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**An Experimental Study of the Rest
Period in Plants**

Pot Grown Woody Plants

THIRD REPORT



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An Experimental Study of the Rest Period in Plants

Pot Grown Woody Plants

W. L. HOWARD

Investigations at the Missouri Agricultural Experiment Station in 1905-6 established the fact that nearly all woody plants native to the temperate zone have a rest period.¹ The only criticism, direct or implied, that has been mentioned in connection with these researches was that twigs of trees and shrubs were used in the tests instead of whole plants growing in the soil. This objection being anticipated, preparations were begun as early as the fall of 1907 for securing a collection of woody plants growing in pots. Considerable difficulty was experienced in finding nursery grown plants for setting in pots. It was necessary to have plants with a comparatively small, fibrous root system. Many species do not naturally grow this way, especially from the seed. In most cases only repeated transplantings will make the right sort of plants for pot purposes.

FIRST EXPERIMENT WITH POT-GROWN WOODY PLANTS

In the spring of 1907 a small collection of woody plants, mostly trees one to two years old, were potted and the pots plunged in the garden where they were left thruout the summer and early fall. This collection consisted of: European beech (*Fagus sylvatica* Linn.), American ash (*Fraxinus Americana* Linn.), flowering ash (*Fraxinus Ornus* Linn.), green ash (*Fraxinus viridis* Michx.), magnolia, probably *Magnolia speciosa*, white oak (*Quercus alba* Linn.), swamp white oak (*Quercus bicolor* Willd.), bur oak (*Quercus macrocarpa* Michx.), black oak (*Quercus nigra* Linn.), red oak (*Quercus rubra* Linn.), rose (*Rosa multiflora* Thunb., var. Crimson Rambler) and spiraea (*Spiraea astilboides* Maxim., var. *floribunda*).

In the fall these plants were moved to the greenhouse without being exposed to frost. The plants for the most part, shed their

¹ Howard, W. L., An experimental study of the rest period in plants. Missouri Agricultural Experiment Station, Research Bulletin No. 1.

leaves after the soil became well dried out. The following treatments were given between November 27 and December 14, 1907 and the results are given in Table 1.

- | | |
|-----------------------|-------------------------------|
| 1. Frozen 24 hours | 6. Etherized 24 hours |
| 2. Frozen 48 hours | 7. Etherized 48 hours |
| 3. Frozen 96 hours | 8. Etherized 24 plus 24 hours |
| 4. Dried 8 days | 9. Etherized 48 plus 48 hours |
| 5. Etherized 12 hours | 10. Check (untreated) |

TABLE 1—RESULTS OF FREEZING, DRYING AND ETHERIZING POT-GROWN WOODY PLANTS FOR THE PURPOSE OF BREAKING THE REST PERIOD

O = No growth. — = No treatment.

Species	Time required for growth to begin after treatment									
	Check	Frozen			Dried	Etherized				
		24 hrs.	48 hrs.	96 hrs.		8 days	12 hrs.	24 hrs.	48 hrs.	24+24 hrs.
days	days	days	days	days	days	days	days	days	days	days
<i>Fagus sylvatica</i> Linn.	0	0	0	0	—	109	93	96	0	0
<i>Fraxinus Americana</i> Linn.	102	103	114	—	—	111	116	99	113	114
<i>Fraxinus Ornus</i> Linn.	122	0	107	106	—	103	101	103	100	109
<i>Fraxinus viridis</i> Michx.	59	65	0	0	—	83	62	66	62	60
<i>Magnolia</i> sp.	63	—	—	—	41	0	0	0	—	—
<i>Quercus alba</i> Linn.	106	0	—	—	—	101	62	99	99	62
<i>Quercus bicolor</i> Willd.	89	78	57	66	—	101	64	76	65	64
<i>Quercus macrocarpa</i> Michx.	96	—	—	—	—	0	79	78	81	70
<i>Quercus nigra</i> Linn.	76	0	0	0	—	112	81	88	89	88
<i>Quercus rubra</i> Linn.	0	—	—	—	—	129	0	126	83	79
<i>Rosa multiflora</i> Thunb., var. <i>Crimson Rambler</i>	13	5	—	—	12	3	1	4	—	—
<i>Spiraea astilboides</i> max- im., var. <i>floribunda</i>	60	17	—	—	8	4	56	10	—	—

GENERAL RESULTS OF FIRST TEST

All of the species were caused to grow thru one treatment or another. All apparently have a rest period, altho in the case of the rose it was very short and easily broken. The rest period apparently was not broken or shortened in very many of the species on account of the treatments.

Results in Detail

Fagus Sylvatica Linn. The check plant failed to grow. Freezing produced no growth. Growth followed the first three ether treatments,

although it was 93 days after etherizing before the first growth was observed, which was from the 24 hour treatment. *F. sylvatica* has a very strong rest period. While it might seem that the treatment broke the rest, this is doubtful as it is highly probable that the rest was practically at an end when the growth mentioned in the table occurred.

Fraxinus Americana Linn. While many of the plants grew following treatment, the earliest was in 99 days following the 48 hour ether treatment. The check required 102 days for growth, and it is possible



Figure 1. *Spiraea astilboides* Maxim., var. *floribunda*. Pot No. 212 check (no treatment); No. 462 dried for 8 days; 509 frozen 24 hours; 401 etherized 12 hours; 402 etherized for 48 hours. Photographed 60 days after treatment.

that growth in all of the plants came as a result of the natural ending of the period of rest. The treatments resulting in growth later than 102 days probably injured the plants so that the growth was actually retarded.

Fraxinus Ornus Linn. The results here were about the same as with the *Fraxinus Americana*.

Fraxinus viridis Michx. Apparently this species has a much shorter rest period than the other two species of ash discussed above. Here

the check plants grew in 59 days. Growth followed six out of the nine treatments, but in no case did it start earlier than the check plants. The conclusion is that the treatments had no effect on shortening the rest period.

Magnolia sp. On account of an insufficient supply of material only the drying and first three ether treatments could be given. The check plant grew in 63 days, while the dried plants grew in 41 days. Those that were etherized failed to grow, probably on account of being injured from the treatment.

Quercus alba Linn. This has a long rest period. The check plant grew after 106 days. Two ether treatments seemed to shorten the rest about one month.

Quercus bicolor Willd. This species has a rather long firmly fixed rest period. The check plants grew in 89 days. None of the treatments, except freezing for 48 hours, shortened the rest very much. The stronger ether treatments may have had some slight effect.

Quercus macrocarpa Michx. This has a strong rest period which is difficult to break by treatment. The ether treatments may have had some little effect, but it was very slight.

Quercus nigra Linn. This species has a very pronounced rest period. None of the treatments shortened the rest.

Quercus rubra Linn. This species is known to have a very strong rest period, although in this experiment the check plant failed to grow. None of the treatments apparently had any marked effect in shortening the rest.

Rosa multiflora Thunb., var Crimson Rambler. This species has a very slight rest period. The check plant grew in 13 days. All of the treatments, with the exception of drying, greatly hastened the growth.

Spiraea astilboides Maxim., var floribunda. This species has a fairly long rest period, although it was easily influenced by treatment. The check plant required 60 days for first growth to appear. Fig. 1 shows the results of treating this species. Pot No. 212 received no treatment. Pot No. 462 was dried 8 days; No. 509 was frozen 24 hours; No. 401 was etherized 12 hours, and No. 402 was etherized 48 hours. Apparently the stronger the ether dosage, the better the results were in securing growth. However, all of the etherized plants made a very good growth. Strangely enough the 12 hour ether treatment caused growth to start the earliest of all.

Apparently woody plants behave just the same, when treated with rest period breaking agents, whether they are whole and connected with a root system or in the form of twigs. It is evidently the buds and not the roots that are affected by the treatments, or, which are



Figure 2. *Acer Negundo* Linn. Pot No. 26 no treatment; No. 22 etherized 48 hours; and No. 20 etherized 48 plus 48 hours. Photographed Dec. 24, 1908, about one month after treatment.

influenced to grow without treatment, in cases where the rest period has ended or is weak enough to be overcome by warmth alone.

These conclusions are drawn from the results of only one test and that consisting of but twelve species. However, that short list contained some of the more interesting forms that were experimented with when the extensive tests with twigs were carried out in 1905-6.

SECOND EXPERIMENT WITH POTTED WOODY PLANTS

In the fall of 1907 several species of seeds of woody plants were ordered and stratified preparatory to being planted the following spring. In the spring of 1908 a shipment consisting of thirty species of 250 plants each, of one to three-year-old trees and shrubs was received from France. These plants were propagated from both seeds and cuttings and all had been transplanted from one to three times. Such as were required for forcing purposes the following winter were planted in flower pots of the proper sizes (7 to 12 inches) and the pots plunged their full length in mellow soil in the garden where they were left all summer. As the leaves began to fall in autumn, the plants were removed to a cold-frame where the temperature was 60 to 65 degrees Fahrenheit. Not all of the plants shed their leaves at the same time. Fearing that some of them might be caught by an unexpected freeze, all were moved to the cold-frame while a few were still in leaf. A few of them, *Quercus robur* in particular (Fig. 7), retained their leaves nearly all winter. It was late in November before all of the plants were ready for treatment.

The object of this experiment was to find:

First, how many of the species were able to grow at once when placed under good growing conditions;

Second, to learn what species if found to have a rest period could be forced into growth; and

Third, what agents were most effective in breaking the rest period.

Treatments Given. The treatments given for breaking the rest period were freezing, drying and etherization. Before any of the treatments were given, it was necessary to let the soil in the pots become dry enough so that the surface, at least, showed no appreciable moisture. The drying was done by placing the pots in an air-heated room. The freezing was done by leaving the plants outside during two nights when the temperature was several degrees below the freezing point. The plants were etherized by means of an apparatus which is fully described in Research Bulletin No. 15 from this station. Briefly, this apparatus consisted of a cylindrical, galvanized iron chamber about eighteen inches in diameter, six feet high, and made in two sections. Either one or both of the sections could be used at the same time, depending upon the number of plants to be treated. Liquid ether was used at the rate of 40 grams to each 100 liters of space in the chamber.

The treatments were as follows:

1. Dried for 8 days
2. Frozen for 24 hours

3. Etherized for 24 hours
4. Etherized for 48 hours
5. Etherized for 48 plus 48 hours
6. Check (untreated)

Beginning November 20, 1908, thirty-six species of pot-grown woody plants were given the above treatments. As a rule four plants of each species were used for each separate treatment. On account of the large number of pots to be handled, and the great care that had to be exercised in bringing the plants to a uniform condition before treatment, particularly with regard to the dryness of the soil, it was

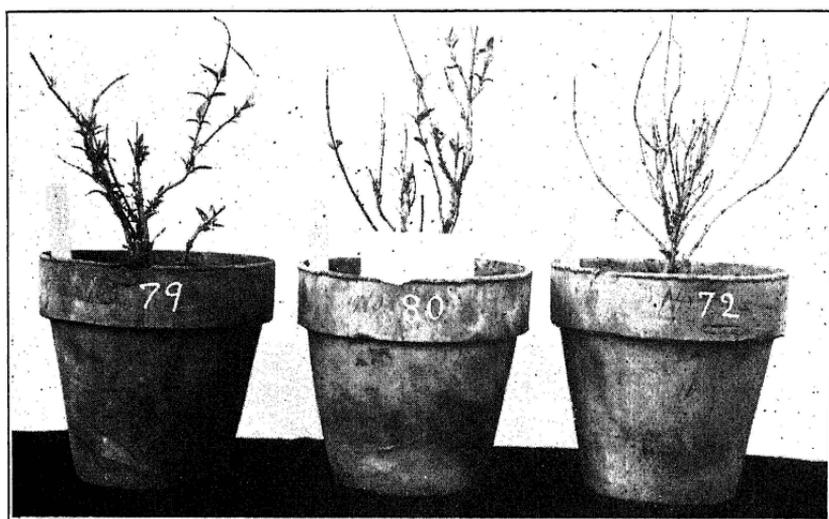


Figure 3. *Deutzia gracilis* Sieb. & Zucc. (Young plants). Pot. No. 79 etherized 48 plus 48 hours; No. 80 etherized 48 hours; and No. 72 no treatment. Photographed about one month after treatment.

January 5, 1909, before all of the treatments were completed. In etherizing, great care had to be taken to see that the soil was not moist. A moist soil readily absorbs ether vapor.

As soon as a given treatment for a set of plants was completed, the pots were placed in a mild hotbed. By the side of them were placed from two to four pots containing check or untreated plants. After the pots were placed in the hotbed, the surface of the soil of each was cultivated and then all were kept watered. The entire collection of pots was left in the hotbed until spring. The results of this test are shown in Table 2.

TABLE 2—REST PERIOD TEST WITH POT-GROWN WOODY PLANTS AND THE VALUE OF DIFFERENT AGENTS FOR FORCING THEM INTO VEGETATIVE GROWTH

Treatments Given Between November 20, 1908, and January 5, 1909

SPECIES	Time required for growth to begin after treatment.					
	Check	Dried	Frozen	Etherized		
		8 days	24 hrs.	24 hrs.	48 hrs.	48+48 hrs.
	days	days	days	days	days	days
<i>Acer dasycarpum</i> Ehrh.....	72	0	45	0	0	22
<i>Acer Negundo</i> Linn.....	0	94	108	29	27	10
<i>Carpinus Betulus</i> Linn.....	36	0	0	0	36	0
<i>Celtis occidentalis</i> Linn.....	112	132	61	0	0	0
<i>Cornus Mas</i> Linn.....	0	72	0	0	36	37
<i>Crataegus Oxyacantha</i> Linn.....	42	0	0	17	28	39
<i>Deutzia gracilis</i> Sieb. & Zucc.....	36	10	14	11	7	7
<i>Euonymus Europaeus</i> Linn.....	51	0	0	27	13	23
<i>Fagus sylvatica</i> Linn.....	0	0	0	0	30	17
<i>Fagus sylvatica</i> Linn. var. <i>purpurea</i>	0	0	0	0	0	11
<i>Forsythia suspensa</i> Vahl.....	30	0	0	0	0	28
<i>Fraxinus Americana</i> Linn.....	0	71	82	0	0	0
<i>Fraxinus viridis</i> Michx.....	0	0	0	7	0	14
<i>Genista alba</i> Lam.....	6	0	9	0	0	0
<i>Hibiscus Syriacus</i> Linn.....	18	25	40	23	13	9
<i>Liriodendron tulipifera</i> Linn.....	32	7	0	27	12	9
<i>Philadelphus Gordonianus</i> Lindl.....	10	4	7	8	9	16
<i>Prunus Persica</i> Sieb. & Zucc.....	24	14	0	0	10	25
<i>Pyrus Malus</i> Linn., var. <i>Doucin</i>	17	13	30	8	12	0
<i>Pyrus Malus</i> Linn., var. <i>Paradisica Hort.</i>	0	0	26	0	0	10
<i>Quercus coccinea</i> Wang.....	116	102	103	108	16	73
<i>Quercus robur</i> Linn.....	0	37	41	38	35	0
<i>Quercus rubra</i> Linn.....	106	126	0	0	32	24
<i>Spiraea Thunbergii</i> Sieb.....	3	1	9	6	7	10
<i>Spiraea Van Houttei</i> Linn.....	7	1	0	5	5	6
<i>Syringa vulgaris</i> Linn., var. <i>rubra major</i> (Charles X).....	10	1	12	7	5	6
<i>Viburnum lantana</i> Linn.....	15	1	0	4	4	5
<i>Viburnum Opulus</i> Linn.....	0	0	0	0	0	14
<i>Weigela rosea</i> Lindl.....	41	20	8	7	8	10
<i>Wisteria speciosa</i> Nutt.....	0	0	0	0	28	39

Of the species treated, thirty-one made some growth, while the following five species made no growth whatever:

Cornus alba Linn.

Cytisus albus Link.

Fraxinus Ornus Linn.

Hydrangea paniculata Sieb.

Juglans nigra Linn.

GENERAL RESULTS OF SECOND TEST

In the main, the potted plants under treatment behaved much the same as treated twigs of the same or similar species in previous experiments. In a few instances the check plants failed to grow. While this makes it impossible to check the exact effects of the treatments, it is still possible to compare them with each other. For the most part those check plants that failed to make any growth whatever were species that are known to have a very pronounced rest period—a rest

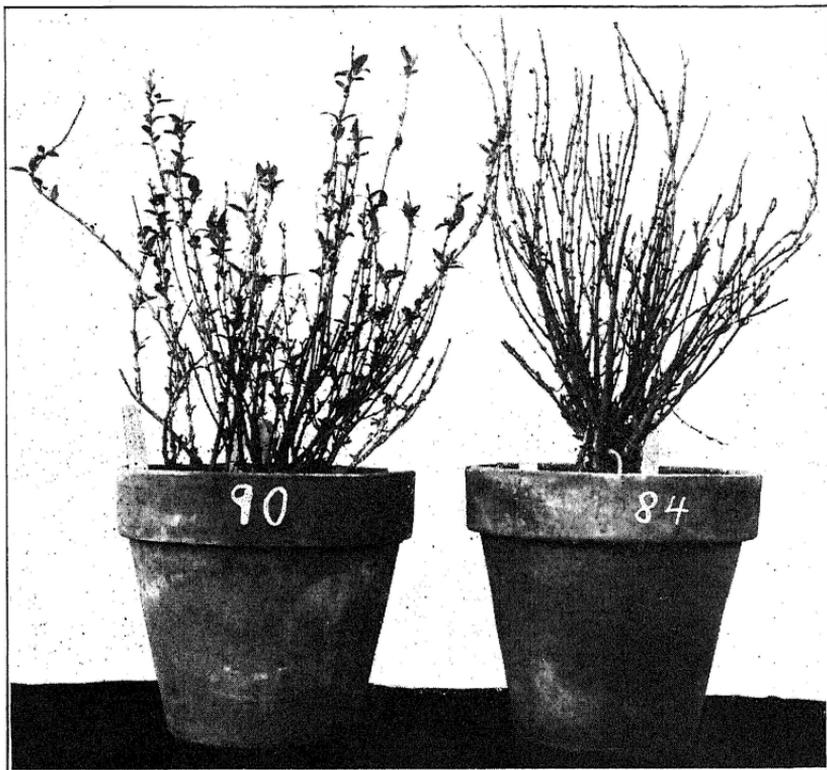


Figure 4. *Deutzia gracilis*. (Old plants.) Pot No. 90 etherized 48 plus 48 hours; and No. 84 not treated.

that is so profound that only the severest treatments will arouse them into growth before spring. Notable examples are the European beech (*Fagus sylvatica* Linn., and *F. sylvatica*, var. *purpurea* Ait.), American ash (*Fraxinus Americana* Linn.), green ash (*Fraxinus viridis* Michx.), and the English oak (*Quercus robur* Linn.).

Strangely enough the red oak (*Quercus rubra* Linn.) was caused to grow in three to four weeks by one of the treatments. Both of the

oaks *Quercus coccinea* Wang and *Quercus rubra* Linn., grew untreated in from fifteen to sixteen weeks, which probably means that their rest period was then at an end.

Of those species that failed to make any growth whatever, either where treated or untreated, at least two—*Fraxinus Ornus* and *Juglans nigra*—have a strong rest period. The other three—*Cornus alba*, *Cytisus albus* and *Hydrangea paniculata*—are not so well known, but evidently they have a strong period of rest. It should be understood that plants with a strong rest period—so strong that they do not respond either to good growing conditions or to treatment—are likely to die if kept in a warm room for several weeks. In these cases death is generally due to loss of moisture, as respiration continues to go on and the roots being apparently inactive, are not able to supply the plants with the necessary water. If plants after treatment could be kept in a room where the temperature is not only warm, but moist, they probably would survive until spring or to the date when their natural rest period comes to an end and growth can begin.

Results in Detail

Acer dasycarpum Ehrh. The treatment bringing about the quickest growth was etherization 48 plus 48 hours; growth occurred in 22 days. The untreated plants began to grow in 72 days. This presumably was the length of their natural rest. Freezing 24 hours produced growth in 45 days. No growth resulted from the other treatments.

It should be explained that the 48 plus 48 hours treatment with ether means that the plants were exposed to the ether fumes for 48 hours; were then taken out and kept in the greenhouse for 48 hours more, and then were again placed under the influence of the ether for another 48 hours. This completed the treatment. This treatment is a very severe one, and while it is the only one that will produce growth in a refractory species, the percentage of growth is likely to be small, as the severity of the treatment often kills the plants.

Acer Negundo Linn. Again the 48 plus 48 hour ether treatment produced by far the earliest growth. The *Acer Negundo* has been listed as a species with a strong rest period. The fact that the check plants here failed to grow would indicate this, as they probably died from drying out before spring. The frozen plants grew after 108 days. This probably indicates that the treatment had no effect on the rest period. All of the ether treatments showed good results.

On December 24, about one month after treatment, the plants given the 48 plus 48 hour ether treatment (pot No. 20), were far ahead of the others. The next best growth followed the 48 hour ether treatment. (See Fig. 2.)

Carpinus Betulus Linn. This is a species having a very pronounced rest period. While at times this rest appears to be short, it is very difficult to arouse the plants into growth during the early phases of the rest. Since the check plants began to grow in 36 days, which was about the first of January, it would seem that this was the end of the



Figure 5. *Euonymus Europaeus Linn.* Pot No. 323 etherized 24 hours; No. 322 etherized 48 hours; No. 320 etherized 48 plus 48 hours; and No. 314 no treatment. Photographed Dec. 26, 1908, about one month after treatment.

rest period. The only growth that followed any of the treatments was from those that were etherized 48 hours, but this growth occurred on almost the same date that the checks did.

Celtis occidentalis Linn. This is a species with a long rest period, but one that will usually yield to treatment. However, in the present

experiment none of the ether treatments produced any growth. Freezing seemed to have some effect as growth occurred after two months. The untreated plants grew in 112 days. If this represents the normal rest period, then the drying actually hindered the growth, as those plants did not grow until after 132 days had elapsed.

Cornus Mas Linn. This species is not one that is usually considered to have a strong rest period. Where twigs are taken from mature trees they will begin growth without treatment inside of three weeks. Here the untreated plants made no growth, and finally died. Those that were dried grew in 72 days; the frozen ones died. Those etherized 24 hours died; those receiving the other two ether treatments grew in 36 and 37 days respectively. No explanation can be given for the response made to the treatments.

Crataegus Oxyacantha Linn. Here the check plants grew in 42 days. Drying and freezing produced no growth. Etherized 24 hours produced the quickest growth—in 17 days. Growth followed the other two ether treatments in 28 and 39 days respectively. It is interesting to note that here the usual effects of ether treatments were reversed, in that the milder the dose, the quicker the growth.

Deutzia gracilis Sieb. and Zucc. This is a species with a medium length rest period. In this test the check plants grew in 36 days. The rest period was broken with comparative ease by different treatments. The two stronger doses of ether produced growth in 7 days; drying produced growth in 10 days; 24-hour ether treatment in 11 days, and freezing in 14 days. Fig. 3 shows the amount of growth that had taken place on December 19, about one month after treatment. Pot No. 79, which was etherized 48 plus 48 hours, made a little the best growth. Pot No. 80 received the 48 hour ether treatment, and No. 72 was one of the check plants. None of the checks had made any growth up to this time. They did begin growing, tho, about a week later. However, the check plants and those treated by drying made a very poor leaf growth in the late winter and did not flower at all. Those that were frozen and etherized continued to grow thruout the winter, and made a fair bloom.

Fig. 4 shows some additional plants of *Deutzia gracilis* which were given the same treatments as those in Fig. 3. The photograph was made about one month after treatment. Pot No. 90 was etherized 48 plus 48 hours, and made the best growth of all. Pot No. 84 received no treatment. For some reason none of these old plants made a very vigorous growth of either leaves or flowers.

Euonymus Europaeus Linn. Experience with this species seems to indicate that it has a rather strong rest period. The first growth among the check plants in this test began in 51 days. The ether treat-

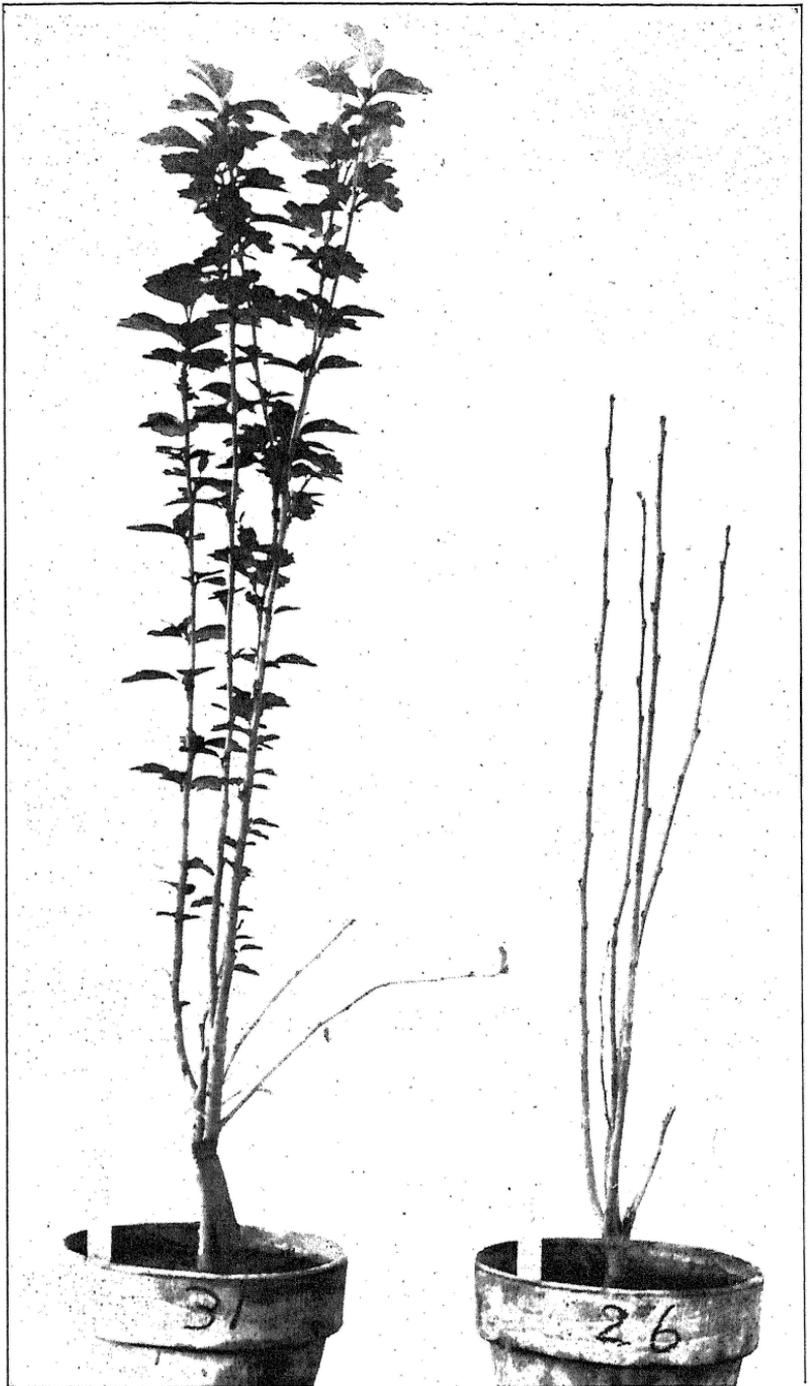


Figure 6. Hibiscus Syriacus Linn. Pot No. 31 was etherized 48 plus 48 hours while No. 26 received no treatment. Photographed Dec. 19, 1908, about one month after pot 31 was etherized. No. 26 began to grow about one month later, Jan. 20, 1909.

ments caused growth in from two to three weeks. The 48-hour treatment with ether produced growth in 13 days. Fig. 5 shows the average condition of growth about one month after treatment. Pot No. 323, on the left, was etherized 24 hours; No. 322, 48 hours; No. 320, 48 plus 48 hours, and No. 314 received no treatment. The latter had made no growth up to December 26. However, it did begin growing two weeks later. Apparently the medium ether treatment produced the best results, although only slightly better than the stronger ether treatment.

Fagus sylvatica Linn. This is a species that has a rest period that is both long and profound and can rarely be broken by any kind of treatment. As a rule the species of the genus *Fagus* are very difficult to force into growth. They have perhaps the strongest and most firmly fixed resting period of any plants experimented with at this station. When twigs of this species were treated, it was never possible to force them into growth during the winter. Here in this experiment with pot plants the two strongest ether treatments produced growth, the 48-hour dose produced growth in 30 days, and the 48 plus 48-hour dose in 17 days. As might have been expected the check plants failed to grow. This species has a rest period that usually continues until about the first of March.

Fagus sylvatica Linn., var. purpurea Ait. This is the purple leaved beech usually regarded as a variety of *F. sylvatica*. Usually the variety *purpurea* can be made to grow by treatment, while its progenitor, *F. sylvatica* can not. In this particular test *F. purpurea* was caused to grow in 11 days by the strongest ether treatment. None of the other treatments produced any growth, and neither did any of the check plants grow.

Forsythia suspensa Vahl. Previous experience with two or three species of the genus *Forsythia* showed that while it has a rest period, the rest period is short and can be easily broken by mild treatments. Here the check plants began to grow in 30 days. Drying, freezing, and etherizing 24 and 48 hours produced no growth. Strangely enough, only the strongest ether treatment produced any growth out of all of the treatments. While the strong ether treatments will produce leaf growth, a 12 to 24-hour treatment is sufficient for the flower buds, as anything stronger will kill them.

Fraxinus Americana Linn. This is a species that has a strong rest period. The check plants failed to grow at all. Those that were dried 8 days, and those frozen 24 hours grew in 71 and 82 days respectively. None of the other treatments produced growth. Ordinarily, strong ether treatments will produce a slight growth after

about two months. In other words, the rest period of this species can not be shortened much by treatment.

Fraxinus viridis Michx. Ordinarily this species behaves very much like the *F. Americana*. In this experiment the check plants failed to grow, but growth was secured following the mildest and the strongest ether treatments. The former produced growth in 7 days, and the latter in 14 days. Evidently the *F. viridis* has a less pronounced



Figure 7. *Quercus robur* Linn. Pot No. 260 check, and 267 etherized 48 hours. The untreated pot had made no growth up to Jan. 8, 1908, when the photograph was made. The old leaves hung on and remained green until spring. No growth occurred until early summer. Leaves on pot 267 are five weeks old.

rest period than the *F. Americana*; that is, while the rest may be just as long, it is not so profound, being much more easily broken by treatment.

Genista alba Lam. This species apparently has a very short rest period as the check plants began growth in 6 days. None of the treatments, except freezing, produced any growth; growth following that treatment began in 9 days. Evidently since this species has only a very light rest period, the treatments hindered the growth. This principle

generally always holds good. As discussed above in connection with *Forsythia*, if growth takes place without treatment or following only a very light treatment, strong doses or other forms of severe treatment are very likely to kill the flower or leaf buds, or both.

Hibiscus Syriacus Linn. This species usually forces with considerable ease as the rest period is neither long nor particularly profound. In Table 2 it will be noticed that the check plants began to grow in 18 days, while with two exceptions growth following the treatments did not begin in less than from 23 to 40 days. The two stronger ether treatments produced growth in 13 and 9 days respectively. The results on the whole are contradictory, as drying, freezing and the 24 hour ether dosage are much milder treatments than the two that produced growth in 13 and 9 days respectively, and yet they seemed to have hindered growth. Fig. 6 shows forcibly the difference between the treated and untreated plants. Pot No. 31 was etherized 48 plus 48 hours, while No. 26 received no treatment. They were photographed about one month after treatment. The untreated plants, as will be seen in the table, afterwards grew.

Liriodendron tulipifera Linn. Previous experience in forcing twigs of this species showed that it seems to have a very pronounced rest period and that it was almost as difficult as the beech to force into growth. Here the pot plants untreated grew in 32 days. Also the various treatments, with one exception, seemed to produce growth easily. Those dried grew in 7 days; etherized 48 plus 48 hours in 9 days; etherized 48 hours in 12 days, and the 24 hour ether treatment in 27 days. While these results are somewhat at variance with the outcome of previous experiments with this species, they are at least consistent and seemingly reliable.

Philadelphus Gordoniana Lindl. This species does not have a very strong rest period and hence is easily aroused into growth by mild treatments. Drying produced growth in 4 days; freezing in 7 days; etherizing 24 hours in 8 days; etherizing 48 hours in 9 days, and the strongest ether treatment in 16 days. The last mentioned treatment seems to have hindered growth which was to be expected, as an unnecessarily severe treatment generally hinders growth.

Prunus Persica Sieb. and Zucc. The untreated plants of this species began growing December 14, 24 days after being placed under growing conditions. The numerous varieties of this species (the common peach) seem to vary somewhat as regards length of rest period. Also the state of vigor of the trees has much to do with the time at which the rest period is likely to set in. It may begin as early as June with many of the twigs, if the trees are exceedingly weak as a result of poor soil, injury, drought or other causes. On the other hand, peach

trees that have been severely pruned in winter will make a very vigorous growth the following summer, and this growth is likely to continue until the trees are overtaken by frost. Under such circumstances the rest period begins perhaps in late October, and consequently will not entirely end until late February, while if the trees are very weak, the rest period begins early in the summer and is practically



Figure 8. *Quercus rubra* Linn. Pot No. 253 was etherized $\frac{1}{8}$ plus $\frac{1}{8}$ hours; No. 247 was not treated. As they appeared Dec. 19, 1909, five weeks after treatment.

ended by the time winter begins. In the latter case the rest period being at an end, the fruit buds are ready to grow at any time during the winter when there is enough warm weather to make them active.

Late in January, three or four bright sunny days may start growth. If a severe freeze comes later, the buds are very apt to be killed. On the other hand where the rest period sets in late and does not end until winter is over, no amount of warm weather during January or

February will cause premature growth in the buds, and consequently they escape freezing out. Thus it seems that the rest period of the peach is a very important factor in determining the hardness of this fruit.

Only two of the treatments—drying 8 days and etherizing 48 hours—produced growth earlier than the check plants. The strongest ether treatment seemed to hinder growth.

Pyrus Malus Linn. var. Doucin. The Doucin or semi-dwarf apple appears to have a notably short rest period. Check plants grew in 17 days. All of the treatments except freezing produced an earlier growth. The best results followed etherizing 24 hours; these grew in 8 days.

Pyrus Malus Linn., var. Paradisiaca Hort. Usually this species—the Paradise or dwarf apple—does not manifest a very strong resting period. In this test, however, the check plants failed to grow, thus seeming to indicate that they have a very long rest period. However, the results are rather contradictory as the strong ether treatment produced growth in 10 days; freezing in 26 days; and other treatments no growth at all. No definite conclusion can be reached from the available data.

Quercus coccinea Wang. All of the oaks as a rule have a very pronounced rest period. *Q. coccinea* plants untreated, grew after 116 days, thus indicating that the rest period is very long. The earliest growth noted was in 16 days as a result of the 48-hour ether treatment. Following the strongest ether treatment, growth occurred in 73 days, while none of the other treatments produced growth in less than 103 days. Evidently the majority of the treatments have very little effect in shortening the rest period of this species.

Quercus robur Linn. Here the check plants failed to grow at all. While difficult to force, past experience teaches that this species will respond to treatment. In this test all of the treatments, except the last of the ether series, produced growth in from five to six weeks. Fig. 7 illustrates the effects of the treatments.

Pot No. 260 received no treatment and no growth had occurred by January 8 when the photograph was taken. This was one of the cases where the old leaves formed the previous summer when growing out-of-doors failed to drop off when the pots were taken in. They hung on until spring. The plants failed to make any growth until the following summer, long after note taking had ceased. Therefore, they are listed as having made no growth. The old leaves remained on until after the new ones were well out. Pot No. 267 was etherized 48 hours; this made the earliest growth of all. Fig. 7 shows the extent

of the growth about five weeks after treatment. The old leaves remained on this plant until the new ones were well out.

Quercus rubra Linn. This is another species known to have a long rest period, from which it is possible to arouse the plants into growth, but usually requiring severe treatment. The check plants grew in 106 days, while the two strong ether treatments brought about growth in 32 and 24 days respectively. Fig. 8 shows the extent of the growth one month after treatment. Pot No. 253 was given the

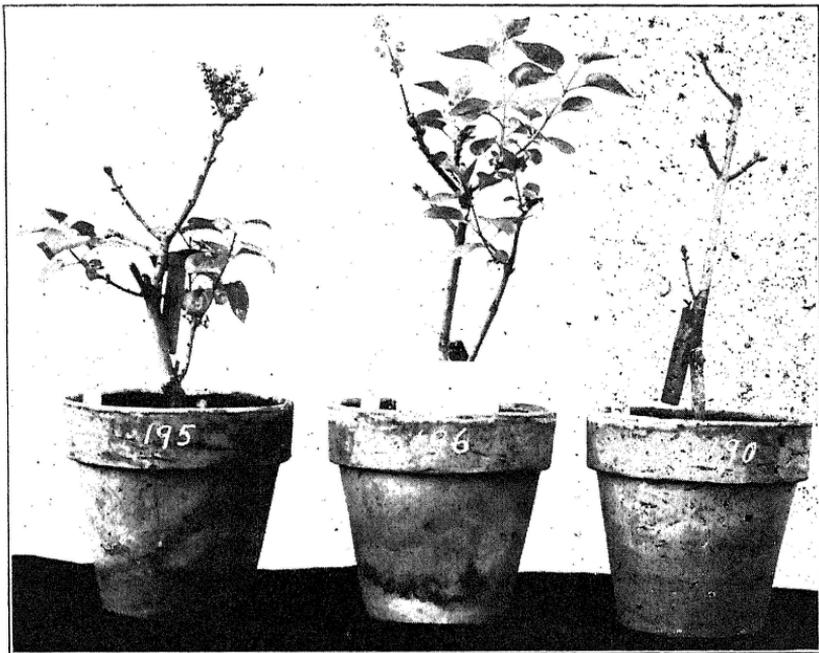


Figure 9. *Syringa vulgaris* Linn., var. *rubra major* (Charles X). Pot No. 195 etherized 48 plus 48 hours; No. 196 etherized 48 hours; and No. 190 check. Photographed Dec. 19, 1908, about four weeks after treatment.

48 plus 48-hour treatment, while No. 247 received no treatment. The latter did not grow for more than three months after the photograph was taken.

Spiraea Thunbergii Sieb. This species has a short rest period and one that is easily broken. The check plants grew in three days. None of the treatments, except drying, seemed to hasten the growth, which is natural in a plant having such a short, easily broken, rest period. In cases of this kind, treatments are likely to actually hinder growth as they apparently did with this species, as shown in Table 2.

Spiraea Van Houttei Linn. Like the last species discussed, this also has a very short, easily broken, rest period. The check plants grew in 7 days, while all of the ether treatments that produced growth at all produced it from one to six days earlier. This shows the differences that may be expected between closely related species.

Syringa vulgaris Linn., var. rubra major (Charles X). This is a species having normally a rather long rest period, but one that can be roused into growth with ease by treatment. In fact this species and variety (Charles X) has been quite generally used for forcing purposes by florists, particularly in Germany and Denmark. Ether is the popular agent for forcing growth. In this test all three of the ether treatments gave good results, securing growth in from 5 to 7 days. Freezing apparently did not hasten the growth. There was a trace of growth following drying, one day after plants were treated. Fig. 9 illustrates the effects of the ether treatments. The photograph was taken on December 19, 1908. Pot No. 195, which had made a good leaf growth and bloomed nicely, was etherized for 48 plus 48 hours, while No. 196, which made an even better leaf growth but did not bloom so vigorously as the other, was given the 48 hour ether treatment. No. 190 received no treatment, and on December 19, one month after being placed under growing conditions, growth had only just begun to show, none of the buds being fully open.

Viburnum lantana Linn. The check plants grew in 15 days. All of the treatments, except freezing, produced growth in from one to five days. Evidently the rest period is very easily broken. Etherization for the 48 hour period produced the best growth of all. The 48 plus 48-hour ether treatment gave some better growth than the untreated plants but the difference was not very marked.

Viburnum Opulus Linn. This species has a much stronger rest period than the *V. lantana*. It does not respond very well to treatment, or at least did not in this test. Growth followed the strongest ether treatment in 14 days, while none of the other treatments produced any growth at all. In Fig. 10 may be seen two of the plants, Nos. 331 and 332, which received the 48 plus 48-hour ether treatment. Both have made a scattering growth. Pot No. 325 received no treatment, and there was no growth. The photograph was made about three weeks after treatment.

Weigela rosea Lindl. This species appears to have a fairly long rest period. The check plants did not begin growing until after 41 days. All of the treatments apparently shortened the dormant period, the 24-hour ether treatment being the best of all. Growth began following this treatment in 7 days. Freezing and the other ether treatments caused growth in from 8 to 10 days. See Fig. 11. Pot No. 375

received no treatment, while No. 379 was frozen for 8 days. This shows the best growth of all of the treatments at the time the photograph was taken, on December 19, about three weeks after treatment.

Wisteria speciosa Nutt. This species has a strong rest period apparently, and is rather difficult to force into growth. The two strongest ether treatments produced growth in 28 and 39 days respectively. None of the other treatments produced growth, and neither did any of the check plants grow. (See Fig. 12.) No. 297 received no treatment, while No. 300 was etherized for 48 plus 48 hours. The photograph was taken on January 8, about seven weeks after treatment.

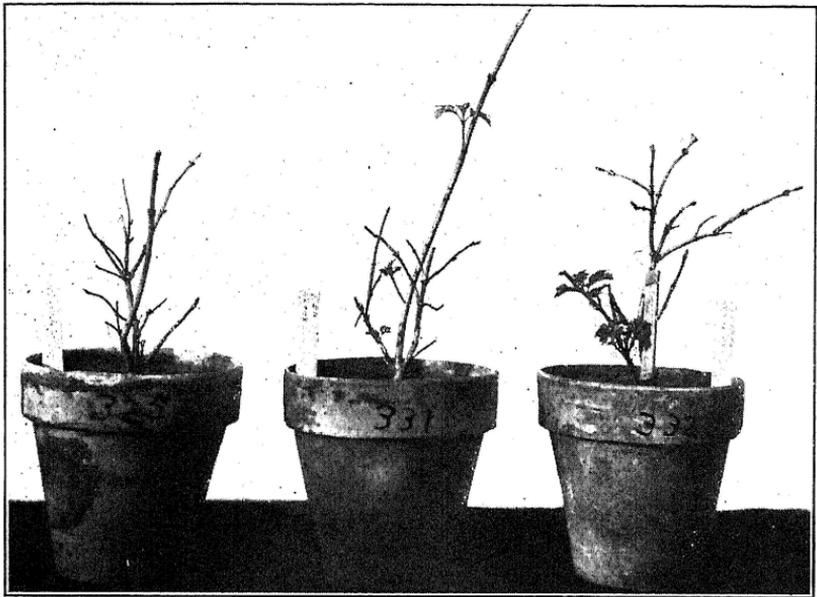


Figure 10. *Viburnum Opulus* Linn. Photographed Dec. 19, 1908, three weeks after treatment. Pot No. 325, check. Pots 331 and 332 received the same treatment, etherizing 48 plus 48 hours. Both grew while the check did not.

SUMMARY OF RESULTS

The second test confirms the conclusions drawn from the first experiment, viz., that rest period studies with woody plants can be just as safely carried on with twigs twelve to fifteen inches long, as with trees or shrubs of the same species growing in pots. While experimenting with twigs it sometimes seemed that a large percentage of the checks died without making any growth, and there was always some question as to whether this might not have been due to their

being twigs rather than plants with a root system. However, the tests with potted plants showed fully as many deaths as the twigs where the species possessed a long rest period and consequently could not grow until late winter or spring, and generally by that time had lost so much moisture from respiration that they were unable to recover.

Evidently then it is the buds alone that are to be dealt with. The secret of the rest period itself lies in the buds rather than in the roots, cambium or any of the tissues of trunk or branches. It is very probable that growth in potted plants following treatments, at first takes place only in the buds and this entirely independent of the roots, the latter becoming active some time later. If it is enzyme activity that causes growth to begin, there seems no reason why these agents might not become active in the buds and this activity gradually extend to other parts of the stem and even to the roots.

The roots of potted plants certainly are not directly affected by the ether treatments as the soil is purposely made very dry to prevent the absorption of the vapor. If the soil were allowed to take up the ether, varying amounts would be absorbed and there would be no means of knowing to what extent the buds had been exposed to the vapor. Besides, perfectly satisfactory results in producing growth from etherizing may be secured by securely covering the soil so that none of the vapor even comes into contact with it.

Of course when plants are frozen, the roots may be affected the same as the buds, but a study of the tables does not disclose any evidence that the roots are affected by one treatment any more than another.

The principal object of this investigation with potted plants was to confirm the fact of the existence of a rest period in certain representative species of woody forms. Also to test the behavior of potted plants both where treated and untreated, for the purpose of comparing the results with the behavior of twigs of similar species which had been treated and otherwise handled in the same manner. For the most part the twigs and plants reacted approximately in the same manner to the various treatments. The only difference noted was that growth, when once started in the potted plants, continued longer than in the twigs, but this is only natural when we remember that the nutritive supply of the twigs is limited to the reserve food stored in the tissues while the plants, after the formation of leaves, are able to absorb what they need from the soil.

In the experiments described in this report, no effort was made to inquire into the causes of the rest period or why growth can be produced in dormant plants by means of treatments. It is very proba-

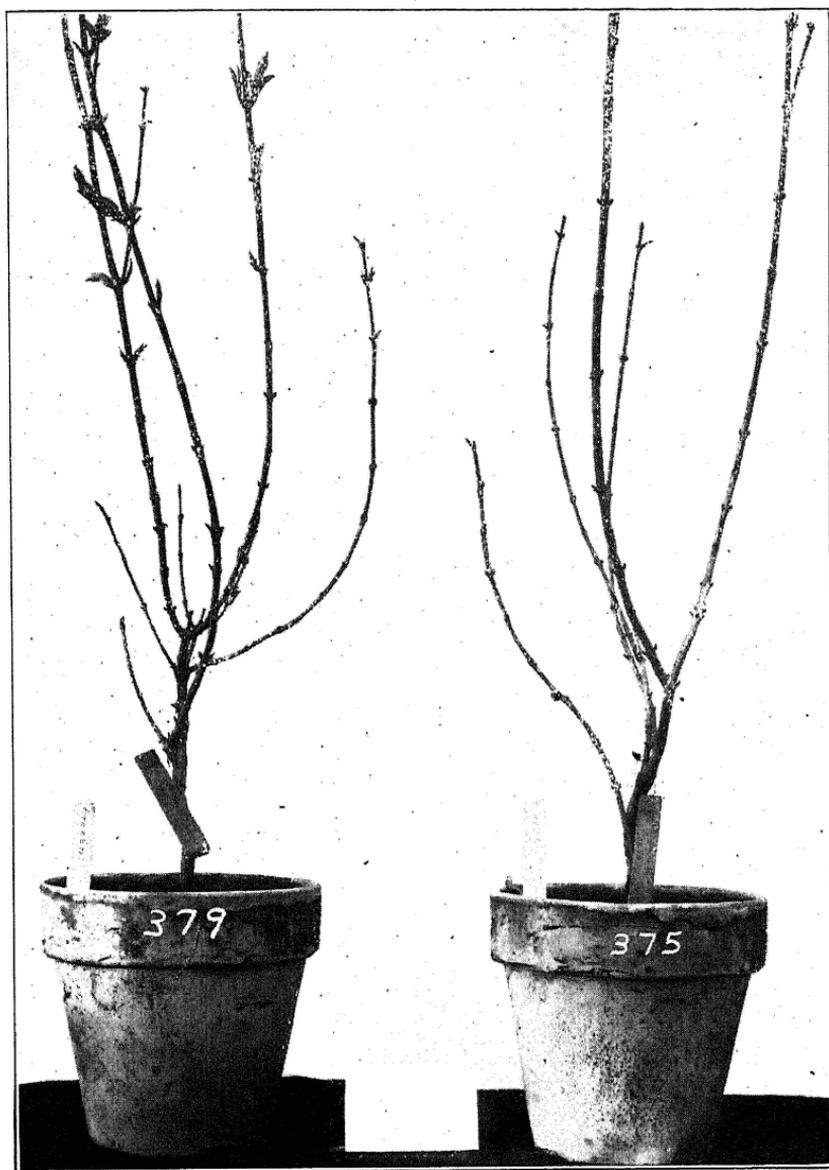


Figure 11. *Weigela rosea* Lindl. No. 379 frozen for 8 days; 375 was not treated. Photographed Dec. 19, 1908, three weeks after treatment.

ble, however, that plants become dormant because the enzymes or ferments cease to work, and that growth starts again when these agents are caused to again become active. If this be true the specific effect of a given treatment which produces growth in a dormant or

resting plant, is to arouse some particular ferment into activity so that it may act upon the organic compounds in the cells and tissues and among other things, convert starch into sugar. An investigation is now underway for the purpose of studying the work and activities of the enzymes during the dormancy of woody plants as well as during growth.

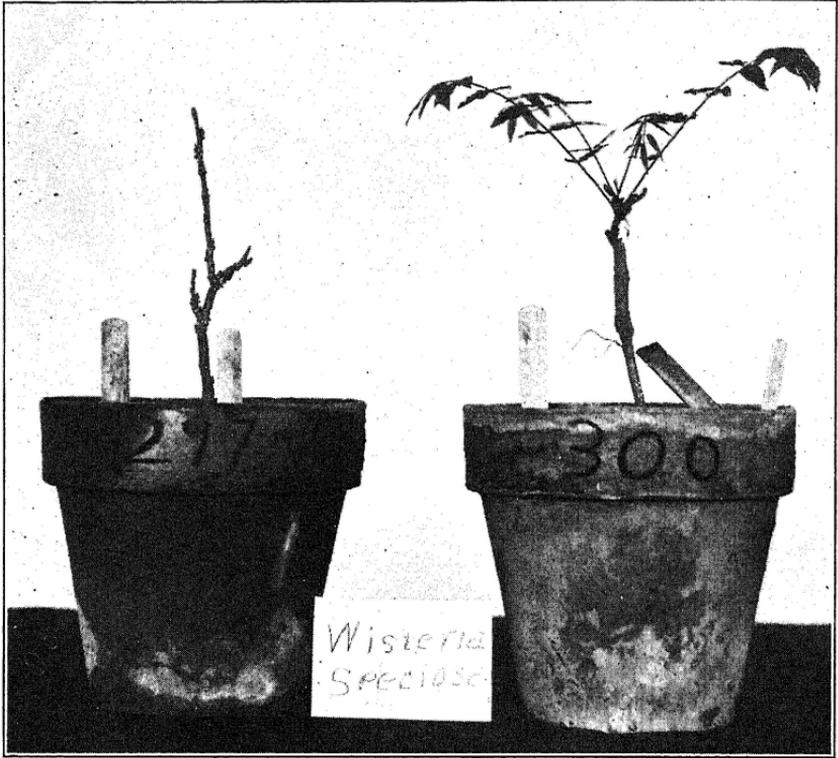


Figure 12. *Wisteria speciosa* Nutt. No. 297 not treated; No. 300 etherized $\frac{1}{8}$ plus $\frac{1}{8}$ hours. Photographed Jan. 8, 1909, about seven weeks after treatment.

CONCLUSIONS

The fact of the existence of a rest period in a large number of species of woody plants has been established and the conclusion seems justifiable that practically all woody forms rest for a longer or shorter period of time.

It is believed that the rest period of all woody plants can be broken by proper treatment, although a few are very difficult to arouse into growth. Some of the more difficult species that do not yield to treatment during the early part of their rest, will grow later.

A woody plant that begins to grow within a week or ten days after being placed under growing conditions, can scarcely be said to have a rest period. The dormancy of such species is an unnatural or enforced rest due to unfavorable growing conditions.

The rest period of woody plants may be tested by using twigs only. It is only necessary to have wood of the last seasons growth which of course bears the newest buds. Latent buds on old wood force with great irregularity.

Forty-two species of woody plants were grown in pots and treated by freezing, drying and etherizing to force growth. Ether is perhaps the most reliable rest period-breaking agent yet used. Species vary greatly as regards the dosage required to produce growth.

Pot-grown woody plants, so far as could be observed, reacted to treatments in precisely the same way that twigs of similar species did in previous experiments. When dormant woody plants are treated, growth first begins in the buds, regardless of whether they are connected with a root system or not.

When potted plants are treated, the roots appear to be uninfluenced. When ether was used, the soil was always made so dry that it could not absorb the vapor. However, such treatments as freezing and drying did not appear to affect the roots, as potted plants responded just as did twigs in previous tests.

What the rest period is, is not known, although it is believed to be in some way associated with enzyme activity. A physiological investigation is now being conducted for the purpose of inquiring into the role of these agents during dormancy, and the part they play in producing growth.