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An Experimental Study of the Rest Period in Plants

The Summer Rest of Bulbs and Herbaceous Perennials

SECOND REPORT

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Agricultural Experiment Station

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An Experimental Study of the Rest Period in Plants

The Summer Rest of Bulbs and Herbaceous Perennials

SECOND REPORT

W. L. HOWARD

Extensive studies of the rest period of woody plants were made at the Missouri Agricultural Experiment Station beginning in 1905 and a first report of results was issued in 1910.[1]

Out of nearly three hundred species experimented with, it was found that practically all have a rest period, but that this rest is much more firmly fixed in some than in others. Some grew with no treatment except to be placed in a warm greenhouse. Others could be aroused only with great difficulty, even with treatments so severe that many were killed. A very few could not be made to grow at all until their rest period was over. For the most part woody plants rest in winter altho many of the buds undoubtedly first begin to enter the resting phase in late summer.

The Rest Period of Bulbs. The present report deals almost entirely with the summer rest. In marked contrast with trees, bulbs appear to rest almost entirely in summer. Most people are familiar with such bulbous plants as hyacinth, tulip, crocus and spring beauty. All of these grow in very early spring, producing leaves, stems, and flowers. With some of these the blooming period may be over in March, or earlier, and the plants actually die down and the bulbs become dormant in April or early May in Missouri. Practically all of our so-called bulbous plants die to the ground in spring and the bulbs become fully dormant by early summer.

When the leaves die it may be said that the bulbs have entered their resting state. Unlike woody plants bulbs almost never begin to grow again before fall. No matter how warm or cold or wet the summer may be, our common bulbs remain perfectly dormant. Under cultivation hyacinth, tulip and others are planted deep in

1. Howard, W. L., An experimental study of the rest period in plants. Mo. Agr. Exp. Sta. Research Bul. No. 1.

late autumn. By November the roots are expected to begin to grow. Where bulbs are to be made to flower in the house, they are first kept for a time in a cool dark place until the roots begin to grow. In principle this treatment is equivalent to planting deep in the ground.

Wild bulbs are observed to begin to make root growth in October and November. A clump of wild spring beauty plants (*Claytonia Virginica*, Linn.), which were under observation thruout the spring, summer, fall, and winter of 1913 and the spring of 1914, flowered and died down as usual in early spring. Bulbs were dug up as late as August but they showed no signs of growth. Warm weather continued until the middle of September. In late September and October there were heavy rains. The weather in October was cool enough for the soil to become cold. In November and December the weather was cool, but there were no hard freezes. About the middle of December many of the plants began to appear above ground. Hundreds were one or two inches high in January when several inches of snow came. During the remainder of the winter there were frequent snows and some severely cold weather, but the plants evidently were not killed as the ground was covered with them at blooming time in March.

Herbaceous Perennial Plants. Under natural conditions most herbaceous plants in Missouri regularly form a number of buds on the upper part of the root stock, at or near the surface of the ground, just before the aerial parts are killed by frost in autumn. Both roots and buds then remain dormant until spring. The buds probably do not have a true rest period but are kept from growing during the fall, winter, and early spring months by the prevailing low temperatures. In fact a great many of the common plants of this class are late in starting in spring. Common examples are iron weed (*Vernonia* sp.) and vervain (*Verbena* sp.). Presumably the soil must become warm to a considerable depth before the roots can become active.

In other instances herbaceous perennials begin growing quite early in spring, pass thru the blooming period, then die down and become dormant in August. The common cultivated lily-of-the-valley (*Convallaria majalis*, Linn.), is a good example. In this case the plant evidently has a short rest period or else it would begin growing again, as there are often heavy rains in this latitude in August and always in September. Still it never grows naturally before spring. However, it is capable of being easily forced into growth in autumn so as to bring it into bloom by Christmas. This is a regular practice among commercial florists.

EXPERIMENTS WITH BULBS

In 1907 experiments were begun for the purpose of studying the rest period of bulbs. It was accepted as a fact that bulbs have a pronounced rest period. The first experiment was for the purpose of finding out if bulbs can be made to grow again as soon as they become dormant.

In October eight species of cultivated bulbs were purchased and planted in a steam-heated hotbed. After two or three weeks heat was turned on and during the remainder of the winter there was a mild circulation of steam. The temperature of the bed from the beginning ranged from 0 to 12 degrees Centigrade.

The plan was to force the bulbs into growth as soon as possible, let them pass thru their regular blooming period and then withhold water, if necessary, to cause them to go dormant. Due to several causes the bulbs continued to bloom thru an abnormally long period so that it was July, 1908, before they were sufficiently dormant for the treatments to begin.

The following species, one common variety of each, were used: Tulip, hyacinth, crocus, anemone, narcissus, oxalis, amaryllis, and spring beauty. The treatments were with ether, chloroform and desiccation employed singly, in combination, and under different conditions.

On July 7 all species were treated as follows:

1. Frozen 24 hours.
2. Frozen 48 hours.
3. Frozen 72 hours.
4. Dried in a dry room.
5. Etherized 24 hours (bulbs moist).
6. Etherized 48 hours (bulbs moist).
7. Etherized 24 hours (bulbs dry).
8. Etherized 48 hours (bulbs dry).
9. Chloroformed 48 hours (bulbs dry).
10. Dried, then frozen 24 hours.
11. Dried, then frozen 48 hours.
12. Dried, then frozen 72 hours.
13. Dried, then etherized 48 hours, while planted in pots.
14. Dried, then etherized 48 hours before planting.
15. Dried, then chloroformed 48 hours.
16. Check (untreated).

The results of the above treatments were mostly negative. None of the bulbs grew any earlier when treated than when untreated. In fact there were some indications that the treatments

were injurious. For example, the untreated anemone bulbs began to grow on July 11, while the treated ones did not grow until November. None of the treated spring beauty bulbs made any growth at any time. With the tulips, hyacinth, crocus, and narcissus there was no growth from any bulbs, treated or untreated, before November.

Other isolated trials were made to force bulbs during 1909 to 1912. While some of the trials seemed to promise results, none were conclusive enough to justify the belief that the early part of the rest period can be broken.

Experiments in 1913-14. In the spring of 1913 eight species of bulbous plants and one rhizome, found growing wild in the vicinity of Columbia, were located while in bloom in order that they might be transplanted after becoming dormant. Early in June, after dying down and becoming dormant in a normal manner, the following were taken up and brought in for treatment: Rue anemone (*Anemone thalictroides*), spring beauty (*Claytonia Virginica*), dutchman's breeches (*Dicentra Cucullaria*), dogtooth violet (*Erythronium mesochoreum*), bloodroot (*Sanguinaria Canadensis*), wake-robin (*Trillium sessile*), star of Bethlehem (*Ornithogalum umbellatum*), Mayapple (*Podophyllum peltatum*) and Jack-in-the-pulpit (*Arisaema triphyllum*). To the list were added four common cultivated bulbs: Roman hyacinth (*Hyacinthus* sp.), tulip (*Tulipa* sp.), jonquil (*Narcissus Jonquilla*) and poet's narcissus (*Narcissus poeticus*).

The object sought in this experiment was to find if the bulbs by any kind of treatment, could be started into an early growth. The following treatments were made use of:

1. Hypodermic injection of ether.
2. Hypodermic injection of Knop's nutrient solution.
3. Exposing to ether fumes for 12 hours.
4. Exposing to ether fumes for 24 hours.
5. Exposing to ether fumes for 36 hours.
6. Hypodermic injection of chloroform.
7. Hypodermic injection of water.
8. Wounding by inserting hypodermic needle.
9. Freezing for 12 hours at a temperature of 24 to 25 degrees F.
10. Freezing for 7 days at a temperature of 24 to 26 degrees F.
11. Desiccating slowly in a dry room until from 10 to 35 per cent of weight was lost.
12. Desiccating quickly in a drying oven at a temperature of 104 degrees F.
13. Desiccating thoroly and then injecting ether.
14. Desiccating thoroly and then injecting Knop's solution.

15. Placing in a bath of warm water (temp. 96 degrees F.) for 8 hours.

16. Placing in a bath of warm water (temp. 104 degrees F.) for 8 hours.

17. Check (no treatment).

It should be explained that the warm bath method (treatments 15 and 16) was first used by Molisch[1] in 1907. The method was successful in producing early growth in several dormant woody plants. So far as known to the writer, this is the first time the treatment has been used in connection with the forcing of bulbs or rhizomes,

Treatments 2 and 14 make use of a nutrient salt solution which was first used for forcing dormant plants by Lakon[2] who employed it with great success in breaking the rest period of lilac, hornbeam, linden, sycamore, maple, hazelnut, horse chestnut, magnolia, beech, ash, and several kinds of oaks. Lakon acted upon the opinion advanced by Klebs that periodicity of growth in plants depends very largely upon climatic and nutritive conditions. The nutrient solution is made by using the following: Calcium nitrate 1 gr., magnesium sulphate .25 gr., acid potassium phosphate .25 gr., and water 1 litre.

Since it did not appear feasible to apply the treatment in any other way, the solution was injected into the bulbs with a hypodermic needle, both while they were in their normal ripened condition and after being severely desiccated. One set of bulbs, used as a check on the injection treatments, was simply wounded by puncturing with the hypodermic needle. The amount of ether, chloroform or Knop's solution injected depended upon the size of the bulb. In tiny bulbs such as *Anemone* not over .1 cc. was used, while in *Hyacinthus* perhaps as much as 1 cc. or more was absorbed. Injection tests made with staining fluids showed that the liquids readily diffused over an area equal to five or ten times the volume injected.

All treatments were made between June 13 and July 3, 1913. The bulbs were planted in pots and placed on a bench in a shaded

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1. Molisch, H., Forcing plants by warm baths. Umschau. 12, (1908), No. 39, pp. 771-773. Abstracts in Sci. Amer. Sup., 66 (1908), No. 1714, p. 298; and in Exp. Sta. Rec. 20, pp. 640-641.

2. Lakon, G., Influence of nutrient solutions on the winter rest of woody plants. A new forcing process. Ztschr. Bot., 4, (1912), No. 8, pp. 561-582. Abstr. in Exp. Sta. Rec. 28, p. 435.

Däs Nahrsalzverfahren, eine neue Methode pflanzen zutreiben. Möller's Deutsch. Garten-Zeitung, 28, No. 2, pp. 18-20; 28, No. 3, pp. 31-32. Abstract in Exp. Sta. Rec. 28, p. 435.

Recent investigations dealing with the annual periodicity of plants, especially woody plants. Naturw. Ztschr. Forst. u. Landw., 11, (1913) pp. 28-48. Abstract in Exp. Sta. Rec. 28, p. 435.

greenhouse. The pots were kept well watered. In August the entire collection of pots was removed to a cool, north basement room of the Horticultural Building where they were plunged in soil spread upon the granitoid floor and kept moist by occasional waterings. About the middle of September the pots were transferred to a bench in the greenhouse where they were in almost full sunlight during the forenoon, but mostly shaded during the afternoon.

RESULTS OF THE EXPERIMENTS

All of the sixteen treatments failed to produce an early growth in any of the bulbs. The earliest growth that was noted began late in August. For the most part growth did not begin until November. In some cases the plants did not show above ground until the following spring. A great many grew during February and March. While growth was very late in taking place, the treated bulbs appeared in most cases to grow somewhat earlier than the checks. In the case of the hyacinth bulbs, those injected with chloroform grew thirteen days earlier than the checks. Those that were desiccated thoroly grew four days before the checks. In both cases the growth was very vigorous. However, the remaining bulbs which had been treated in different ways grew vigorously after they finally started, which was from a week to three weeks after those that have been mentioned. Desiccation followed by injection of Knop's solution appeared to have some effect upon the jonquils by stimulating a slightly earlier growth than the other treatments. The same was true in a somewhat more moderate degree with the poet's narcissus. Injection with ether following desiccation did almost as well.

On the whole the results were rather inconclusive. In the first place it is quite probable that the bulbs after treatment were not placed under favorable growing conditions. In nature, bulbs of the kinds being studied make all their growth during the cool season of late fall and early spring. Had the treated bulbs been at once placed where they would be moist and at the same time exposed to a temperature of 40 to 60 degrees F., rather than 80 to 95 degrees, the results might have been different. Whether the treatments actually hindered growth was not clear, as the results were somewhat contradictory. In this connection it is interesting to note that no growth occurred in any of the bulbs either treated or untreated until they were moved to the cool basement room, and the first signs of life were noticeable there after they had been in this new position some little time, so it is probable that no growth whatever took place

while the bulbs were in the greenhouse where they were placed immediately after treatment.

Additional Treatments of Bulbs. Late in the fall of 1913 a set of bulbs representing several species was purchased for the purpose of finding whether, by means of treatments, an earlier growth could be brought about in bulbs at a time when they are naturally expected to grow, soon after planting. The following species were included in this test: *Gladiolus* sp., *Oxalis Deppei*, *Cooperia Drummondii*, *Montbretia* sp., *Zephyranthes rosea*, *Millia biflora*, *Chilianthus fragans*, *Hyacinthus candicans*, *Caladium esculentum*, and *Ornithogalum caudatum*.

Between December 2 and December 27, 1913, the bulbs just mentioned were given the same treatments as described in the last experiment. After treatment the bulbs were planted in pots which were plunged in the soil in an exhausted hotbed that could be heated by means of steam pipes. Aside from the first week or two after planting, the temperature was low, particularly at night, probably going almost to the freezing point in one or two instances, but during the day under the influence of bright sunlight, the soil and air were quite warm. After this period steam was always on at night and sometimes during the daytime. In fact after the first cool period the temperature of the hotbed was very similar to that of an average greenhouse room. The following results were noted:

Gladiolus sp. The untreated plants grew in twelve days. In those that were desiccated thoroly, growth took place in six days. When they were frozen seven days, growth took place in fourteen days. Injected with ether and etherized twelve hours, each grew in sixteen days. All of the other treatments produced growth in from twenty-one days, where injected with chloroform, to twenty-five days, where desiccated rapidly.

Oxalis Deppei. No growth took place in less than one month and three days. The check bulbs did not grow for more than four months, while all of the others grew in from two to three months.

Cooperia Drummondii. The check bulbs grew in fourteen days, while all of the treated ones grew in from three to twelve days. Those that were desiccated and then injected with Knop's solution actually began growing in three days after being planted. Those that were etherized for twelve and twenty-four hour periods, and those that were injected with water, grew as early as the checks.

Montbretia sp. Only a few of these produced any growth at all, so that comparison of treatments cannot be made.

Zephyranthes rosea. All of the treatments, except injection with Knop's solution and desiccation followed by injection of ether,

produced an earlier growth than where untreated. Again desiccation followed by injection of Knop's solution produced growth in three days.

Millia biflora. Only a few of the plants grew, so that comparison cannot be made.

Chilianthus fragans. The check bulbs grew in eighteen days. Once more desiccation followed by injection of Knop's solution seemed to greatly stimulate the bulbs as those treated in this way began growing in four days. Practically all of the other treatments failed to produce growth in less than twenty to twenty-five days, and sometimes much longer.

Hyacinthus candicans. Desiccation followed by injection with Knop's solution produced growth in sixteen days, while similarly desiccated specimens injected with ether grew in ten days. None of the others grew in less than a month. The untreated ones did not grow for nearly four months.

Caladium esculentum. All of the treatments with the exception of those desiccated and injected with ether, seemed actually to have hindered growth. The untreated bulbs grew in twenty-six days, while the treated ones just mentioned grew in twenty-four days. All others required from one to three months for growth to begin.

Ornithogalum caudatum. Those desiccated and injected with ether grew in four days, while those untreated required twenty-two days. The next best record was made by those desiccated and injected with Knop's solution which required thirteen days for first growth. Practically all of the treatments hastened growth from two to five days.

After the gladioli had completed their growth in the spring of 1914, they were allowed to die down and then taken up and stored in a dry place until they were thought to be thoroly dormant. About fifty were selected for treatment by the same methods that were used in the preceding experiments. The treatments were made between May 23 and June 1, 1914. Only seven of the treatments produced any growth whatever. The remainder, with the exception of the untreated bulbs, died. All those that grew at all began at approximately the same time, about July 17.

Conclusions

There seems to be no question but what most bulbs, and possibly all of them, have a strong rest period which sets in as soon as the flowers and leaves die down. It is also apparent that it is very difficult to shorten this dormant period, at least during the earlier

phases of the rest. The experiments that have been described were not always carried out under ideal conditions for growth after the treatments were given, so that the results are not conclusive.

While poor results have attended all efforts to break the rest period during its earlier phases, the conviction has gradually grown stronger that if the bulbs, immediately after treatment, could be planted in moist soil and kept where the temperature would never rise above 60 degrees F., the rest period could be broken, especially with such species as *Gladiolus* sp., *Cooperia Drummondii*, *Chilianthus fragans* and *Ornithogalum caudatum*.

Of all the treatments employed, desiccation followed by injection with ether and Knop's solution, and combinations of these, were most effective in shortening the rest period.

EXPERIMENTS WITH HERBACEOUS PERENNIAL PLANTS

Altho the numerous experiments with woody plants at the Missouri Agricultural Experiment Station in previous years showed that a large number have a pronounced rest period, little was known about herbaceous perennials in this regard. While most herbaceous perennials in principle behave much like woody forms—that is, grow from spring until fall, form buds (at the crown), then die to the ground—there are some important differences. Many are known to become perfectly dormant in summer, year after year, regardless of whether the season is wet or dry, cool or hot. Others have been observed to begin growing again in December when abnormally mild weather prevailed in that month.

In 1907 a rest period study was begun with herbaceous perennials. This was mainly a test of the influence of various materials and treatments for forcing growth. This investigation was made possible by reason of the good collection of herbaceous perennial plants growing upon the horticultural grounds of the University of Missouri. In late fall sixty-five species were transplanted to pots and removed to a cold frame until ready to be treated. The plants were taken up as they became thoroly dormant. Because they were not all taken in at the same time, about half of the collection became slightly frozen before being dug up. For the most part the plants were set in 6 and 8 inch flower pots. The pots were thoroly watered and after a few days the soil was settled and dry enough for the plants to be treated. In all cases it was necessary to have the surface of the soil dry so that it would not absorb the ether fumes.

The First Test

The thirty-six species that had been slightly frozen were selected for the first experiment. The object of this test was to determine the length of the natural dormant period of the plants as shown by specimens to be left untreated, and also the effects of the different treatments in hastening growth. The first list of thirty-four species was treated between December 7 and 28, 1907. The following treatments were given: Freezing, 24 hours; drying, 8 hours; etherizing, 5 hours; etherizing, 12 hours; etherizing, 24 hours; etherizing, 48 hours; check (untreated).

The freezing was done by leaving the plants out in the open during two cold nights. The drying was done by taking the plants into an air-heated room where the temperature was between 70 and 80 degrees F., day and night. The etherizing was done by means of a specially constructed chamber made of galvanized iron. The chamber was shaped like a cylinder, was about two feet in diameter and made in two sections, each about three feet in length. (Fig. 1.) One section was fitted with a bottom and at the top around the rim a groove was constructed which was filled with fine sand. The rim flared out so as to accommodate a lid. The lid could be fitted on and made tight by forcing down in the sand. The second section of the cylinder was exactly like the first, except that it was bottomless. When it was necessary to treat a large number of plants at one time, the second section was placed upon the first, the lower end being forced into the sand. The upper part of this section contained a groove which was filled with sand so that the lid could be fitted on as described for the other section.

In the lid was an opening which could be tightly closed by means of a screw cap. This opening was for the purpose of admitting the ether. The ether was used at the rate of 40 grams to each 100 litres of space. The liquid was poured in at the top and the cap quickly fastened on. The quantity of ether used was sufficient to fill the vessel with fumes under considerable pressure. The lid was prevented from being pushed off by weighting down with bricks. The vessel was kept in a greenhouse where the ether treatments were given. This house was so situated that it was in full sunlight during the forenoon only. Treatments were usually given in the afternoon when there was no change in the temperature. When it became necessary to make the treatments in the forenoon, the sunlight was often bright enough to make the vessel quite warm, thus causing the ether vapor to exert considerable pressure. At such times the sand was covered with a layer of hot paraffin in order to prevent the gas from leaking thru it.

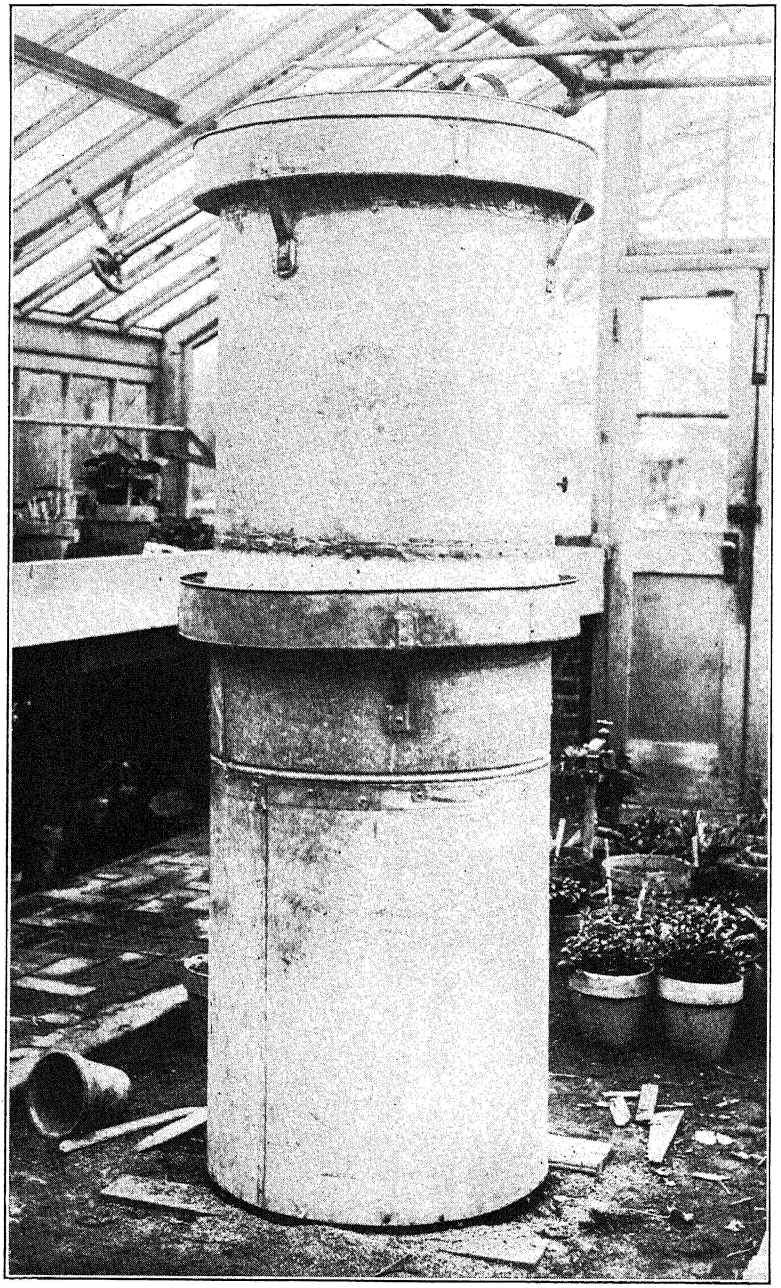

Figure 1. Etherizing chamber used in treating plants. The plants were placed inside, the lid fitted on and made tight by means of fine sand covered with a coating of paraffin. The ether was poured in thru a small opening in the lid which could be securely closed by means of a screw cap.

Figure 2. Anthemis sp. *Pot No. 546 received no treatment; No. 551 was etherized 24 hours; No. 549 was etherized for 12 hours. The treatments hindered the growth. Photographed March 12, 1908, forty-five to forty-seven days after treatment.*

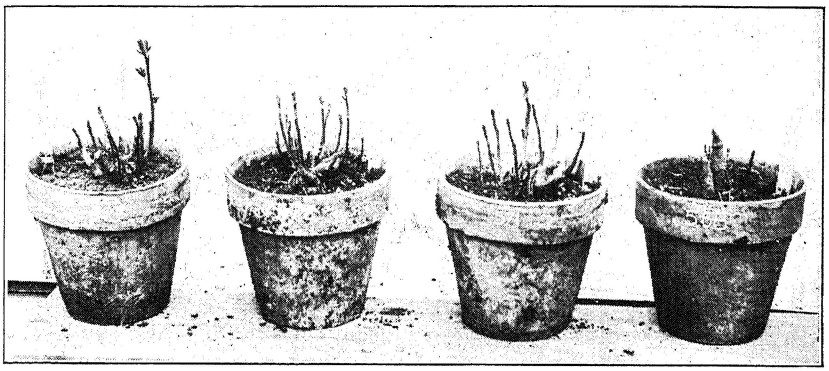

Figure 3. Cassia sp. *Pot 573 was etherized for 48 hours; 572, etherized 24 hours; 571 same as 572; 568, check. Growth somewhat hastened by treatments.*

Figure 4. Calliopsis sp. *The three pots were treated as follows: No. 586, check; No. 589, etherized 12 hours; 591, etherized 24 hours. Another pot not shown here was etherized for 48 hours. The plant was killed. Photographed March 13, 1908, forty-five to forty-seven days after treatment.*

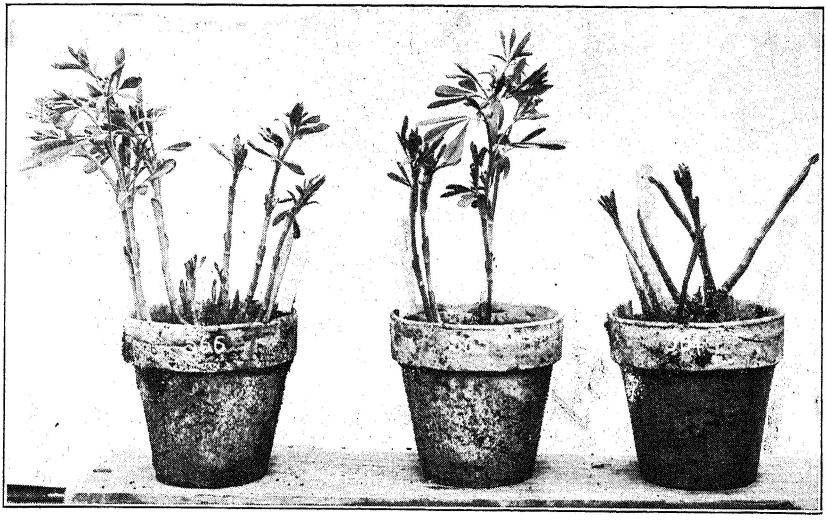

Figure 5. Baptisia australis, *R. Br. Treated as follows: Pot 566, etherized 48 hours; 565, etherized 24 hours; 564, check (no treatment). Growth greatly hastened by treatments.*

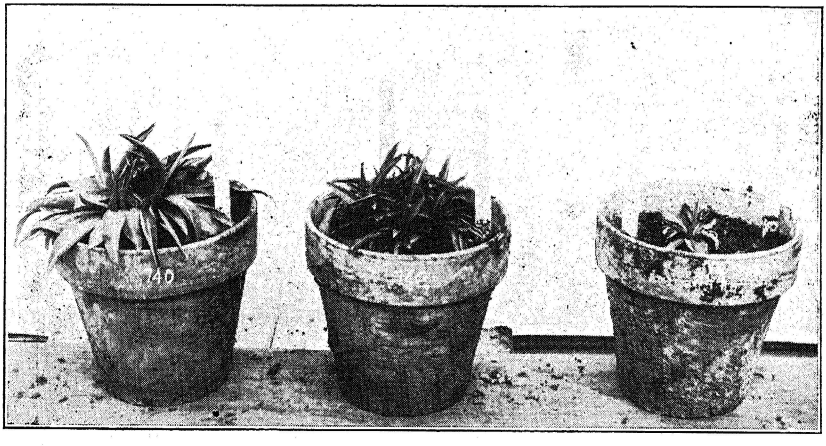

Figure 6. Stokesia cyanea, *L'Herit. Pots received the following treatments: No 740, check; 742, etherized 12 hours; 744, etherized 24 hours. The treatments hindered the growth. Photographed March 13, 1908, forty-five to forty-seven days after treatment.*

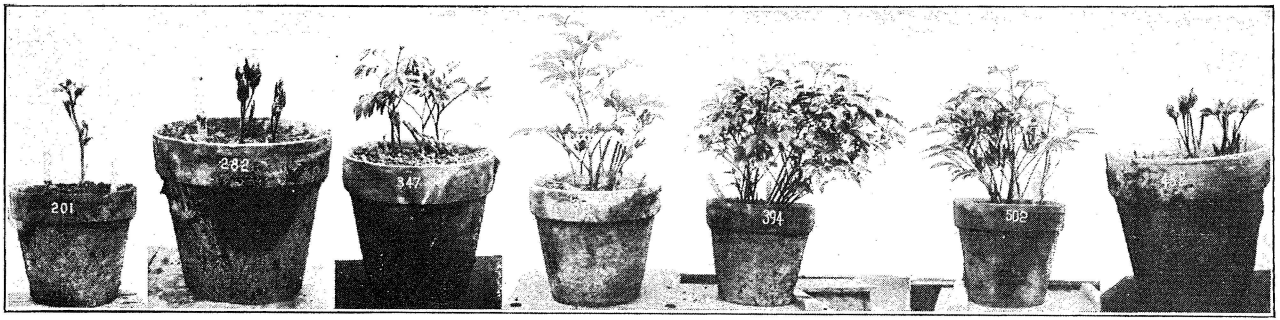

Figure 7. Peony sp. *Slightly frozen before transplanting to pots. Afterwards treated as follows: Pot No. 201, check (no treatment); No. 282, etherized 5 hours; 347, etherized 12 hours; 348, etherized 24 hours; 394, etherized 48 hours; 502, frozen for 24 hours; 452, dried for 8 days. Photographed sixty days after treatment.*

Figure 8. Chrysanthemum hortorum, *var. King Edward VIII. Treated as follows: Pot No. 585, dried in a warm room; 584, frozen 24 hours; 582, etherized 24 hours; 580, etherized 12 hours; 578, check. The treatments hindered growth. Photographed March 13, 1908, forty-three to forty-seven days after treatment.*

As rapidly as treatments were completed, the pots were placed in a hotbed under good growing conditions. Untreated pots of all the species in the experiment were placed beside the treated ones. On account of the large number of plants being handled and the length of time required for certain treatments, several days elapsed between the time of completing the first and the last. Thus the period occupied for the treatments covered the time between December 7 and 28. All of the plants were slightly frozen while in the ground before being removed to the hotbed.

Table 1 and the list of nine species which follow show the results of the treatments.

The following species made no growth whatever from any of the treatments:

Azalea sp., *Hemerocallis* sp., *Hieracium aurantiacum*, L., *Iris* sp., *Lychnis Flos—Jovis*, Desv., *Papaver orientale*, L., *Physostegia Virginiana*, Benth var. *speciosa.*, *Potentilla Nepalensis*, L., *Sedum spectabile*, Bor.

There was considerable lack of uniformity in the behavior of the plants under the different treatments. While perhaps a majority of the plants seemed to be able to grow in a short time without treatment, there were indications that others have a rest period. The list of nine species that did not grow at all seems to indicate that they at least are possessed of a rather strong resting phase. On the other hand, some of these plants were undoubtedly injured by the treatments. A few of these grew in the spring, but some of them never grew at all even long after the effects of the treatments had passed away. This seems to indicate that they were injured by the treatments. However, the check plants of these species also failed to grow. On the whole it would appear that probably all of these nine species died as a result of transplanting.

Despite the lack of uniformity in the results following the different treatments, it is possible to deduce from the figures shown in the table that the best results on the whole in producing growth were secured from drying and etherizing forty-eight hours. On the average the 48-hour treatment with ether caused the earliest growth. All of the plants in this test had been frozen before being treated. Those that were frozen again during the treatment seemed to be influenced to the extent of growing, on the average, a few days earlier than the check plants.

The Second Test

The second test was with twenty-five species of plants which were transplanted to the hotbed without being frozen. These were

TABLE 1.—LENGTH OF NATURAL DORMANT PERIOD OF HERBACEOUS PERENNIAL PLANTS AND EFFECTS OF DIFFERENT TREATMENTS GIVEN TO SHORTEN THE REST

Species	Check		Frozen 24 hours		Dried 8 days		Etherized 5 hours		Etherized 12 hours		Etherized 24 hours		Etherized 48 hours	
	Growth began in	Fully open in	Growth began in	Fully open in	Growth began in	Fully open in	Growth began in	Fully open in	Growth began in	Fully open in	Growth began in	Fully open in	Growth began in	Fully open in
	days	days	days	days	days	days	days	days	days	days	days	days	days	days
Aquilegia sp.	0	0	°8	°15	0	0	*15	°110	*120	0	*112	*126	0	0
Armeria maritima splendens, Boiss	0	0	°8	0	0	0	0	0	*79	*82	0	0	0	0
Asparagus officinalis, L.	°27	°61	°10	0	°28	0	.....	.....	.....	.....	°56	0	°9	0
Baptisia australis, R. Br.	°3	°54	.....	.....	°79	*119	.....	.....	°14	°25	.....	.....	°5	°34
Cassia Marylandica, L.	°36	°54	°46	°74	°32	0	.....	.....	.....	.....	.....	.....	°46	0
Chrysanthemum sp. var. King Edward VIII.	0	0	°10	0	0	0	0	0	0	0	0	0	0	0
Clematis sp.	0	0	°8	°16	°5	°18	°12	°19	.....	.....	°9	°17	°8	°12
Convallaria majalis, L.	°52	0	.....	.....	°42	°54	°21	0	.....	.....	.....	.....	°32	°44
Dahlia sp.	°15	°40	0	0	°22	°25	.....	.....	.....	.....	.....	.....	°17	°20
Dianthus Chinensis, L.	*15	*27	°10	0	*46	*54	*66	*101	*70	*95	*45	0	*41	*51
Dirca palustris, L.	0	0	0	0	°57	°99	°116	0	0	0	°65	0	°37	°63
Eupatorium purpureum, L.	°77	0	°92	°96	°48	°52	.....	.....	.....	.....	°35	°41	°24	°33
Gladiolus sp.	°35	°46	°9	°29	°24	°37	.....	.....	.....	.....	°29	°40	°12	°25
Helenium midiflorium, Nutt. var. Grandicephalum striatum	0	0	°18	°22	0	0	0	0	0	0	0	0	0	0
Heuchera sanguinea, Engler.	°25	°28	.....	.....	°22	°24	°28	°32	.....	.....	°22	°26	.....	.....
Kniphofia aloides, Moench.	°13	°101	0	0	0	0	0	0	.....	.....	.....	.....	°9	0
Liatris pycnostochya, Michx.	°24	°34	.....	.....	.....	.....	°13	°20	.....	.....	.....	.....	.....	.....
Lilium tigrinum, Andr.	°24	°42	°18	°25	°15	°32	.....	.....	.....	.....	°10	°23	°8	°22
Myosotis sylvatica, Hoffm. var. alpestris	0	0	0	0	0	0	0	0	0	0	*58	*75	*61	*68
Peony sp.	°34	0	°5	°35	°26	°52	°18	°41	°14	°39	°9	°34	°5	°20
Phlox sp.	0	0	°9	°20	°21	°31	°25	°31	°11	°13	°19	°24	°2	°7
Physostegia Virginiana, Benth. var. alba.	0	0	°7	°44	0	0	0	0	.....	.....	.....	.....	.....	.....
Platycodon sp.	°32	°36	°14	°23	°49	°57	.....	.....	.....	.....	°25	°29	°35	°43
Polianthes tuberosa, L.	0	0	0	0	0	0	0	0	0	0	°53	°60	°41	°50
Rheum Rhaponticum, L.	°20	°29	°18	°27	°20	°30	.....	.....	.....	.....	.....	.....	°4	°13

°Leaf bud. *Flower bud. 0 No growth. ..... Treatment not given.

given the same treatments as mentioned in the previous test. This list was also treated between the dates December 7 and 28. In fact most of these were treated along with those mentioned in Table 1, but kept separate because they had not been frozen previous to treatment.

Table 2, with the list that follows shows the results of these treatments.

Those in the list below failed to make any growth whatever from any of the treatments: *Acanthus mollis*, L., var. *latifolius*, *Campanula Medium*, L., var. *calycanthema*, *Chelone Lyoni*, Pursh, *Hesperis matronalis*, L., *Matricaria inodora*, L., var. *plenissima*.

It is noticeable that those that were frozen in this test showed better results in producing early growth than did those in the first test, thus indicating that the effects of freezing are not cumulative.

While the data are incomplete, all of the treatments, at least with certain species, seemed to stimulate the growth in a very marked manner. On the other hand there were instances where the growth was positively hindered by the treatments.

The Third Test

The third test embraced thirty-one species. Many of these were treated in one or the other of the two previous tests. All of the plants in this third test belonged to the lot that were removed to the cold frame without being frozen. This list was not treated until early in January, 1908. In the meantime the plants had been kept in a cold frame where the temperature ranged between 55 and 65 degrees Fahrenheit. At the time of treatment most of the species had already begun to show signs of growth. In a great many instances a few of the leaves were out. On account of the advanced state of growth of so many of the plants, it was not possible to tabulate the results of the treatments. In many instances the treatments injured the leaves that were already out. The treatments given in this test were the same as those previously mentioned. The results follow.

As stated above, many of the leaves were fully out at time of treatment. These, in case of the ether treatments as well as the freezing, were badly injured. The dried plants made the best growth of all, altho the ether treatments seemed somewhat to stimulate the growth. The injury from the ether treatments was in direct proportion to the length of time exposed to the fumes.

Anthemus sp. Growth seemed to be hindered by all the treatments, as the check plants grew much better than any of the

TABLE 2.—LENGTH OF NATURAL DORMANT PERIOD OF HERBACEOUS PERENNIAL PLANTS AND EFFECTS OF DIFFERENT TREATMENTS GIVEN TO SHORTEN THE REST PERIOD. TRANSPLANTED TO HOTBED WITHOUT BEING FROZEN.

Species	Check		Frozen 24 hours		Dried 8 days		Etherized 5 hours		Etherized 12 hours		Etherized 24 hours		Etherized 48 hours	
	Growth began in	Fully open in	Growth began in	Fully open in	Growth began in	Fully open in	Growth began in	Fully open in	Growth began in	Fully open in	Growth began in	Fully open in	Growth began in	Fully open in
	days	days	days	days	days	days	days	days	days	days	days	days	days	days
Althaea rosea, Cav.	0	0	°7	°18	0	0	----	----	0	0	0	0	0	0
Anthemis sp.	0	0	°7	0	0	0	*77	0	*61	*68	0	0	----	----
Armeria formosa, Willd.	*77	*94	----	----	----	----	----	----	*20	*39	*70	*107	----	----
Asclepias tuberosa, L.	°35	°40	0	0	0	0	----	----	----	----	0	0	0	0
Bocconia cordata, Willd.	°8	°17	°6	°12	°24	°28	----	----	----	----	°10	°18	°4	°9
Cerastium tomentosum, L.	0	0	0	0	0	0	0	0	*103	0	0	0	*85	*91
Coreopsis lanceolata, L. var. grandiflora	----	----	°6	0	0	0	0	0	0	0	0	0	0	0
Chrysanthemum Leucanthemum, L.	0	0	°12	°17	0	0	0	0	----	----	0	0	----	----
Delphinium, sp.	0	0	°9	°17	°13	°15	----	----	----	----	*55	*84	°9	0
Delphinium sp. var. Gold Medal	0	0	°9	°20	0	0	0	0	0	0	0	0	0	0
Digitalis purpurea, L. var. gloxiniaeflora	0	0	0	0	0	0	0	0	0	0	*90	0	0	0
Eryngium amethystinum, L.	0	0	°5	0	0	0	0	0	0	0	0	0	0	0
Gaillardia sp.	*63	*90	°5	0	*73	0	*	*	*61	*88	0	0	0	0
Gypsophila paniculata, L.	°21	°28	°2	°13	*15	*32	°13	°20	°11	°19	°10	°15	°2	°12
Hibiscus sp.	0	0	----	----	0	0	0	0	----	----	*113	*123	----	----
Liatris sp.	°24	0	°30	°35	°28	°34	°20	°24	°21	0	°14	°22	°17	°22
Lychnis Chalcedonica, L.	°32	°36	0	0	0	0	0	0	0	0	0	0	0	0
Lychnis Coronaria, L	0	0	----	----	*69	*94	0	0	----	----	----	----	----	----
Primula officinalis, Jacq.	----	----	°1	°4	*63	*73	*43	*47	0	0	*66	*70	*57	*62
Sanvitalia procumbens, Lam.	0	0	----	----	0	0	0	0	*80	*90	0	0	----	----
Stokesia cyanea, L'Herit.	–	–	°8	°13	–	–	°11	°27	°13	°26	°16	°25	0	0
Thalictrum sp.	°13	0	°12	°21	°29	°77	°11	0	°13	0	°13	0	°8	0
Valeriana sp.	*39	*46	----	----	----	----	*55	*59	0	0	0	0	----	----
Veronica sp.	0	0	0	0	0	0	*58	*62	0	0	----	----	0	0
Vitex sp.	°32	°38	°93	0	°62	0	----	----	----	----	°37	°42	°26	°35

– Leaves were out when treatment was given.
° Leaf bud.
---- Treatment not given.
* Flower bud.
0 No growth.

others. The 24-hour ether treatment caused considerable injury to the leaves. All of the plants were in leaf when treated. Fig. 2 shows the average condition of plants a month and a half after treatment. Pot No. 546 received no treatment; No. 551 was etherized twenty-four hours, and No. 549 was etherized twelve hours. The last mentioned pot showed only a trace of growth; No. 551 made slight growth, while the check plant made excellent growth.

Aquilegia sp. Leaves were out when treated. Plants subjected to each of the treatments, except drying, made sufficient growth to produce blooms. However, the treatments did not seem to hasten growth, as in only one case did a treated plant produce flowers earlier than the check. The treatments did not seem to injure the foliage except in the case of those that were frozen. The effects of the treatments on this species may be said to have been negligible.

Asparagus officinalis, L. Where the leaves were out at the time of treatment, they did not seem to be injured. The check plants made the best growth, altho those that were etherized twenty-four hours began to grow first; those etherized forty-eight-hours began growing still five days earlier.

Bocconia cordata, Willd. Those etherized forty-eight hours made the earliest growth and most leaves were out at time of treatment. The check plants grew a little earlier than those that were treated. Freezing and etherizing twelve and twenty-four hours resulted in no growth from this species.

Baptisia australis, R. Br. The leaf buds were practically open at time of treatment. The treatments seemed to greatly hasten growth. The ether treatments exerted the greatest influence. Fig. 4 shows the average results. Pot 556 etherized forty-eight-hours; pot 565 etherized twenty-four hours; pot 564 received no treatment. All were photographed one and one-half months after treatment.

Campanula sp. Leaves were out before being treated. The 24-hour ether treatment killed the foliage. Those plants etherized twelve hours were so badly injured that they died later. The check plants continued to grow uninterruptedly. Those frozen and dried made no growth.

Cassia Marylandica, L. In this case the treatments seemed to greatly hasten the growth. Etherizing produced better results than drying or freezing. The treated plants made very satsifactory growth. Only the ether treatments hastened the growth very much. Fig. 5 shows the results of treatments quite accurately. Pot 573 was etherized forty-eight hours; pots 572 and 571 were etherized twenty-four hours; pot 568 received no treatment. The photograph was taken on March 13, 1908, forty-six days after treatment.

Calliopsis sp. On the average the treatments retarded growth. The check plants made the best growth—decidedly better than those that were etherized. Those that were frozen did almost as well as the check plants. Several of those that were etherized died. All were in leaf when treated. Fig. 3 well represents the record of the results. Pot 586 was not treated, pot 589 was etherized twelve hours and pot 591 was etherized twenty-four hours. It will be noticed that the twelve-hour ether treatment produced better results than the twenty-four hour treatment. The plants etherized forty-eight hours were killed.

Chrysanthemum hortorum, var. King Edward VIII. On the whole the treatments may be said to have hindered growth. This is particularly true of those that were etherized and frozen. However, the treated plants grew almost as well as the checks. All were in leaf when treated, which probably accounts for the bad effects of the ether treatments as the foliage was badly injured. See Fig. 8 for graphic record of results.

Chrysanthemum Leucanthemum, L. The leaves were out at the time of treatment, but were not badly injured. The check plants made no growth. All of those that were treated grew, with the exception of the 48-hour ether treated plants, all starting approximately at the same time. The results of the treatments were not decisive.

Clematis sp. The leaves were out on practically all plants at time of treatment which resulted in some injury, especially with those that were frozen. None of the treatments appeared to cause any increased growth. The frozen plants died after a short time.

Convallaria Majalis, L. All of the ether treatments greatly hastened the growth, but freezing and drying gave poor results.

Dahlia sp. All treatments, except freezing, gave good results. Drying was the most effective treatment. The etherized plants grew far better than the checks. The 48-hour treatment gave much better results than either the 12 or 24-hour. The frozen plants died, as might have been expected, as the dahlia is not expected to withstand frost.

Digitalis purpurea, L., var. gloxinaefolium, Hort. The check plants produced leaves abundantly but the flowers were very slow in forming. The ether treatments produced just the opposite effect, the blooming period being greatly hastened while the leaves made little growth. Those treated by freezing died.

Eryngium amethystinium, L. All leaves were out when treated. Severe injury resulted from freezing. Aside from the plants frozen,

all that were treated grew, but the growth was little if any better than the checks.

Gaillardia sp. The leaves were out at the time of treatment. Freezing was the only treatment that injured the foliage. None of the treatments caused any markedly earlier growth than the checks. However, those that were etherized forty-eight hours gave the best continued growth during the spring.

Gypsophila paniculata, L. The leaves were out when treatments were given but the foliage did not appear to be injured. Etherizing twelve hours gave the best results in hastening growth.

Hesperis Matronalis, L. The leaves were out when treated. Freezing killed the plants. The check plants made the earliest and best growth of all.

Iris sp. The plants treated by freezing died. While all of the others grew, the growth was no better than from the check plants.

Lychnis Chalcedonica, L. The leaves were out but not much injury resulted from treatments. The 48-hour ether treatment seemed to hurt the plants somewhat. Those treated with ether for twelve and twenty-four hours made the best continued growth up until April 1 when the last notes were taken.

Peony sp. At the time of treatment the buds had made considerable growth, being about three-fourths of an inch long. Etherizing for forty-eight hours caused the earliest growth, particularly for the first ten days after treatment. All of the ether treatments stimulated leaf growth.

The peony plants responded to the various treatments in such decisive manner as to be of special interest. (Refer to Fig. 7.) Pot No. 201 received no treatment; No. 282 was etherized for five hours; No. 347, twelve hours; No. 348, twenty-four hours; No. 394, forty-eight hours; No. 502 was frozen for twenty-four hours; and No. 452 was dried for eight days. The ether treatments were all effective in producing early growth, and the growth was strong in direct proportion to the length of time they were exposed to the anesthetic. Freezing was practically as effective as the strongest ether treatment while desiccation was little better than no treatment at all. All plants were photographed early in February, 1908, sixty days after treatment.

If conclusions are justifiable as a result of a single test, it would seem that peonies might be successfully forced into early flowering on a commercial scale.

Phlox sp. Leaves were out when treated. Etherizing twelve and twenty-four hours, and freezing, injured the plants severely, as

all these died. The check plants grew better than any that were treated.

Physostegia Virginica, Benth. The leaves were out but no injury resulted from ether treatments. On account of scarcity of material, two of the regular treatments—freezing and drying—had to be omitted from this test. Only one plant of the lot grew and that was one that had the 48-hour ether treatment.

Platycodon grandiflorum, DC. Only a few leaves were out at the time of treatment. Freezing killed the plants. The ether treatments, particularly the 12 and 24-hour exposures, hastened the growth by at least two weeks.

Rheum Rhaponticum, L. The leaves were showing but apparently no injury resulted from any of the treatments. Those given the 48-hour ether treatment made the best continuous growth and had the largest and strongest leaf stems. The growth following the 12 and 24-hour ether treatments, as well as freezing and drying, was about equal. The state of vigor in all of these was about the same.

Stokesia cyanea, L'Herit. Leaves on all plants were out at the time of treatments. The foliage on a part of those given the 24-hour ether treatment was badly injured, and the same was true of a few of those receiving the 12-hour treatment. Drying and freezing also injured the plants, the latter so badly that they died. None of the plants etherized seemed to thrive. The check plants made by far the most satisfactory growth. Fig. 6 illustrates the results of the treatments very nicely. Pot No. 740 received no treatment; No. 742 was etherized twelve hours and No. 744 was etherized twenty-four hours. All were photographed March 13, 1908, from forty-five to forty-seven days after treatment.

Thalictrum sp. The leaves were beginning to come out at the time of treatment, but the exposed parts were not injured. All of the treated plants grew, but none were ahead of the checks. The treatments seemed neither to hasten nor retard the growth.

Veronica sp. All of the treatments were very beneficial in that they caused the plants to grow earlier and better than the checks. Drying appeared to be as effective as etherizing.

Helenium midiflorium, Nutt. var. grandicephalum striatum and Kniphofia aloides, Moench. These made no growth at all, possibly due to injury in transplanting as the checks also failed to grow.

SUMMARY OF RESULTS

Bulbous plants have a pronounced rest period which occurs in summer. Preliminary experiments with ether and other agents which have been successfully used in breaking the rest period of woody plants, failed to arouse bulbs into growth, especially during the earlier part of their dormancy.

From experience gained in the work it is believed that the rest period of certain bulbs at least, can be broken if they are kept at a temperature of 60 degrees F. or lower after treatment.

Sixty-five species of herbaceous perennial plants were transplanted in late fall after becoming dormant, and treated in various ways to force them into growth. In the first experiment with thirty-six species, practically all that grew at all began growing in from one to three weeks. Nine species made no growth, either treated or untreated. Freezing was perhaps the best treatment for forcing early growth.

In the second test, twenty-five species of herbaceous perennials were used. All but five grew. There were great extremes in time of starting. Again freezing was the most effective treatment for causing early growth. The plants in the first test were all slightly frozen before being transplanted. In the second test none were frozen, except those given the freezing treatment. Freezing twice exerted less influence on the plants than freezing once, thus indicating that the effects of this treatment are not cumulative.

Thirty-one species were included in the third test. All grew except two. Many were in leaf when treated, and most of these were more or less severely injured by the treatments. Etherizing and freezing were especially harmful to the leaves. Some species were greatly stimulated, while in others the growth was markedly hindered by the treatments. Growth was greatly accelerated with *Baptisia*, *Cassia*, *Convallaria*, *Dahlia*, *Peony*, *Platycodon* and *Veronica* by treatments, while it was very much retarded in the case of *Anthemis*, *Campanula*, *Calliopsis*, *Chrysanthemum*, *Hesperis* and *Stokesia*. A few of the species were neither hurt nor benefited by the treatments.

It is believed that several species of herbaceous perennials have a rest period, and apparently most of these may be aroused into growth by proper treatments. Frost, desiccation, and ether appear to be the most effective rest period breaking agents.