer, he only recorded the results as rooted or not rooted.

When the cuttings were removed, the best replicate (10 cuttings) in each treatment was photographed.

1. Statistical Results

The statistical results which follow were tabulated in the following manner:

The cuttings taken for all treatments were arranged in tables so that the variation might be observed in any one treatment throughout the entire experiment. From this arrangement it was possible to determine whether there was a consistent variation in rooting as the daylength which the parent plants received varied and to observe whether there was a consistent variation due to daylength received by the cuttings themselves in the propagating bench. In the case of the nine-hour day cuttings and the 18-hour day cuttings, the daylength received by the cuttings did not vary but the daylength received by the parent plants did. In the case of the normal-day group the daylength received by the parent plant and the cuttings was the same.

The results are also tabulated according to the rooting obtained by varying the daylength of the cuttings in each lot. Here, the long day, short day and normal day cuttings taken at one date are tabulated together and the results may be observed directly from these tables. Tables I, II and III represent the statistical analysis of the individual treatments while Tables IV through XIV represent the comparison between the three treatments at any one date.

The following tables are included to show the effect on the subsequent rooting of the cuttings of the daylength the parent plants were receiving at time of propagation.

Table V

Rooting of Cuttings as Affected by Daylength on the Parent Plant and Nine Hour Day in Cutting Bench.

		Replicate							
Group	Daylength	1	2	3	4	5	Sum	Av.	Date Prop.
I	15.4 hrs.	1	6	1	2	1	11	2.2	6/24/46
II	15.0 "	7	1	4	6	2	20	4.0	7/15/46
III	14.3 "	8	4	3	4	4	23	4.6	8/5/46
IV	13.5 "	6	6	7	8	6	33	6.6	8/26/46
V	12.5 "	7	5	7	5	7	31	6.2	9/16/46
VI	11.4 "	7	8	3	8	7	33	6.6	10/6/46
VII	10.0 "	7	7	9	6	6	35	7.0	11/8/46
VIII	9.3 "	9	6	7	6	7	35	7.0	11/30/46
IX	9.1 "	8	6	7	8	8	37	7.4	12/26/46
X	9.6 "	7	8	9	10	8	42	8.4	1/22/46
Totals		67	57	57	63	56	300		

Complete Analysis of Variance

Variation Due to	D/F	Sum of Squares	Mean Square	F	s
Blocks	4	9.2	2.3	0.8+	
Treatment	9	154.2	17.1	6.3*	
Error	36	96.6	2.7		1.63
Total	49	260.0			

* - significant at 5% level

Table VI

Variation in Rooting of Cuttings as Affected by Daylength on the Parent Plant and Normal Day in Cutting Bench

Group	1	2	3	4	5	Sum	Ave.	Date of Propagation	Treatment of Cuttings (Normal Day)
I	2	4	0	4	1	11	2.2	6/24/46	15 hrs. daylight
II	6	0	1	2	1	10	2.0	7/15/46	14.2 " "
III	4	2	6	3	2	17	3.4	8/5/46	13.0 " "
IV	4	2	1	8	4	19	3.8	8/26/46	12.4 " "
V	4	3	4	5	3	19	3.8	9/16/46	11.4 " "
VI	5	1	3	4	6	19	3.8	10/6/46	10.4 " "
VII	6	3	4	5	3	21	4.2	11/6/46	9.6 " "
VIII	8	8	3	6	6	31	6.2	11/30/46	9.3 " "
IX	8	9	4	7	5	33	6.6	12/26/46	9.6 " "
X	9	7	10	9	9	44	8.8	1/22/46	9.9 " "
Totals	56	39	36	53	40	224			

These figures for Table VI are used in the complete analysis of variance which follows.

Variation Due to	D/F	Sum of Squares	Mean Square	F	s
Blocks	4	28.2	7.05	3.03	
Treatment	9	222.0	24.7	12.4 *	
Error	36	73.8	2.05	1.46	
Totals	49	324.0			

* Significant at 5% level

Table VII

Variation in Rooting of Cuttings as Affected by Daylength on the Parent Plant and Eighteen Hour Day in Cutting Bench

Group	Replicates 1	2	3	4	5	Sum	Ave.	Date of Propagation
I	1	1	2	3	0	7	1.4	6/24/46
II	1	0	0	4	5	5	1.0	7/15/46
III	4	4	2	4	3	17	3.4	8/5/46
IV	3	4	4	2	6	19	3.8	8/26/46
V	3	2	2	1	2	10	2.0	9/16/46
VI	4	2	5	3	2	16	3.2	10/6/46
VII	2	2	0	4	3	11	2.2	11/8/46
VIII	6	3	6	4	6	25	5.0	11/30/46
IX	6	3	5	6	5	25	5.0	12/26/46
X	2	4	4	6	6	22	4.4	1/22/47
Totals	32	25	30	37	38	162		

Complete Analysis of Variance for Long Day Cuttings

Variation Due to	D/F	Sum of Squares	Mean Square	F	S
Blocks	4	27.5	6.9	3.06	
Treatment	9	93.3	10.37	5.40*	
Error	36	71.6	1.9		1.378
Totals	49	192.4			

* Significant at 5% level

The comparison between rooting of cuttings as related to the photoperiodic treatment of the cuttings is presented in the following group of tables. Each of the following tables represents a group of 150 cuttings, taken at the stated date and daylength. Accompanying each table is a plate which shows the variation in number of roots that are formed on the cuttings. Each group was examined at the end of six weeks and does not indicate the total possible rooting but only the rooting in a six weeks period. Each replicate represents ten cuttings.

Table VIII (Plate 1)

Lot

Treatment	Replicates 1	2	3	4	5	Sum	Ave.
Long Day (18 hrs.)	1	1	2	3	0	7	1.4
Normal Day (15 hrs.)	2	4	0	4	1	11	2.2
Short Day (9 hrs.)	1	6	1	2	1	11	2.2

Date Propagated: June 24, 1946

Date Examined: July 28, 1946

This was the first group of cuttings propagated. These cuttings were examined beginning the fourth week to observe the optimum time for examining all cuttings. It was found from these results that it was necessary to keep all following groups in the propagating bench six weeks. The photograph was taken at the end of eight weeks, and although the cuttings were callused and still healthy, there was little sign of rooting. New top growth was evident.

Table IX

Lot

	Replicates						
Treatment	1	2	3	4	5	Sum	Ave.
Long Day (18 hrs.)	1	0	0	0	4	5	1.0
Normal Day (15 hrs.)	6	0	1	2	1	10	2.0
Short Day (9 hrs.)	7	1	4	6	2	20	4.0

Date Propagated: July 15, 1946

Date Examined: August 25, 1946

Table X

Propagation Group III (Plate II)(Plate III)

Treatment	1	2	3	4	5	Sum	Ave.
Long Day (18 hrs.)	4	4	2	4	3	17	3.4
Normal Day (14.3 hrs.)	4	2	6	3	2	17	3.4
Short Day (9 hrs.)	8	4	3	4	4	23	4.6

Date Propagated: August 5, 1946

Date Examined: September 16, 1946

Compare the rooting of this group with Plate I. Flower buds also occur here only on those cuttings receiving nine hours daylight.

Table XI

Propagation Group IV

Treatment	1	2	3	4	5	Sum	Ave.
Long Day (18 hrs.)	3	4	4	2	6	19	3.8
Normal Day (13.5 hrs.)	4	2	1	8	4	19	3.8
Short Day (9 hrs.)	6	6	7	8	6	33	6.6

Date Propagated: August 26, 1941

Date Examined: October 9, 1946

Table XII

Propagation Group V (Plate IV)

Treatment	1	2	3	4	5	Sum	Ave.
Long Day (18 hrs.)	3	2	2	1	2	10	2.0
Normal Day (12.5 hrs.)	4	3	4	5	3	19	3.8
Short Day (9 hrs.)	7	5	7	5	7	31	6.2

Date Propagated: September 18, 1946

Date Examined: October 30, 1946

Again cuttings receiving nine hours in one case produced roots at locations other than at the base of the cutting and an increase over Plate II on the roots per cutting in both normal and short day cuttings.

Table XIII

Propagation Group VI (Plate V)

Treatment	Replicates 1	2	3	4	5	Sum	Ave.
Long Day (18 hrs.)	4	2	5	3	2	16	3.2
Normal Day (11.4 hrs.)	5	1	3	4	6	19	3.8
Short Day (9 hrs.)	7	8	5	8	7	33	6.6

Date Propagated: October 9, 1946

Date Examined: November 26, 1946

Table XIV

Propagation Group VII

Treatment	Replicates 1	2	3	4	5	Sum	Ave.
Long Day (18 hrs.)	2	2	0	4	3	11	2.2
Normal Day (10 hrs.)	6	3	4	5	3	21	4.2
Short Day (9 hrs.)	7	7	9	6	6	35	7.0

Date Propagated: November 8, 1946

Date Examined: December 24, 1946

Table XV

Propagation Group VIII (Plate VI)

Treatment	Replicates 1	2	3	4	5	Sum	Ave.
Long Day (18 hrs.)	6	3	6	4	6	25	5
Normal Day (9.3 hrs.)	8	8	3	6	6	31	6.2
Short Day (9 hrs.)	9	6	7	6	7	35	7.0

Date Propagated: November 30, 1946

Date Examined: January 11, 1947

Note the similarity in rooting between the normal and nine hour day cuttings as compared with those receiving eighteen hours daylight. Compare the amount of rooting with plates I, II, and III.

Table XVI

Propagation Group IX (Plate VII)

Treatment	Replicates 1	2	3	4	5	Sum	Ave.
Long Day (18 hrs.)	6	3	5	6	5	25	5
Normal Day (9.6 hrs.)	8	9	4	7	5	33	6.6
Short Day (9 hrs.)	8	6	7	8	8	37	7.4

Date Propagated: December 26, 1946

Date Examined: February 8, 1946

Table XVII

Propagation Group X (Plate VIII)

Treatment	Replicates 1	2	3	4	5	Sum	Ave.
Long Day (18 hrs.)	2	4	4	6	6	22	4.4
Normal Day (10.5 hrs.)	9	7	10	9	9	44	8.8
Short Day (9 hrs.)	7	8	9	10	8	42	8.4

Date Propagated: January 22, 1947

Date Examined: March 8, 1947

This group shows the greatest amount of roots per cutting and is apparently the culmination of the effect of the decreasing daylengths on the parent plant. Flower buds are present on both the nine hour and normal day cuttings.

Plate I

Top - Cuttings taken June 24, examined and photographed at the end of eight weeks. Cuttings received nine hours daylight.

Bottom - Cuttings propagated June 24, examined at the end of eight weeks. Cuttings received eighteen hours daylength.

Plate II

Top - Cuttings taken August 5 at the end of six weeks which received only nine hours daylight.

Middle - Cuttings taken August 5 which received normal daylight (14.3 hrs.).

Bottom - Cuttings taken August 5 which received 18 hours daylight.

Plate III

Cuttings which had rooted on September 18 and allowed to remain in the sand two weeks to observe the growth of roots under the various daylengths.

Top - Cuttings which received nine hours light.

Middle - Cuttings which received normal daylength.

Bottom - Cuttings which received eighteen hours light.

Plate IV

Cuttings propagated September 18 and examined October 30.

Top - Cuttings which received 18 hrs. daylight.

Middle - Cuttings which received normal daylight (12.5 hours).

Bottom - Cuttings which received nine hours daylight.

Plate V

Cuttings propagated October 9 at the end of six weeks.

Top - Cuttings which received nine hours daylight.

Middle - Cuttings which received normal (11.4 hrs.) daylight.

Bottom - Cuttings which received eighteen hours daylight.

Plate VI

Cuttings propagated November 30 at the end of six weeks.

Top - Cuttings which received nine hours daylight.

Middle - Cuttings which received normal (9.3 hours.) daylight.

Bottom - Cuttings which received 18 hours daylight.

Plate VII

Cuttings propagated December 26 at the end of six weeks.

Top - Cuttings which received nine hours daylight.

Middle - Cuttings which received normal (9.6 hours) daylight.

Bottom - Cuttings which received 18 hours daylight.

Plate VIII

Cuttings propagated January 22 and examined at end of six weeks.

Top - Cuttings receiving nine hours daylight.

Middle - Cuttings receiving normal (10.2) hours daylight.

Bottom - Cuttings receiving eighteen hours daylight.

2. Discussion

The most striking result shown in the preceding tables (I, II, III) is that there is a definite effect on the rooting of gardenia cuttings when the parent plants receive different daylengths. On the shortest days of the year, the best results are obtained, while the poorest results are obtained on the longest days. Again, this effect is discernible regardless of the treatment of the cuttings. Whether the cuttings received short or long days, there was an increase in the number of cuttings which rooted in six weeks as the days grew shorter.

To explain this, the author refers to the paper by Moshkov (22) in which he states that stored food is necessary for the initiation of new roots. Kemp (19) also points out that the initiation of roots was dependent on stored food and since hardwood cuttings of lilac required much of this food for development of buds, the cuttings seldom rooted. Softwood cuttings however would root because the stored food was available for root initiation.

In the case of gardenias, as the daylength decreases, there is a corresponding decrease in vegetative growth and an increase in production of flower buds.

With a decrease in vegetative growth, there is more stored food available and the wood becomes as we term it, "hard". In the summer it was observed that the growth was light green and very succulent. This wood was used in the case of the cuttings taken in June and July. It will be noticed from the results that few of the cuttings rooted when the parent plants were receiving long daylengths. In opposition to this, wood taken from plants in December and January was dark green and "hardened". At this time the cuttings rooted successfully in six weeks. This change in the type of vegetative growth of plants as affected by daylength is discussed at length by Garner and Allard (12).

In general, they state that daylength will regulate the vegetative response of plants and in the case of plants that flower under short days, a long day will result in optimum vegetative growth. Woody plants, one of which is the gardenia, occupy an intermediate position regarding vegetative growth and an indefinite rate of growth is induced by long days while growth is completely inhibited by short days and flower production is stimulated. It was during this period of short days when vegetative growth was at a minimum that the best rooting results were obtained.

In discussing the effect of light period on the cuttings themselves, one might automatically assume that with extra light, the best rooting would always occur. However, nowhere in the literature can one find any statement that would corroborate this theory. On the contrary, Garner and Allard (12) point out that root growth and shoot growth are not necessarily "contemporaneous" and that a decrease in shoot growth due to short days does not indicate a decrease in root growth. They cite the growth of a cutting of Biloxi soy bean which made no new topgrowth during the winter but upon examination of the roots in the spring, they found a mass of roots altogether out of proportion to the topgrowth. In other instances they have found that daylengths unfavorable to topgrowth, increased and intensified root growth. It is interesting to read further that these authors state that under daylength which is optimum for vegetative growth, the food stream is directed toward the tip and utilized for vegetative growth, but a change in daylength in the opposite direction will cause the "stream of food" to move downward, resulting in the formation of lower branches, bulbs, tubers and roots.

It was further observed that in the cuttings which received additional light there was a tendency for roots to form irregularly and to be somewhat distorted (Plate 10). The roots generally formed first below a node and continued growth in that direction whereas little growth of roots was observed in the case of roots not below a node.

Priestly (27) points out that with such cuttings as Coleus, root formation was greatly influenced by the growing leaves and root production lagged behind on the sides of the stem not subtending a leaf, probably indicating a hormone action rather than a simple food condition since the stems were full of carbohydrates.

Returning to the tables (IV through XIII) the writer finds that at no time did cuttings which received extra light root as well as did those which received only nine hours of light. However, the cuttings which received the normal daylength rooted as well as those which received only nine hours if the normal daylength was approximately nine hours. The cuttings receiving normal daylength compared somewhat in rooting with the cuttings receiving 18 hours when the daylength approximated 15 hours.

The author suggests the following possible reasons for the variations in rooting:

With a decrease in daylength, vegetative growth was reduced in the parent plants, resulting in an increase of stored food which may be utilized in initiation of roots.

With the decrease in daylength the change from vegetative to reproductive growth and flower bud initiation may release auxin compounds formed in the leaves.

Swingle (34) points out that there is a striking similarity in the initiation of flower buds and in the initiation of roots.

A shortening of the daylength results in a change in the "hardness" of the tissues used for propagation which may influence the rooting.

The fact that the cuttings require at least four weeks to produce sufficient roots for water intake may result in the death of succulent summer cuttings due to attack by fungi before they are able to root.

It has been suggested that growth enzymes accumulate in the leaves of some plants in the fall (27). This may be the case with cuttings of gardenia, and this again would be associated with flower-bud formation.

These five theories presented are all based on similar results and theories expressed by other investigation.

As to why the cuttings which received nine hours of light rooted better than those receiving 18 hours of light, the following explanations are suggested:

As has been shown in the literature, extra light would increase the shoot growth but not necessarily increase root growth. In this case, those cuttings which received only nine hours light did not produce any new growth while rooting but rooted well. Those which received 18 hours of light produced new top growth but poor roots, possibly the production of new shoots at the expense of new roots.

Cuttings which received nine hours of daylight would produce flower buds while rooting but those which received 18 hours of light made only vegetative growth. There may be a connection between flower-bud formation and growth substances.

Stoutemyer points out an interaction between daylength and growth regulators (32). Zimmerman suggests in personal correspondence (40)an inhibiting of root-producing substances where extra light is used in the propagating bed. This has been noted by the writer in the case of carnation cuttings when continuous light was used.

The application of light to the cuttings might also cause a change in the normal growth conditions in the plant, resulting in a high carbohydrate content in the plant which may discourage rooting, since it recalled that an accumulation of carbohydrates does not necessarily mean the production of conditions favorable to root initiation.

The writer is inclined from all this to hold most strongly to the following:

With a decrease in daylength, there is a change in the plant from the vegetative stage to the reproductive stage, involving the production of root-inducing substances along with flower buds.

In the case of the daylength received by the cuttings, he feels that the added light inhibited root-producing substance, as Sinecost pointed out, cuttings taken when the parent plants were receiving long day-lengths rooted better under the nine hour day than the normal day. But when both received approximately nine hours daylength as well as the parent plants, there was a marked similarity in the rooting.

From these results, it is clear that daylength effects the rooting of gardenia cuttings both through its effect on the parent plant and on the cuttings themselves. Therefore, the writer suggests that it might be feasible to shorten the daylength during the summer months on some of our more difficult species and then take softwood cuttings to observe the effect on the subsequent rooting, or to take cuttings during the summer months and give the cuttings a decreased daylength to facilitate the rooting. Obviously the optimum daylength would have to be determined for each species.

Furthermore, it is shown that the optimum rooting results are obtained from gardenia cuttings when they are taken in the months of December and January since there would naturally be a lag between the effect of the short days on the parent plants and on the cuttings taken from such plants.

It has been suggested to the author by Zimmerman, B.T.I., that work be done to determine the effect of daylength on root promoting substances. By using artificial growth substances, a set of data might be obtained that would indicate whether or not the cuttings receiving excess light lack the ability to root even when root-inducing substances are present or whether they actually lack the natural hormones.

V. Summary

Cuttings of Gardenia jasminoides, Ellis var. Hadley were studied to determine the effects of daylength (photoperiod) on the rooting of the cuttings. It was found desirable to observe both the subsequent effect when the parent plants received varied day-lengths and the variation in rooting when the cuttings were subjected to different photoperiods.

The 150 cuttings were taken every 21 days from June 24, 1946 to March 5, 1947. The cuttings were divided into three lots, one receiving 18 hours of light, one receiving normal day and a third group receiving nine hours of light. Each lot included five replicates of ten cuttings.

The cuttings which received extra light had 15-25 f.c. supplied at the end of the normal photoperiod by a 40 watt Mazda lamp. Cuttings receiving nine hours photoperiod were shaded with a double thick black sateen cloth screen at such time so as to limit the daylength to nine hours. A black screen, hung between the cuttings receiving extra light and those receiving normal or short photoperiods, prevented any undesired light effects on those cuttings.

The cuttings were examined at the end of six weeks and the results recorded as either rooted or not rooted. These results were then submitted to statistical analysis to determine any variation in rooting caused by either effects of daylength on the parent plants or on the cuttings themselves.

The results show that both the daylength received by the parent plants and that received by the cuttings affects the number of cuttings to root in a given length of time.

In the case of the gardenia, the best results were obtained when the cuttings were taken during the shortest days of the year and received nine hours of light during the time of rooting. Even when cuttings were taken at a time when the normal daylength was longer than nine hours, those cuttings which received only nine hours of light daily rooted best.

VI. Conclusions

Gardenia cuttings root best when the parent plants receive short days: This would mean propagating the cuttings in December and January. Cuttings will root when taken at other times.

Additional light does not facilitate the rooting of the cuttings and is of no practical value in propagating gardenias.

Additional light on the cuttings of gardenia causes an unnatural root growth. Nine hours of daylight resulted in thicker individual roots and a more abundant root system (Plate VIII).

When cuttings receive only nine hours of daylight, new top growth does not develop while cuttings receiving 18 hours of daylight produce new top growth and few new roots.

Relative humidity is essential to the propagation of gardenias.

The location of the basal cut may be either below or above the node; there is no variation in the rooting in either case.

Cuttings which received nine hours of light during the propagation period produced flower buds by the time the cuttings had rooted, while those receiving

18 hours of light did not produce flower buds.

The selection of the propagating wood is in the successful rooting of the cuttings.

Propagating wood should be greyish green and just beginning to "harden".

When cuttings receivednine hours of light, they rooted in six weeks, while many cuttings receiving 18 hours of light were alive but unrooted at the end of six weeks, when the parent plants received short days.

Roots were initiated at various points on the stem in the case of cuttings receiving nine hours of light while cuttings receiving 18 hours of light produced roots above the callus only.

While it is possible to set up a statistical analysis on the rooting of cuttings it can be used in comparing rooting or non-rooting of cuttings in a given length of time.

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Approved by:

Charles L. Thayer
Chairman

William L. Doran

Wm G. Colby

Thesis Committee

Date: May 29, 1947.