T H E S I S

on

THE EFFECT OF LIGHT ON THE ROOTING OF SOFTWOOD CUTTINGS

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INTRODUCTION

It has been suggested that the rooting response of leaf cuttings might be influenced by the time of day in which they are made. It might be expected that leaf cuttings made in the morning when the starch content of the leaves is low would show less root development than similar cuttings made in the afternoon when the starch content of the leaves would be relatively high, the leaves having had opportunity to synthesize starch during the day.

Propogation by means of softwood cuttings is often carried on during the winter months when sunlight is of low intensity and short duration. In order to prevent excessive transpiration, cuttings are frequently shaded thus causing a further limitation of the light striking the cuttings during the rooting period. Softwood cuttings propogated during the summer months are usually shaded. Kains (8) states that "Shading, especially of newly made greenwood and leaf cuttings is essential to success because the moisture in the cuttings themselves must not be greatly depleted." These conditions limit the photosynthetic activity of the leaves of the cuttings and consequently limit the quantity of carbohydrates manufactured.

This investigation was undertaken to determine the possible influence on the rooting of softwood cuttings of (1) the time of day that leaf cuttings are made, and (2) the influence of the amount of light striking cuttings during the rooting period.

GENERAL METHODS

Except for varying the quantity of light, commercial methods of handling cuttings of the plants used were adopted. All of the cuttings were rooted in the greenhouse. Sand was used as the rooting medium.

Observations on light intensity were made by means of an actinometer ordinarily used to determine light intensity in photographic work. Although this method measures only the shorter wave lengths of light, it does give a fairly close approximation of the relative difference between the various light conditions. The light intensity can be considered as being inversely proportional to the time required for the sensitized paper to reach the standard color.

The plants and cuttings in continuous artificial light received, in addition to sunlight, the light from a 500 Watt electric lamp suspended about eighteen inches above the plants or cuttings. This treatment raised the temperature about 1° Centigrade.

Comparative starch content was determined by treating the leaves, after the chlorophyll had been extracted by alcohol, in a solution of iodine in potassium iodide.

The dry weight of the samples was determined after drying to constant weight in a vacuum oven at 85° C.

REVIEW OF LITERATURE

It has been found by Kraus and Kraybill (11), Starring (25), Reid (18, 19, 20), and Schrader (22) that a large content of carbohydrates and a relatively small amount of nitrogen was most favorable for root development of tomato cuttings. Similar results were obtained by Starring (25) with cuttings of Tradescantia Virginiani, L. Winkler (26) reports a direct correlation between the starch content and rooting ability of grape cuttings. Smith (24) noted a similar relationship with coleus cuttings. Carlson (2) found that the ability of Dorothy Perkins rose cuttings to root in humid air was associated with high reserve starch content.

Miller (16) found that the starch content of the leaves of corn and the sorghums reached a maximum during the afternoon and a minimum early in the morning.

Long (13) reports that the amount of carbohydrates shown in leaves gradually increased from early morning until the hour following midday. Kokin (10) found that the starch content of leaves was highest between 12:00 and 7:00 o'clock in the afternoon, the exact time depending upon the species of plant used. Mason and Maskell (14) found that the percentage of reserve polysaccharides of leaves of the cotton plant was highest between 3:30 and 5:30 P.M.

Blackman and Matthaei (1) state that the amount of assimilation of carbon dioxide is a measure of light providing that temperature is not a limiting factor. Hendricks and Harvey (7) found that the starch content of Easter Lily leaves grown under continuous artificial light was 6.41% as compared to 2.35% for leaves of plants grown in daylight. Pfeiffer (17) states that "In plants with longer light duration, there is an increase in carbohydrate reserves—". Deats (4) found that the starch content of tomato and pepper plants was directly proportional to the length of day. Harvey (6) working in Minnesota found that cabbage leaves grown in the greenhouse during the winter showed a pronounced absence of sugars. Kraybill (12) reports that shaded portions of apple and peach trees were lower in free reducing sugars and starch than unshaded parts.

Gourley and Nightingale (5) working with several species of plants state that "The root systems of all the herbaceous plants studied were materially reduced by growing the plants in shade". Similar results on the effect of shading upon the root systems of plants have been found by Maximow and Lebedincev (15) and Shirley (25).

Pfeiffer (17) found that the root system of four o'clock and tomato plants increased as the period of daily illumination increased. Crist and Stout (3) have shown that in lettuce and radish plants, the top-root ratio was lowered as the period of daily illumination was lengthened. Reid (21), using a large number of plants found that root growth of seedlings was strongly favored by light. She also noted that the ratio of shoots to roots is lower in months having long days.

Zimmerman (27) states that "Where wilting can be prevented, the larger the leaf areas on greenwood cuttings, the quicker the root growth." With cuttings of the black currant, he found that the presence of leaves was essential to rooting in the summer, but that as autumn approaches, a time is reached when leaves can be dispensed with (28). Kemp (9) working with lilac cuttings reached the conclusion that "successful rooting would seem to be correlated in the first place with their power of continuous assimilation and in the second place with the fact that food materials were not drawn upon by developing buds."

Reid (18, 19, 20) found that root development of tomato cuttings was considerably greater in the light than in the dark. This was most pronounced in cuttings low in carbohydrates.

RESULTS AND DISCUSSION

EFFECT OF TIME OF DAY THAT LEAF CUTTINGS ARE MADE UPON ROOTING

Cuttings were taken from plants of Rex begonia (Begonia Rex, Putz) that had been exposed to sunlight during the day and also from plants that had been in the dark during the previous forty-eight hour period. There was no apparent difference in the rooting response of these two lots of cuttings.

Two possible explanations are suggested for the failure of the cuttings made from the daylight plants to show the best rooting of the two lots.

1. The light was of low intensity and short duration during this period. Starch tests showed no starch present in the leaves that had been in the dark, and only a small

amount in the leaves that had been in the light.

2. Since the cuttings consist entirely of leaf tissue, it is possible that the starch that would accumulate during one day, even when photosynthesis was proceeding rapidly, would be very insignificant in comparison with the total amount of starch synthesized during the rooting period.

With these points in view, the following experiments were performed:

Plants were placed under a 500 Watt light for 24 hours with one-half of the leaves of each plant in darkness. The iodine test showed a high starch content in the leaves that had been in the light and an absence of starch in the leaves that had been in the dark. Cuttings made from the leaves of these plants were rooted under the 500 Watt light as well as in daylight. Table I shows the comparative light intensities in the two conditions.

TABLE I

AVERAGE NUMBER OF SECONDS FOR SENSITIZED PAPER TO REACH THE STANDARD COLOR

	7:30 AM	9:00 AM	11:00 AM	1:00 PM	3:00 PM	5:00 PM	During the Night
Under the 500 Watt Light	68	12	8	7	10	49	85
Daylight	128	15	9	8	11	67	Dark

As shown in Table II and Figs. 1 and 2, the opportunity of the leaves to accumulate starch previous to the time the cuttings are made had no significant effect on the rooting of these cuttings. However the cuttings exposed to the greater amount of light showed a decidedly superior development of new growth.

TABLE II

THE EFFECT OF LIGHT ON THE ROOTING OF CUTTINGS OF REX BEGONIA ROOTING PERIOD 23 DAYS

		Lot No.	No. of Cuttings	Percent Rooting	Average Dry Wt. of new Growth per cutting grams
Leaves under 500 Watt Light for 24 Hours	Cuttings rooted under 500 Watt Light	I	30	93	.0154
	Cuttings rooted in Daylight	II	30	73	.0097
Leaves in Dark for 24 Hours	Cuttings rooted under 500 Watt Light	III	30	100	.0157
	Cuttings rooted in Daylight	IV	30	93	.0104

The low percentage of rooting in Lot II cannot be attributed to the treatment received since some of these cuttings died from an attack of damping-off disease.

The actual relative difference between cuttings rooted under continuous artificial light and daylight was even greater than the figures indicate since the base of the cutting from which the new growth arises is included under new growth. The base of the cutting is included here because it is practically impossible to separate it from the new growth.

EFFECT OF CONTINUOUS ARTIFICIAL LIGHT UPON ROOTING

The results shown in Table II indicate that continuous illumination favors root development of Rex Begonia Cuttings. The following experiments were performed in order to determine whether a similar condition exists in cuttings of Melior begonia (Begonia socotrana, Hook) and Wandering Jew (Tradescantia fluminensis, Vell.) and also to further verify the results obtained with Rex begonia.

The cuttings of Melior begonia showed the most root development under continuous artificial light (Table III and Fig. 3). The stimulation of root development caused by increased illumination is especially significant because cuttings from this plant are rather difficult to root, and shading is usually practiced to prevent excessive transpiration during the rooting period. About 50% of the leaf surface of the cuttings placed under the 500 Watt light developed a red color while the cuttings in daylight showed onły a trace of this red color. This color is probably caused by a relatively high carbohydrate accumulation.

TABLE III

EFFECT OF LIGHT ON THE ROOT DEVELOPMENT OF CUTTINGS OF MELIOR BEGONIA. ROOTING PERIOD 57 DAYS

	Number of Cuttings	Percent Rooting	Average dry weight of Roots per Cutting Grams
Cuttings Rooted Under 500 Watt Light	20	75	.0119
Cuttings Rooted in Daylight	21	86	.0084

The effect of light on the root development of cuttings of Wandering Jew are shown in Table IV and Figs. 4 and 5. The depressing effect of continuous artificial light on the root development of cuttings of Wandering Jew was probably caused by injury to the leaves which was occasioned by this treatment (Fig. 4). This is not surprising since this plant seems to be best adapted to shady locations.

TABLE IV

EFFECT OF LIGHT ON ROOT DEVELOPMENT OF CUTTINGS OF WANDERING JEW. ROOTING PERIOD - - 21 DAYS

	Number of Cuttings	Percent Rooting	Average dry weight of Roots per Cutting Grams
Cuttings rooted under 500 Watt Light	41	100	.0024
Cuttings Rooted in Daylight	41	100	.0043

The results obtained with Rex begonia are shown in Table V. These results are similar to those previously noted (Table II).

TABLE V

THE EFFECT OF LIGHT ON THE ROOTING OF CUTTINGS OF REX BEGONIA. ROOTING PERIOD 33 DAYS

	Number of Cuttings	Percent Rooting	Average dry weight of New Growth per Cutting - Grams
Cuttings Rooted under 500 Watt Light	26	100	.0312
Cuttings Rooted in Daylight	25	100	.0214

THE EFFECT OF SHADING UPON THE ROOTING RESPONSE OF CUTTINGS.

Shading of softwood cuttings is usually practiced during the summer months in order to prevent excessive transpiration. The propogating frame is sometimes covered with glass, but the additional expense usually limits its use. When glass is used, some form of shade is usually applied during the daytime. These practices suggested the following questions: Is it possible for shading by excluding some light, to inhibit root development of cuttings? Does shading cause a higher percentage of rooting but a smaller weight of roots per cutting? Is it possible that shading is desirable for cuttings of some plants but detrimental to others? What is the comparative efficiency of lath and muslin? How much light should be excluded if shading is to be practiced? What effect does extreme shading have, i. e. darkness? Is better root development obtained when glass is used instead of shading to prevent excessive water loss? Is glass plus shade better than either one alone? This phase of the investigation was undertaken in an attempt to throw some light on the question raised.

Eight propagating frames, each three feet long, two foot wide, and one foot high, were constructed. The sides of these frames were of solid board. Table VI shows the coverings of each of these frames.

Light and temperature readings were taken on various days during the course of the experiment. These readings were made between the hours of 8:00 A. M. and 4:30 P. M. The averages of these readings are given in Table VI.

TABLE VI

TEMPERATURE AND LIGHT READINGS IN VARIOUS LIGHT CONDITIONS - AVERAGE OF 14 READINGS

Frame No.	Covering	Average Temperature °C.	Average Number of Seconds for Sensitized Paper to Reach Standard Color
1	No Covering	26	6.3
2	1 inch Lath spaced 1 inch apart	26.1	13.6
3	One Layer of Muslin	25.8	17.3
4	Four Layers of Muslin	24.7	104.8
5	Glass	27.0	11.9
6	Glass & Lath	25.7	21.3
7	Glass & Muslin	26.2	26.1
8	Board with Small Opening to Allow for Ventilation	24.6	6 Hours --Nearly complete darkness

Twenty-five cuttings of each of the following plant materials were set in each of the frames:

1. Wandering Jew — Tradescantia fluminensis, Vell.
2. German Ivy — Senecio Mikanioides, Otto.
3. Forget-Me-Not — Myosotis sylvatica, Hoffm.

4.	Dusty Miller	Lychnis Coronaria, Desr.
5.	Snap Dragon	Antirrhinum Majus, Linn.
6.	Common Privet	Ligustrum Vulgare, Linn.
7.	Privet	Ligustrum Stauntoni, DC.
8.	Laurristinus	Prunus Laurocerosus, Linn.

All of the cuttings were set between March 28 and April 1.

Tables VII to XIV inclusive show the results obtained with these cuttings. Figs. 6 to 17 inclusive illustrate the differences in rooting obtained under the different conditions with Wandering Jew, German Ivy, and Forget-Me-Not.

The relatively low percentage of rooting obtained with Dusty Miller was probably due to accidentally allowing the cuttings to become too dry at the start of the experiment. About a month later, cuttings of this plant wereset under the same conditions but were more carefully watered. Ninety-five per cent of these cuttings rooted (except under solid board where no rooting was obtained).

It is interesting to note that cuttings of Snap Dragon and Dusty Miller made larger top growth under glass.

TABLE VII

EFFECT OF SHADING ON THE ROOTING OF WANDERING JEW. ROOTING PERIOD - 25 DAYS

Frame No.	Covering	Percent Rooting	Average dry weight of Roots per Cutting Grams
1	No Covering	100	.0109
2	Lath	92	.0045
3	1 Layer of Muslin	96	.0041
4	4 Layers of Muslin	100	.0035
5	Glass	100	.0072
6	Glass & Lath	100	.0049
7	Glass & Muslin	100	.0035
8	Solid Board	0	0

TABLE VIII

EFFECT OF SHADING ON THE ROOTING OF GERMAN IVY.

ROOTING PERIOD - 26 DAYS

Frame No.	Covering	Percent Rooting	Average dry weight of Roots per Cutting-Grams
1	No Covering	100	.0072
2	Lath	100	.0047
3	1 Layer of Muslin	100	.0056
4	4 Layers of Muslin	100	.0010
5	Glass	100	.0064
6	Glass & Lath	100	.0027
7	Glass & Muslin	100	.0032
8	Solid Board	0	0

TABLE IX

EFFECT OF SHADING ON THE ROOT OF FORGET-ME-NOT

ROOTING PERIOD - 35 DAYS

Frame No.	Covering	Percent Rooting	Average dry weight of Roots per Cutting-Grams
1	No Covering	96	.0194
2	Lath	96	.0172
3	1 Layer of Muslin	88	.0126
4	4 Layers of Muslin	96	.0037
5	Glass	92	.0150
6	Glass & Lath	100	.0075
7	Glass & Muslin	92	.0088
8	Solid Board	0	0

TABLE X

EFFECT OF SHADING ON THE ROOTING OF DUSTY MILLER

ROOTING PERIOD - 48 DAYS

Frame No.	Covering	Percent Rooting	Average dry weight of Roots per Cutting-Grams
1	No Covering	64	.0259
2	Lath	40	.0096
3	1 Layer of Muslin	36	.0082
4	4 Layers of Muslin	60	.0014
5	Glass	52	.0068
6	Glass & Lath	44	.0045
7	Glass & Muslin	52	.0027
8	Solid Board	0	0

TABLE XI

EFFECT OF SHADING ON THE ROOTING OF SNAP DRAGON

ROOTING PERIOD - 55 DAYS

Frame No.	Covering	Percent Rooting	Average dry weight of Roots per Cutting-Grams
1	No Covering	44	.0101
2	Lath	32	.0047
3	1 Layer of Muslin	36	.0077
4	4 Layers of Muslin	60	.0009
5	Glass	80	.0066
6	Glass & Lath	80	.0082
7	Glass & Muslin	48	.005
8	Solid Board	0	0

TABLE XII

EFFECT OF SHADING ON THE ROOTING OF COMMON PRIVET

(L. VULGARE) ROOTING PERIOD - 120 DAYS

Frame No.	Covering	Percent Rooting	Average dry weight of Roots per Cutting-Grams
1	No Covering	36	.051
2	Lath	60	.054
3	1 Layer of Muslin	80	.068
4	4 Layers of Muslin	56	.015
5	Glass	80	.089
6	Glass & Lath	68	.044
7	Glass & Muslin	52	.023
8	Solid Board	0	0

TABLE XIII

EFFECT OF SHADING ON THE ROOTING OF PRIVET

(L. STAUNTONI). ROOTING PERIOD - 120 DAYS

Frame No.	Covering	Percent Rooting	Average dry weight of Roots per Cutting-Grams
1	No Covering	36	.051
2	Lath	48	.024
3	1 Layer of Muslin	64	.039
4	4 Layers of Muslin	48	.005
5	Glass	72	.057
6	Glass & Lath	60	.039
7	Glass & Muslin	64	.029
8	Solid Board	0	0

TABLE XIV

EFFECT OF SHADING ON THE ROOTING OF LAURUSTINUS

ROOTING PERIOD - 120 DAYS

Frame No.	Covering	Percent Rooting	Average dry weight of Roots per Cutting-Grams
1	No Covering	20	.094
2	Lath	12	.020
3	1 Layer of Muslin	32	.088
4	4 Layers of Muslin	84	.029
5	Glass	48	.053
6	Glass & Lath	28	.051
7	Glass & Muslin	48	.056
8	Solid Board	0	0

Weight of Roots as Influenced by Shading

Except in the case of the privets, the average dry weight of roots per cutting was greatest in the uncovered lots. Shading with four layers of muslin resulted in a much smaller weight of roots per cutting than was obtained in the lots with no covering or where lath or one layer of muslin was used, except in the lath covered lot of Laurustinus which showed a smaller weight of roots per cutting than the lot covered with four layers of muslin. In the cuttings not under glass, the dry weight of the roots produced, seemed to be, in general, proportional to the amount of light received during the rooting period.

Percentage of Rooting as Influenced by Shading

In the case of the privets, the shaded lots showed a higher percentage of rooting than was obtained in the uncovered lots. The uncovered lot of Laurustinus showed a smaller percentage of rooting than the lot under four layers of muslin but there was no significant difference between the lots covered with lath or one layer of muslin and the uncovered lot. The uncovered lots of cuttings probably suffered more from excessive transpiration, thus accounting for the lower percentage of rooting in the privets and Laurustinus. In the other plants, the percent rooting was practically the same in the shaded and unshaded lots.

Effect of Glass on Rooting

Except in the Privets, the cuttings under glass showed less root development than did the uncovered lots. The smaller weight of roots per cutting obtained under glass can probably be accounted for by the fact that glass excludes a portion of the light (Table VI).

The percent rooting obtained under glass was somewhat higher than the other lots in the case of the Privets, Snap Dragon and Laurustinus. Some of the cuttings from these plants apparently died from loss of mositure in the lots not protected by glass. Glass had no effect on the percent rooting obtained with the other plants when compared with the cuttings not under glass.

Glass alone showed greater dry weight of roots per cutting than glass and lath or glass and muslin, but there was no difference in percentage of rooting. In general, the cuttings under glass alone showed a somewhat larger dry weight of roots per cutting and a slightly higher percentage of roots than either lath alone or muslin alone.

Comparison of Lath and Muslin

There was very little difference in weight of roots or percentage of rooting between lath alone and one thickness of muslin. Muslin excludes somewhat more light but it is possible that the cuttings under lath suffered more from water loss. Under glass, there was no significant difference in percentage of rooting but the cuttings under lath showed somewhat greater dry weight of roots. Lath allows more light to pass through and since moisture is less of a problem under glass, it is probable that greater light intensity accounts for the larger root development under lath.

Effect of Nature of Plant

It is evident from the foregoing discussion that all plants did not respond in a like manner. This is probably due to difference in resistance to transpiration from the leaves of the cuttings. The cuttings that rooted slowly seemed to require protection to secure the most successful rooting. The plants used in this experiment can be divided into three groups as regards their behavior with respect to light intensity.

Group I. Cuttings that produced largest root development when receiving most light without reduction in percentage of rooting.

1. Dusty Miller

2. Wandering Jew

3. German Ivy

4. Forget-Me-Not

Group II. Cuttings generally show greatest dry weight of roots under conditions of most light but somewhat greater percentage of rooting when protected.

1. Snap Dragon.

Group III. Percentage of rooting, and often weight of roots, less when least protected from water loss.

1. Laurustinus

2. Privet (L. Stauntoni)

3. Common Privet (L. Vulgare)

Under glass, the cuttings in Group III produced the greatest weight of roots in the higher light intensities. This is especially true in the privets (Tables XII and XIII). It is possible that the greatest success with these plants would be obtained if the cuttings were protected against water loss during the first part of the rooting period, thus allowing the cuttings to establish themselves and insure a good percentage of rooting; and then during the latter part of the rooting period, to allow the cuttings to remain uncovered. Unfortunately, a study of this was not made.

Effect of Darkness on Rooting

The failure of any of the cuttings to root in the darkness was very striking. Reid (18, 19, 20) obtained some rooting with tomato cuttings in the dark although the amount of rooting was considerably less than in the light. The failure of the results reported herein to harmonize with those of Reid can probably be explained by the fact that tomato cuttings strike root quickly and the rather large stem can furnish sufficient food reserves to enable the cutting to produce roots. In this experiment, the cuttings that root rapidly had only a small amount of stem tissue. The cuttings that did have a comparatively large amount of stem tissue were slow rooting species.

Relation of Photosynthesis to Rooting

The complete absence of rooting in the dark shows that the initial supply of food reserves in the cuttings was not sufficient to enable the cuttings to develop them This indicates that the rooting of softwood cuttings is at least partially dependent upon the food materials synthesized by the leaves during the rooting period. The larger weights of roots obtained, when moisture was not the limiting factor, in cuttings exposed to greater light intensities gives further credence to this view.

It has been pointed out that a large supply of carbohydrate reserves in cuttings is most favorable for root development (2, 11, 18, 19, 20, 22, 25, 26). Although no chemical studies were made in this connection, it is reasonable to assume that the generally superior rooting obtained in the lots of cuttings receiving the most light was the result of a greater supply of carbohydrates available, since photosynthesis of carbohydrates proceeds more rapidly under conditions of greater light (1, 4, 6, 7, 12, 17).

Zimmerman (27, 28) reports that a large leaf surface, where wilting can be prevented, facilitates the rooting of cuttings but that as autumn approaches, leaves are not as essential to success. It appears reasonable to believe that the increased rooting obtained with a greater number of leaves can be attributed to the greater supply of food reserves synthesized by the larger leaf surface during the rooting period. As autumn approaches, leaves become less essential, possibly because there is sufficient food stored in the stem by this time of the year.

Locality and Time of Year

The cuttings used to study the effect of shading were set between March 28 and April 1, 1929 in a greenhouse at Corvallis, Oregon. The rooting period lasted from 25 to 120 days, depending upon the species of plant used (Tables VII to XIV). It is obvious that if the cuttings were set about a month or two later in a hotter part of the country, more of the cuttings would probably require protection against water loss, although the average temperature recorded during the day in this experiment was quite high (Table VI). On the other hand, if this experiment was carried on during the winter months, it might be expected that shading would become less essential.

SUMMARY AND CONCLUSIONS

1. Initial starch content has no apparent effect on the rooting of cuttings of Rex Begnaia. This indicates that the time of day that these cuttings are made is a negligible factor in their root development.

2. Continuous artificial light stimulated root development of Rex and Melior begonias but had a depressing effect on the rooting of cuttings of Wandering Jews.

3. Shading decreased the weight of roots produced by cuttings except in species that show comparatively little resistance to water loss.

4. Cuttings with a long rooting period seemed to require protection against excessive transpiration to insure the most successful rooting.

5. No rooting was obtained in the dark.

6. The weight of roots produced under four layers of muslin was very small.

7. Somewhat better root development was produced under glass than under lath or muslin.

8. Little difference between lath and muslin was noted.

9. The results reported herein indicate that rooting of softwood cuttings, when moisture is not a limiting

factor, is at least partially dependent upon the light received during the rooting period. Light seems to have its influence through causing an increase in manufacture of carbohydrates by the leaves.

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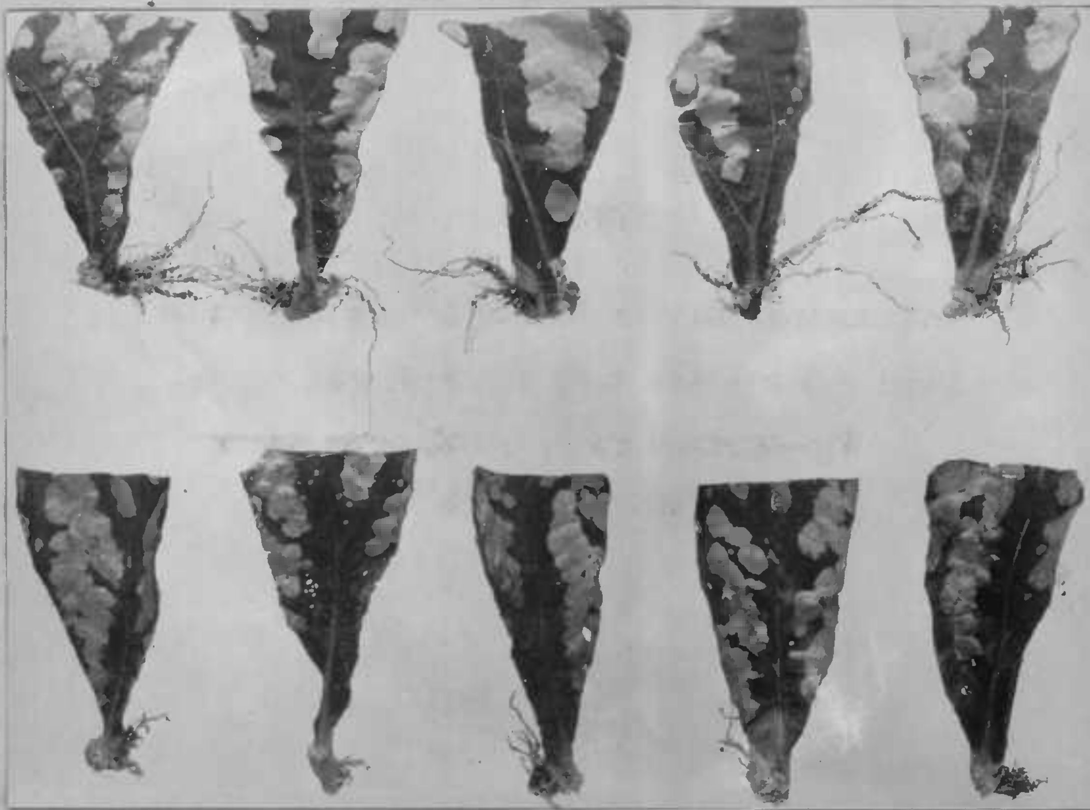


FIGURE 1

Rex Begonia Cuttings from Leaves That Had Been under a 500 Watt Light for 24 Hours.

Top--Rooted under a 500 Watt Light

Bottom--Rooted in Daylight

FIGURE 2

Rex Begonia Cuttings from Leaves That Had Been in Dark 24 Hours.

Top--Rooted under 500 Watt Light

Bottom--Rooted in Daylight

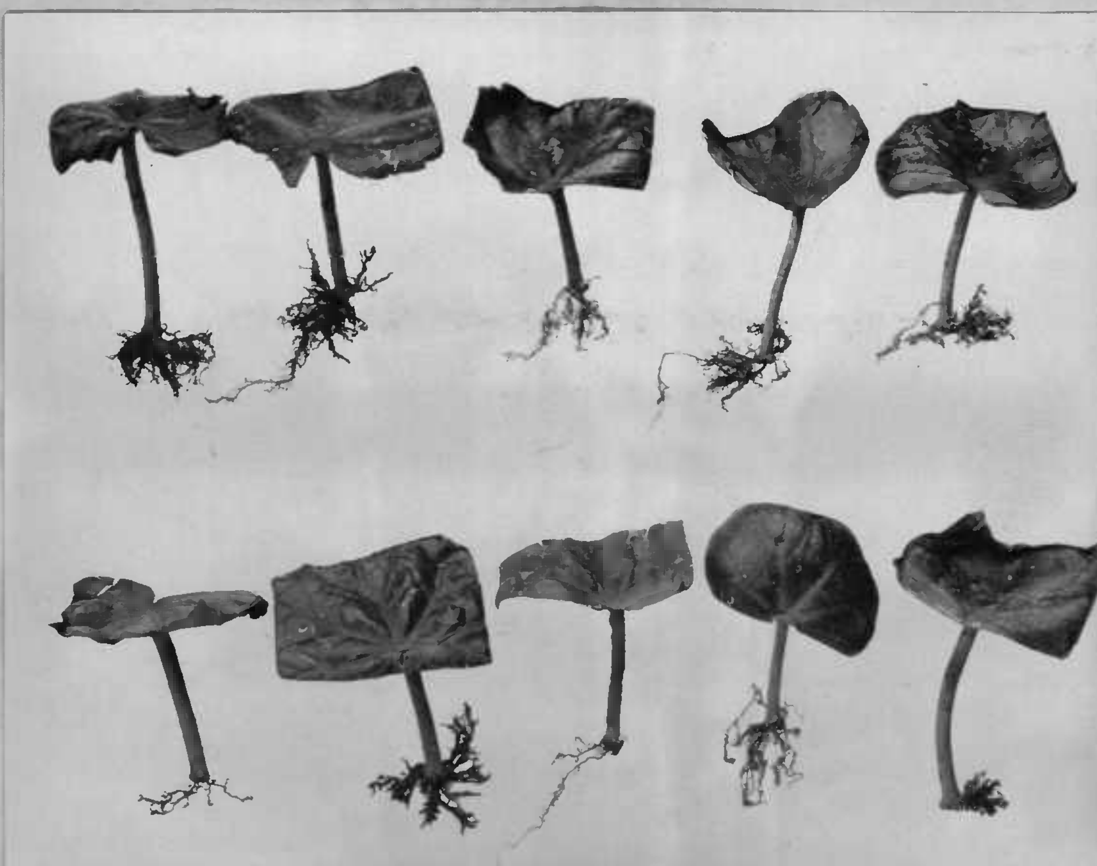


FIGURE 3

Melior Begonia

Top---Rooted Under a 500 Watt Light

Bottom---Rooted in Daylight

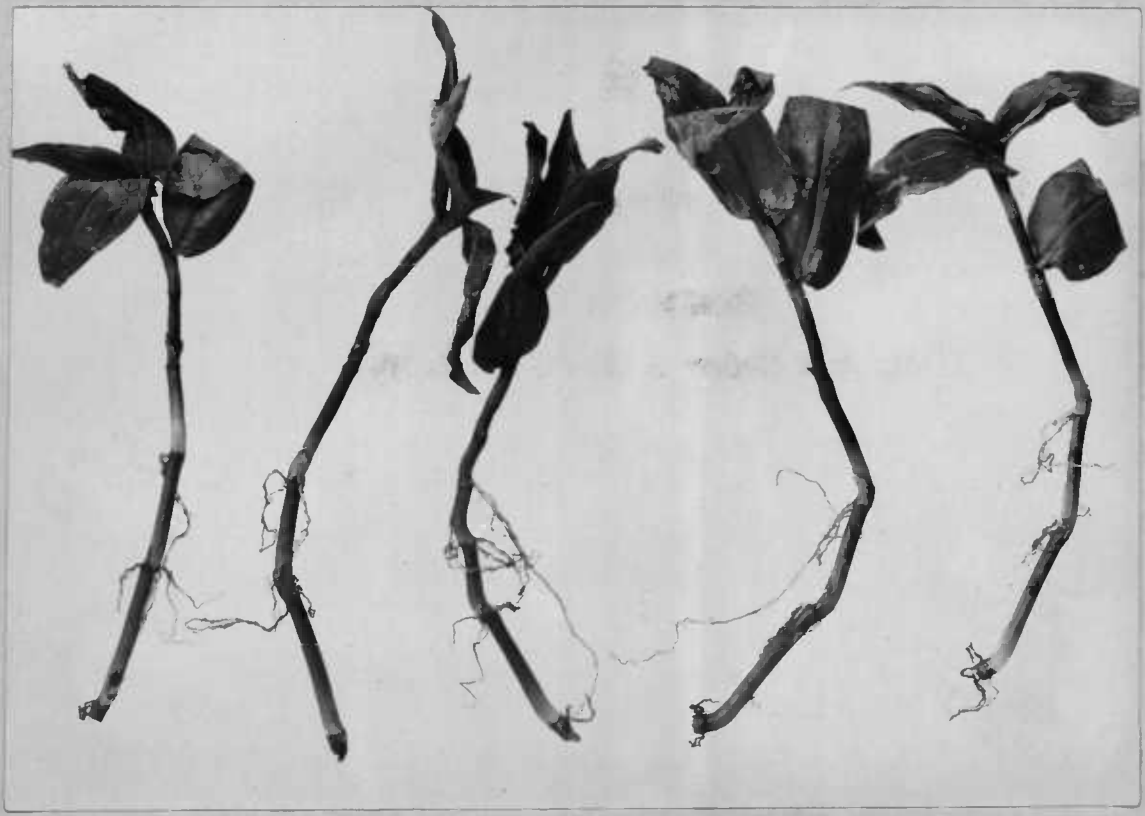


FIGURE 4

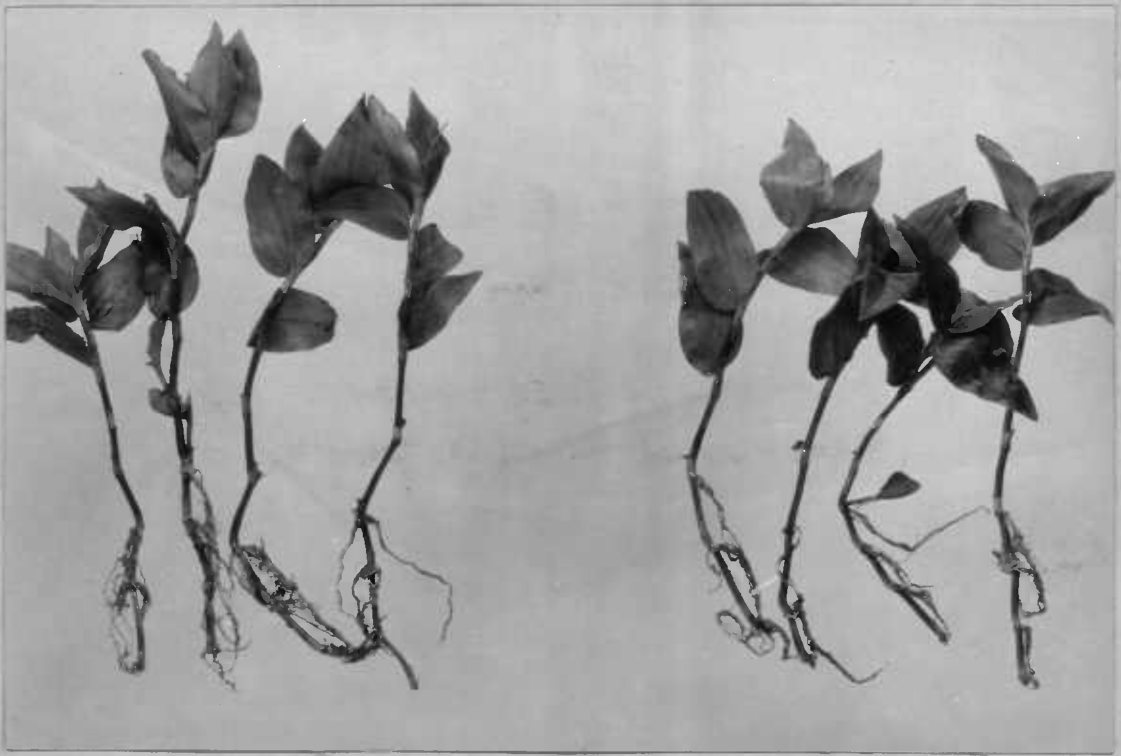
Wandering Jew

Rooted Under a 500 Watt Light

FIGURE 5

Wandering Jew

Rooted in Daylight



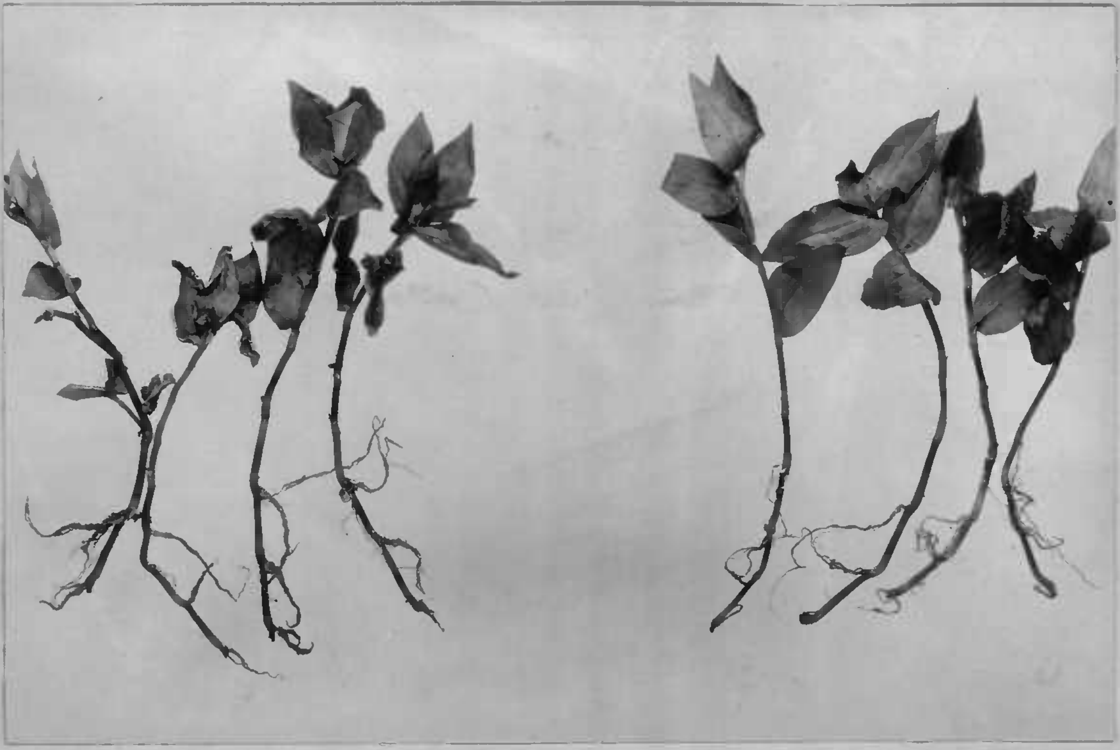


FIGURE 6

Wandering Jew

Left--Rooted with No Covering

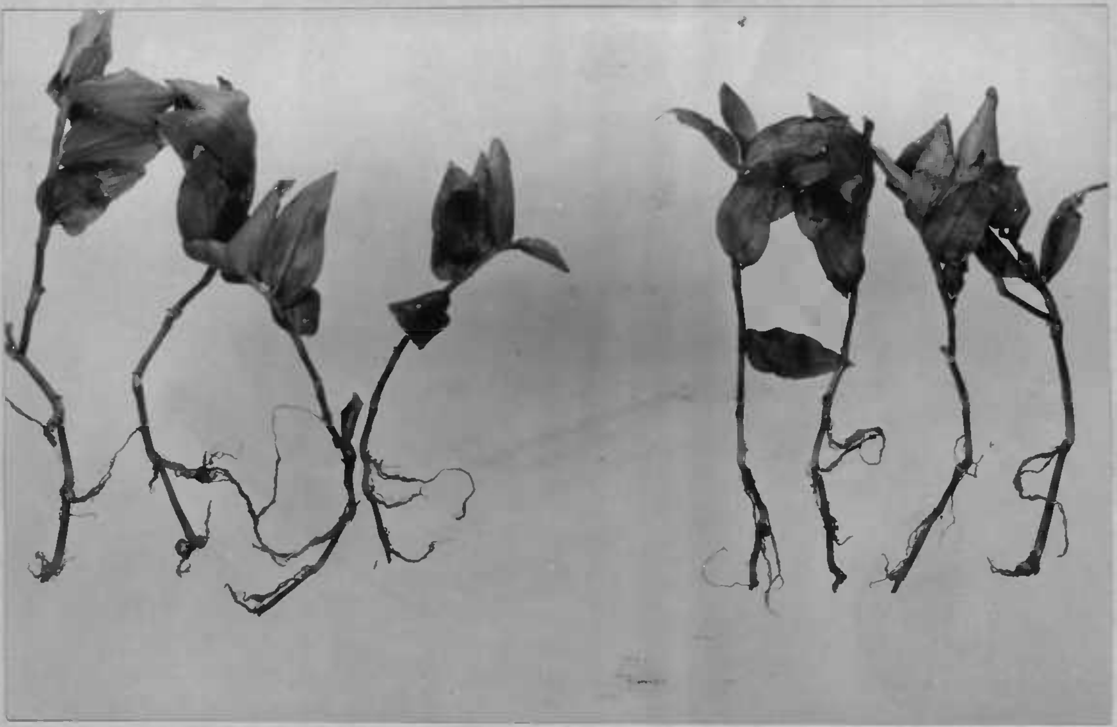
Right--Rooted Under Lath Covering

FIGURE 7

Wandering Jew

Left--Rooted Under 1 Layer Muslin

Right--Rooted Under 4 Layers Muslin



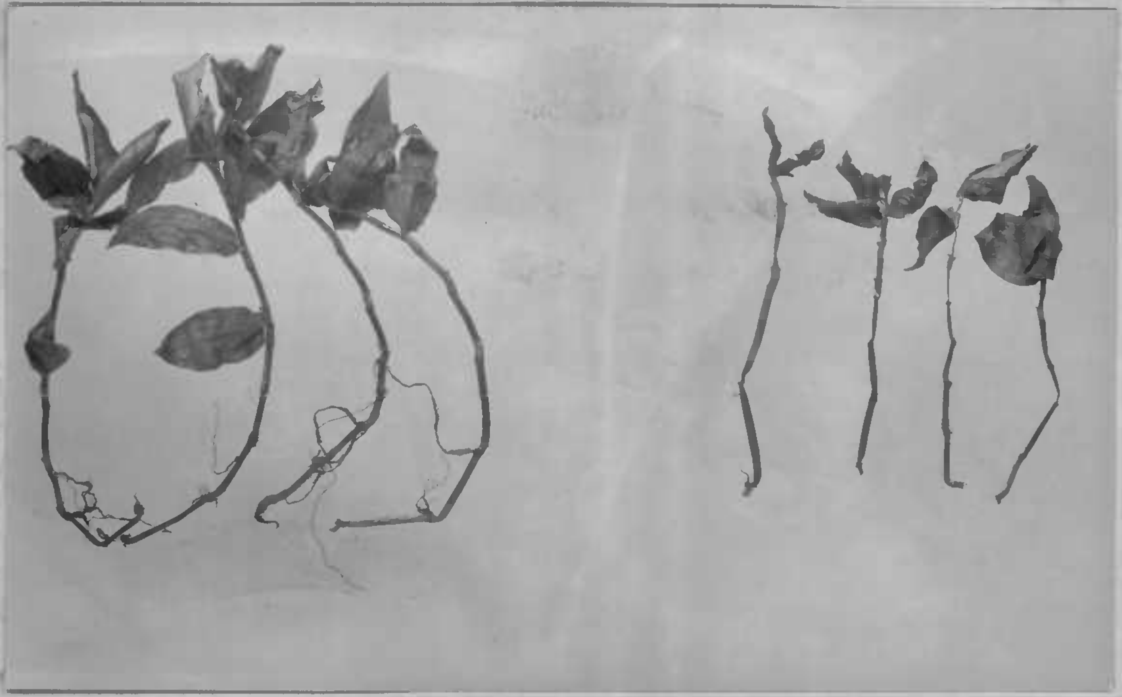


FIGURE 8

Wandering Jew

Left--Rooted Under Glass

Right--Rooted Under Glass & Lath

FIGURE 9

Wandering Jew

Left--Rooted Under Glass & Muslin

Right--Rooted in Dark

FIGURE 10

German Ivy

Left--Rooted With No Covering

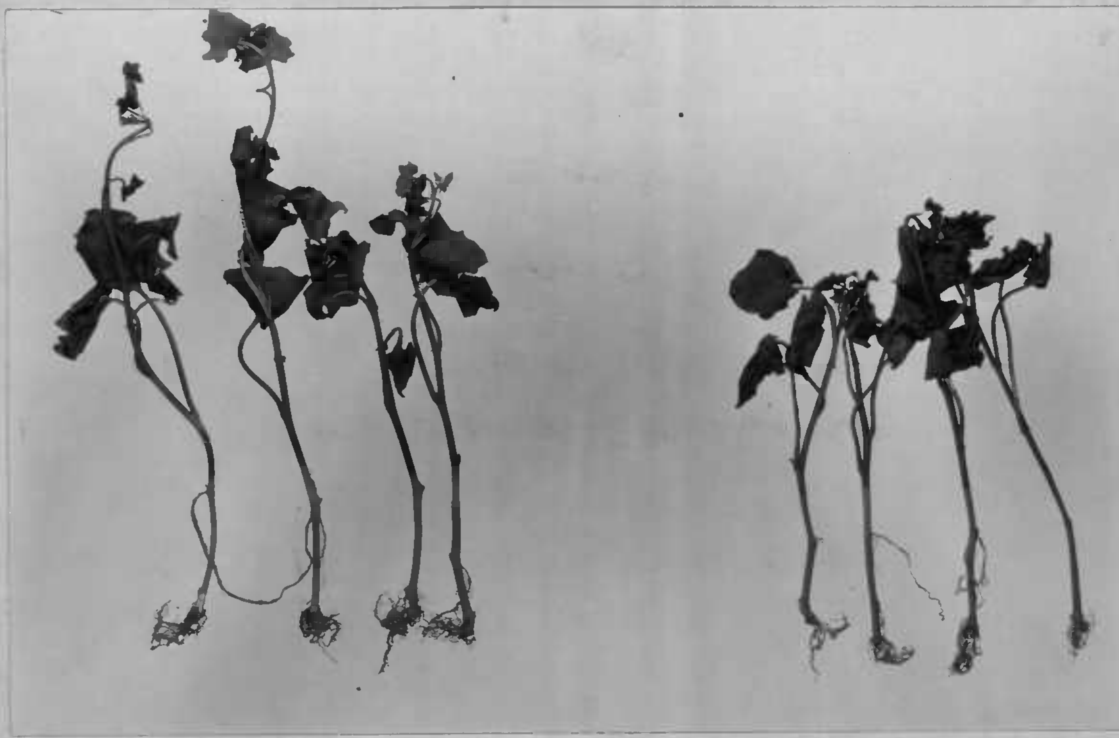
Right--Rooted Under Lath

FIGURE 11

German Ivy

Left--Rooted Under 1 Layer Muslin

Right--Rooted Under 4 Layers of Muslin



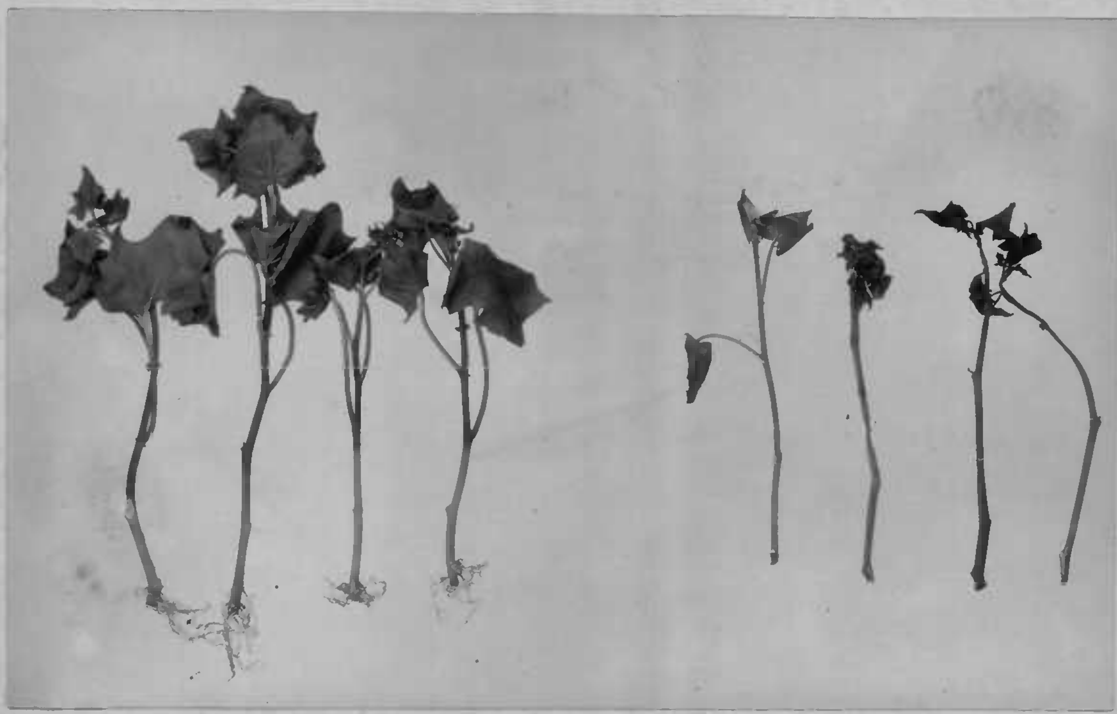


FIGURE 12

Parlor Ivy

Left--Rooted Under Glass

Right--Rooted Under Glass & Lath

FIGURE 13

Parlor Ivy

Left--Rooted Under Glass & Muslin

Right--Rooted in Dark

FIGURE 14

Forget-Me-Not

Left--Rooted With No Covering

Right--Rooted Under Lath

FIGURE 15

Forget-Me-Not

Left--Rooted Under 1 Layer of Muslin

Right--Rooted Under 4 Layers of Muslin

FIGURE 16

Forget-Me-Not

Left--Rooted Under Glass

Right--Rooted Under Glass & Lath

FIGURE 17

Forget-Me-Not

Left--Rooted Under Glass & Muslin

Right--Rooted in Dark