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# An Experimental Study of the Rest Period in Plants

## Seeds

FOURTH REPORT

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## COLLEGE OF AGRICULTURE

# Agricultural Experiment Station

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W. L. HOWARD

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Plant physiologists have known for many years that certain seeds appear to pass thru a resting phase before they will germinate. It is also a matter of common experience that seeds of most economic plants appear to be improved by being stored for a few weeks before planting. Gardeners are familiar with the fact that a few kinds of vegetable seed will sprout quickly when planted immediately after ripening, and that some will germinate readily even before they are mature.

Germination in seeds may be delayed thru a number of causes. Chief among these is the rest period. Old seeds often germinate slowly, if at all. Some seeds quickly lose their ability to sprout, or germinate slowly and make a weak growth, on account of injury in storage. Common field corn is a good example. As a rule if seeds are harvested when immature, they germinate badly. Wet weather at harvest time is apt to cause seeds to possess low vitality. Seeds may easily be injured where it is necessary to cure them artificially before storing. Such injury is the result of too severe drying out. Great extremes of heat and cold during storage lowers the vitality of many seeds. Too much moisture in the air during storage is fatal to most field and garden seeds. On the other hand, fleshy seeds, like acorns, may die in a uniformly dry atmosphere.

Seeds may fail to germinate if planted too deeply or if the soil be cold or too wet. Exclusion of air (oxygen) will generally prevent germination. No seed can germinate where there is an insufficient supply of moisture.

The nature of the seed coat often determines whether a seed will germinate quickly or slowly, or even at all. The seed coat may be naturally hard and almost impervious to water, or it may become so from drying out in storage. Such seeds must be planted at once following maturity, or kept where they are in contact with a moist

medium, as damp soil or sand. This fact has given rise to the practice of stratification, so extensively followed by gardeners and nurseymen.

Seeds like the cocklebur (*Xanthium canadense,* Mill.), often fail to germinate even when planted under the most favorable growing conditions. It is also a matter of common observation that a large number of common weeds do not begin growing from the seed until settled summer weather has come. These seeds will lie in the warm soil for weeks during April, May, June, and often into July or August before beginning to grow.

If a viable seed with no hindering seed coat refuses to grow when planted in a warm, moist soil, it may be said to have a pronounced rest period. If a seed fails to grow when planted under favorable growing conditions, immediately after ripening, it has a rest period. Also if seeds fail to grow after being in dry storage for a month, they probably have a rest period.

The rest period of seeds, then, is a physiological condition or state which inhibits germination in certain seeds immediately after maturity, or possibly later, even tho they be planted in an ideal environment for growth. In other words, it is that period during which the resting embryo refuses to resume growth activity when all hindering external factors are excluded.

It is thus seen that the resting phase is due to internal causes. External factors may and do prevent germination, but failure to sprout under such circumstances must not be always attributed to a rest period. In the case of seeds that have been in storage for a time, germination may be slow and imperfect as a result of both internal and external hindrances; that is, the rest period may be just setting in or may not be quite over and also the seed coats may have become dry and hard in storage.

The fact of a rest period in plants has been fully established by Johannsen[1] and others. Nearly 300 species of woody plants were studied at the Missouri Agricultural Experiment Station[2] and it was found that practically all have a rest period. It was also found that the period of rest in woody plants is of varying length; in fact the length of rest ranges all the way from a few days or weeks to several months. The intensity of the resting state varies greatly among the different species. Some species can be easily forced into

1. Johannsen, W., Das Aetherverfahren beim Fruhtreiben mit Besonderer Berucksichtigung der Fliedertreiberi. Jena, 1906.

2. Howard, W. L., Experimental Study of the Rest Period of Plants. The Winter Rest. Research Bul. No. 1, Mo. Agr. Exp. Sta. 1910.

growth even during the early part of their rest, while others are very difficult to force during any stage of their dormancy, and a few can not be forced at all until the rest period is at an end. These tests were made with twigs twelve to sixteen inches long which were cut from trees and shrubs and kept standing in vessels of water after treatment. Later, forcing tests were made with many of the same species which were growing in pots.[1] These tests confirmed the fact of a rest period in practically all trees and shrubs of the temperate zone, and also demonstrated that twigs may be used for forcing tests and the results be just as reliable as where pot-grown plants are employed.

Additional rest period studies at this Agricultural Experiment Station were made with bulbs and herebaceous perennial plants.[2] These studies apparently proved that bulbs have a pronounced period of rest. The resting phase of bulbs was found to be so strong that they can not be aroused into growth by any of the treatments tried.

## PRELIMINARY EXPERIMENTS WITH SEEDS

The first of the rest period studies with seeds was begun in the spring of 1907. Several species of seeds, representing both wild and cultivated forms, growing in the vicinity of Columbia were collected and planted at different stages of maturity to find if they would grow at once.

The object in collecting immature seeds was to discover if possible just when the resting phase begins. It has been assumed that the rest does not set in until the seeds are mature. While this conclusion seems logical and appears to be warranted, there seems to be no experimental proof in support of such a conclusion. If seeds are able to grow before they are mature and not immediately afterward, it seems safe to conclude that the rest begins at the time of maturity. If seeds do not grow when immature and also do not grow immediately after maturity, such results would neither prove nor disprove when the rest period sets in. If they are able to grow before maturity and will not grow afterward, this would indicate that the rest period sets in with the conclusion of the ripening process. The process of germination in its last analysis is nothing more than the resumption of growth on the part of the embryo which has been dormant for a time. The use of the term "germination,"

1. Howard, W. L., Rest Period Studies with Pot-Grown Woody Plants. Research Bul. No. 16, Mo. Agr. Exp. Sta. 1915.

2. Howard, W. L., Rest Period Studies with Bulbs and Herbaceous Perennial Plants. Research Bul. No. 15, Mo. Agr. Exp. Sta. 1915.

then, in a way assumes that a seed is ripe or mature, and if it is ripe or mature the embryo has become dormant, sometimes even in an immature state. Presumably the embryo of a "ripe" seed is entirely mature or at rest. On the other hand it may be that immature seeds "germinate" because they are able to continue growing without becoming mature or entering into a state of rest.

The development of the seed from the fertilized egg cell in the ovule is a process of growth which involves not only the embryo itself which has to attain a certain size before it becomes dormant, but also the storage of reserve food either in the cotyledons, which are a part of the embryo, or in the form of endosperm which goes to make up the bulk of the "seed" or that part which is enclosed within the seed coat. When the reserve food is deposited in the cotyledon, or in the form of endosperm, the deposition continues to go on until the seed has reached a practical state of maturity. The external evidences of this stage are the usual ones which we are accustomed to associate with ripening seeds and which, of course, vary with the different species. In peas, for example, maturity is indicated by the hardening or drying of the pod and this, upon being opened, discloses that the seeds themselves are hardening and changing to a darker color.

In this experiment no provisions were made for morphological studies of the seeds so that the exact condition of the embryos at particular stages was not determined. Seeds were collected in two stages of immaturity. As nearly as could be determined, these were when "half ripe" and "nearly ripe." For various reasons it was possible to secure immature seeds, particularly in the half ripe stage, from but four species, and of the nearly ripe stage from only nine species. Fully ripe seeds were collected from twenty-two species. In all cases the seeds were planted in moist sand in the greenhouse.

TABLE 1. GERMINATION TEST WITH HALF RIPE SEEDS

| Species | Days required for germination | Percentage of germination |
|---|---|---|
| Hordeum sativum, Jessen | 4 | 60.7 |
| Pisum sativum, Linn | 4 | 93 |
| Raphanus sativum, Linn | 4 | 63 |
| Spinacia oleracea, Mill | 12 | 23 |

This preliminary test, while very incomplete in that it covers but little ground, is of interest because it shows that seeds of many annual plants are able to germinate when still quite immature, and the percentage that grow average as high as the growth from mature

TABLE 2. GERMINATION TEST WITH NEARLY RIPE SEEDS

| Species | Days required for germination | Percentage of germination |
|---|---|---|
| Avena sativa, Linn | 6 | 100 |
| Hordeum sativum, Jessen | 3.5 | 80 |
| Phleum pratense, Linn | 10 | 26 |
| Pisum sativum, Linn | 4 | 65 |
| Raphanus sativum, Linn | 2 | 63.3 |
| Spinacia oleracea, Mill | 7 | 16.6 |
| Trifolium sp. | 5 | 54 |

*Ptelea trifoliata*, Linn. and *Vitus Labrusca*, Linn. failed to grow from slightly immature seeds.

TABLE 3. GERMINATION TEST WITH FULLY RIPE SEEDS

| Species | Days required for germination | Percentage of germination |
|---|---|---|
| Althaea rosea, Cav. | 9 | 68 |
| Cucumis sativus, Linn. | 5 | 75 |
| Dianthus sp. | 17 | 41 |
| Hordeum sativum, Jessen | 3.5 | 51.6 |
| Lactuca sp. | 4 | 75 |
| Lactuca Scariola, Linn. | 17 | 2 |
| Spinacia oleracea, Mill. | 7 | 73 |
| Triticum vulgare, Vill. | 5 | 90 |

*Aquilegia vulgaris*, Linn., *Cleome integrifolia*, Torr & Gray, *Coreopsis tinctoria*, Nutt., *Papaver* sp., *Panax quinquefolium*, Linn., *Rubus Phoenicolasius*, Maxim., *Rubus villosus*, Ait., *Rubus occidentalis*, Linn., *Rubus nigrobaccus*, var *sativus* Bailey, and *Vitis Labrucsa*, Linn., failed to germinate when planted immediately after ripening.

seeds planted at once after ripening. As a result of experience gained in the work, it is believed that where a species will germinate when immature, that it will also germinate with careful handling, immediately after ripening, or, in other words, it has no rest period. However, it should be clearly understood that this statement is advanced merely as an opinion, not as a fact that has been fully proven.

Table 3 shows that out of eighteen species tested for germination immediately following maturity, eight, or 44.4 per cent, grew. Since the list that grew immediately after maturity included annuals and woody and herbaceous perennials, it may be regarded as a fairly representative collection of plants, and even tho small, may be taken as a strong indication that almost half of the species of wild and cultivated seeds possess a rest period.

Two preliminary experiments in etherizing seeds were performed. First, nearly ripe seeds of barley (*Hordeum sativum*), and oats (*Avena sativa*), were exposed to ether fumes for twenty-four hours.

Both grew in four days. The treatment hastened the germination by two days in the case of the oats, but only slightly in the case of the barley.

The second etherization test was with newly ripened seeds of fox-glove (*Digitalis purpurea*), larkspur (*Delphinium* sp.), dock (*Rumex* sp.), and tomato (*Lycopersicum esculentum*). The treatment was for twenty-four hours. All grew in from three to twelve days but germination was hastened but little, if at all.

These preliminary tests seem to indicate that treating with ether will not kill seeds even while in an immature state. Also it would seem that the treatment has more effect upon green seeds than upon ripe ones.

**Seed Experiments in 1908.** Beginning in the spring of 1908, the experiments with seeds were resumed. The work the previous year having shown in the main that they would grow when planted in an immature state and also immediately after maturing, it was decided to try to find out when the rest period sets in. It was also desirable to learn what relation the seed coat bears to germination or failure to germinate. It was assumed that if a seed will grow when planted immediately after being fully matured, it has no rest period. If seeds that are found to grow at once are kept for several days in a dry room so that the seed coat becomes hard and the seeds fail to germinate, it seems fair to conclude that the failure is due to a mechanical hindrance—that of a hard seed coat. It must be admitted, however, that there is a bare possibility that failure to grow after drying for two or three weeks might be due to a rest period. In this event it would be clear that the rest period does not necessarily set in at the time of maturity, but may take place some time later.

Beginning in the spring, as soon as the earliest maturing seeds began to ripen, a list of eighty-one species was gathered. A quantity of each species was planted at once and a similar quantity kept in a dry room from one to two weeks. In a few instances where the seeds were large and very juicy it was necessary to dry them longer than two weeks. On the other hand certain small seeds did not require as much as one week to become dried out sufficiently. The plan of the experiment called for drying the seeds to a degree that would fit them for being placed safely in ordinary storage for the winter.

The list of species included both herbaceous and woody plants. Some of the herbaceous forms were annuals while perhaps the majority were perennials.

TABLE 4. RESULTS WITH SEEDS OF HERBACEOUS PLANTS PLANTED IMMEDIATELY AFTER RIPENING AND AFTER BEING DRIED OUT SUITABLE FOR PERMANENT STORAGE.

| Species—Herbaceous Forms | Seeds planted immediately after maturing | | Seeds dried before planting | |
|---|---|---|---|---|
| | Grew in days | Percentage growth | Grew in days | Percentage growth |
| Abutilon Theophrasti, Medic.. | 21 | 4 | * | .. |
| Aquilegia sp. | 10 | 52 | 10 | 52 |
| Asparagus officinalis, Linn. | 18 | 57 | 19 | 48 |
| Avena sativa, Linn. | 22 | 52 | 21 | 70 |
| Bidens Trichosperma, (Michx.) Britton | 31 | 20 | 68 | 10 |
| Capsicum sp. | 8 | 64 | 8 | 24 |
| Cardiospermum Halicacabum, L. | 9 | 32 | 21 | 3 |
| Cirsium lanceolatum, Hill. | * | .. | 18 | 50 |
| Citrullus vulgaris, Schrad. | 6 | 20 | * | .. |
| Cucurbita Pepo, Linn. | 6 | 64 | 10 | 95 |
| Cucurbita Maxima, Duchesne.. | 13 | 16 | 20 | 45 |
| Cucumis Melo, Linn. | 4 | 84 | 12 | 84 |
| Cynoglossum officinale, Linn... | 5 | 7.2 | 12 | 2.9 |
| Daucus Carota, Linn. | 10 | 50 | 8 | 68 |
| Dysodia chrysanthemoides, Lag. | 4 | 64 | 3 | 80 |
| Helianthus annuus, Linn. | 55 | 11.4 | 54 | 5.7 |
| Hibiscus Moscheutos, Linn. | 11 | 58 | * | .. |
| Hordeum sativum, Jessen. | 10 | 44 | 4 | 55 |
| Impatiens sp. | 9 | 46 | 23 | 30 |
| Lactuca canadensis, Linn. | 6 | 50 | 5 | 26 |
| Lathyrus latifolius, Linn. | * | .. | 50 | 34 |
| Lycopersicum esculentum, Mill. | 11 | 50 | 25 | 75 |
| Plantago lanceolata, Linn. | 7 | 2 | 8 | 8 |
| Rumex crispus, Linn. | 7 | 52 | 7 | 46 |
| Secale cereale, Linn. | 5 | 24.4 | 3 | 12 |
| Sisymbrium sp. | * | .. | 6 | 2 |
| Tragopogon porrifolius, L. | 26 | 44 | 19 | 68 |
| Vigna Catjang, Walp. | 10 | 65 | 5 | 100 |
| Zea Mays, Linn. var. indenta.... | 6 | 100 | 12 | 100 |
| Zea Mays, Linn. var. saccharata. | 6 | 64 | 3 | 100 |

TABLE 5. RESULTS WITH SEEDS OF WOODY PLANTS PLANTED IMMEDIATELY AFTER RIPENING AND AFTER BEING DRIED OUT SUITABLE FOR PERMANENT STORAGE.

| Species—woody forms | Seeds planted immediately after maturing | | Seeds dried before planting | |
|---|---|---|---|---|
| | Grew in days | Percentage growth | Grew in days | Percentage growth |
| Althaea rosea, Cav. | 7 | 54 | 4 | 60 |
| Gleditschia triacanthos, Linn... | 5 | 55 | 7 | 44 |
| Morus alba, Linn. | 5 | 82 | 12 | 38 |
| Quercus alba, Linn. | * | .. | 16 | 100 |
| Robinia Pseudo-acacia, Linn... | * | .. | 7 | 10 |

*—No growth.

The following herbaceous species failed to grow either when just ripe or after being dried out:

*Amaranthus spinosus*, Linn.
*Bidens connata*, Muhl.
*Bidens bipinnata*, Linn.
*Blephilia ciliata*, Raf.
*Calliopsis* sp.
*Carex Shortiana*, Dewey & Torrey.
*Digitalis purpurea*, Linn.
*Ellisia Nyctelea*, Linn.
*Erigeron canadensis*, Linn.
*Fragaria virginiana*, Duchesne.
*Galium* sp.
*Geranium maculatum*, Linn.
*Lactuca Scariola*, Linn.
*Lathyrus* sp.
*Lepidium virginicum*, Linn.
*Oxalis* sp.
*Phleum pratense*, Linn.
*Phytolacca decandra*, Linn.
*Plantago major*, Linn.
*Saponaria officinalis*, Linn.
*Sida spinosa*, Linn.
*Solanum carolinense*, Linn.
*Trifolium repens*, Linn.
*Trifolium pratense*, Linn.
*Verbascum Blattaria*, Linn.

The following woody species failed to make any growth whatever, both where they were just ripe and after being dried out during the summer or fall:

*Amelanchier canadensis*, Torr. & Gray.
*Aesculus Hippocastanum*, Linn.
*Asimina triloba*, Dunal.
*Caragana arborescens*, Lam.
*Carya ovata*, (Mill.) K. Koch.
*Elaeagnus longipes*, Gray.
*Fraxinus americana*, Linn.
*Hamamelis virginiana*, Linn.
*Juglans nigra*, Linn.
*Lonicera tatarica*, Linn.
*Prunus Cerasus*, Linn.
*Prunus* sp. (plum).
*Prunus Persica*, Sieb. & Zucc.
*Rhamnus lanceolata*, Purch.
*Rhus Cotinus*, Linn.
*Rhus* sp.
*Ribes nigrum*, Linn.
*Ribes gracile*, Michx.
*Rubus Idaeus*, Linn., var. *aculeatissimus*, Hort.

Of the fifty-five species of seeds of herbaceous forms planted, twenty-five or 45.5 per cent, failed to germinate either immediately following maturity or after being dried out. Of the remaining 54.5 per cent that grew, there was an equal number of the mature and dried seeds altho three from each list (but not the same species in each case) made no growth.

Twenty-four species of seeds of woody plants were tested for germination, both at maturity and after being dried out. Three of the former and five of the latter, or a total of 20.8 per cent, germinated while 79.2 per cent made no growth whatever.

Of all the twenty-seven species of seeds planted at maturity that grew, the average time required for germination was 12.4 days, while the average for those that were dried out was 16.8 days. Drying apparently lengthened the time required for growth to the extent of 4.4 days.

Comparing the percentage of the mature and dried seeds that germinated, it is found that the former amounted, on the average, to 44.3 per cent, while the latter was 47.9 per cent. The dried seeds, therefore, required a longer time for germination to take place, but the germination was greater by 3.6 per cent.

Two things seem to be proved by these tests—first, that seeds of more than half of the species of plant forms as they occur in Missouri have a pronounced rest period, and, second, that of the species having a rest period, by far the greater percentage are woody forms. In ten instances the dried seeds grew earlier than those that were not dried; in nine instances those that were not dried grew first, and in three cases the dried and undried seeds grew at the same time.

It is impossible to say whether the woody species failed to grow because the seed coats were too hard to begin with, or were hindered by reason of having a rest period. Experience with some of the seeds, however, leads to the belief that even though it had been possible to remove the mechanical obstruction, germination would not have taken place for some months.

## REST PERIOD INVESTIGATIONS WITH SEEDS DURING 1911, 1912, 1913*

These investigations were begun in June, 1911, and were continued thruout the summer and early fall of that year. The work was resumed in the spring of 1912, and a vigilant lookout was kept for the first seeds of any species that ripened. Thereafter so far as possible, seeds of all species of wild and cultivated plants growing in the vicinity of Columbia, were gathered. This continued until late in July, when, due to illness on the part of the collector, the work had to be discontinued until October. Such seeds as were still available at that time and later during the fall were collected. During the fall and winter of 1912-13 extensive experiments were carried on with the seeds that had been collected. Some of the last seeds planted were still under observation as late as May 1, 1913.

During the two seasons these investigations were carried on, almost 200 species, representing fifty-one orders, were collected. In all more than 900 samples of seeds were planted. The usual number of seeds in each sample was 100; therefore, this part of the seed investigations represents a planting of nearly 100,000 seeds. The most

* In carrying out the investigations reported in succeeding pages of this bulletin, the writer wishes to acknowledge, to the fullest extent, the valuable services rendered by Mr. C. C. Wiggans, Research Scholar in Horticulture, (now instructor in Horticulture in the University of Missouri). Mr. Wiggans not only made the large collections of seeds during two seasons, but had charge of all the details of planting, experimental treatments and observations. The collection and proper classification of the large number of wild species of seeds alone required a vast amount of patience and devotion to the work. Without this expert assistance, it would have been physically impossible to carry the investigations thru on so large a scale.

extensive previous work of this kind outside of this Agricultural Experiment Station of which any record was found, was that of Fawcett[1] who collected and planted ninety-two samples of seeds, representing fifty-two species. The collection made at the Missouri Agricultural Experiment Station in 1908 (described in the first part of this bulletin) consisted of ninety-three species of seeds.

## OBJECTS OF THE INVESTIGATION

The main objects of this investigation were: first, to find if seeds have a rest period; second, what species are subject to the resting phase; and third, whether the rest period can be broken, how and also the effects of various treatments on dry and moist seeds. Incidentally, it was hoped that light might be thrown upon various interesting questions pertaining to the behavior of seeds in farm and garden practice as well as in nature. For example, the behavior of the common cocklebur (*Xanthium canadense,* Mill.), indicates that these seeds are able to remain in the soil for two and even three years before germinating. Moreover many wild plants, mostly weeds, spring up from the soil in large numbers at certain times during the season. In the latitude of Missouri some begin to sprout before freezing weather is over in late winter or very early spring; others sprout while the soil is still cold during March and April; and still others do not begin to grow until the arrival of settled weather in June or July.

It was thought best to disregard the many absorbing questions that might claim attention during an extensive seed study, and confine the investigation mainly to the testing of as many species of seeds as possible to find which have a rest period and whether this phenomenon appears to be confined to isolated species, or is peculiar to certain genera or orders.

Previous preliminary tests with seeds at this station having shown that approximately 50 per cent of the species worked with seem to have a rest period, it was designed to make the present investigation complete and thoro for all the different kinds of seeds commonly grown in the vicinity of Columbia.

**Experiments in 1911.** Collecting began in the spring as the first seeds commenced ripening. The plan of the experiment called for collecting the seeds just at the time when they were considered to be fully matured. In some cases it was difficult to decide just when this stage was reached, but it was assumed that they were mature when they began to fall naturally, or when the pericarp (pod or fruit) was ripe.

1. Fawcett, H. S., Proc. Iowa Acad. of Science, No. 38, vol. 15.

A sample of each species was planted immediately after it was collected, while another sample was placed in the laboratory to become air-dry, on the surface at least, when it also was planted. The drying process usually lasted for about thirty days, so that the two plantings of seeds of each species followed each other at intervals of about one month.

The idea in view in making these two plantings was to find which species are able to germinate immediately upon ripening, and which require a further period of ripening or development before germination can take place. It was assumed that seeds at maturity contain perhaps a greater amount of moisture than at any time thereafter until planted. Allowing them to become air-dry before planting might introduce a serious external hindrance to growth in the form of a hard seed coat. Therefore, it was hoped to find from these plantings: first, whether the seeds had a natural rest period—that is, failed to grow at maturity—and second, whether the drying out process, such as would take place in ordinary storage, might not prevent germination on account of a hardened seed coat, or because the rest period sets in later than at maturity.

All plantings of seeds were made in moist sand on a greenhouse bench. The seed bed was four or five inches deep and was kept moist by frequent sprinklings. All outside conditions, such as light, heat and moisture were the same for both the first and second plantings.

The collection made in 1911 consisted of 122 species of seeds. The first were planted on May 20 and plantings continued as seeds were collected, throughout June, July, August, and up until September 14. For the most part the seeds were from herbaceous plants, including annuals, biennials, and perennials. However, there were a goodly number of woody forms included in the list.

Table 6 shows the entire list of seeds, together with the treatments and results. For convenience in studying the behavior of the species under treatment, as regards their botanical relationships, they are arranged in the table by natural orders. The first column of figures shows the dates on which the various species were collected. An effort was made to plant one sample on the date collected, the second sample of the same species being planted when sufficiently dry, which as already stated, was usually after about thirty days. Columns two and three, under the headings "mature seeds" and "dry seeds," show the number of days elapsing in each case before the seeds began to germinate. The last two columns of figures show the percentage of mature and dried seeds that sprouted. In some instances the dried seeds, and sometimes even the newly ripened seeds, failed to make any growth up to the time when observations ceased, on October 15.

TABLE 6. SEEDS PLANTED DURING THE SEASON OF 1911 IMMEDIATELY AFTER MATURITY AND AFTER BEING DRIED FOR ABOUT ONE MONTH

| Species | Date collected | Number of days required for germination | | Total percentage of germination | |
|---|---|---|---|---|---|
| | | Mature seeds | Dry seeds | Mature seeds | Dry seeds |
| **Gramineae** | | | | | |
| Alopecurus pratensis, L. | May 20 | * | 50 | 0 | 5 |
| Hordeum nodosum, L. | June 9 | 61 | 38 | 90 | 96 |
| Bromus mollus, L. | June 15 | 22 | 7 | 57 | 84 |
| Lolium perenne, L. | June 21 | 14 | 6 | 52 | 53 |
| Panicum crus-galli, L. | June 24 | * | 44 | 0 | 2 |
| Setaria glauca, (L.) Beauv. | June 30 | 48 | 14 | 14 | 0 |
| Triticum vulgare, Vill. | June 13 | 7 | 4 | 66 | 96 |
| Dactylis glomerata, L. | June 15 | 22 | 8 | 32 | 59 |
| Avena sativa, L. | July 3 | 16 | 4 | 23 | 71 |
| Phleum pratense, L. | July 22 | 7 | 8 | 71 | 90 |
| **Cyperaceae** | | | | | |
| Cyperus sp. | June 24 | * | 11 | 0 | 48 |
| **Liliaceae** | | | | | |
| Asparagus officinalis, L. | Aug. 3 | 8 | 11 | 93 | 57 |
| Yucca filamentosa, L. | Aug. 8 | 19 | 28 | 61 | 27 |
| Canna sp. | Aug. 26 | 16 | 35 | 22 | 7 |
| **Urticaceae** | | | | | |
| Morus alba, L. | June 5 | 13 | 8 | 42 | 57 |
| **Polygonaceae** | | | | | |
| Rumex crispus, L. | June 5 | 18 | 22 | 73 | 71 |
| **Phytolaccaceae** | | | | | |
| Phytolacca decandra, L. | Aug. 25 | 26 | * | 42 | 0 |
| **Caryophyllaceae** | | | | | |
| Lychnis calcedonica, L. | June 22 | 45 | 10 | 1 | 20 |
| Saponaria officinalis, L. | July 13 | 16 | 40 | 3 | 5 |
| Lychnis alba, Mill. | Aug. 26 | 7 | 6 | 34 | 35 |
| **Ranunculaceae** | | | | | |
| Aquilegia sp. | June 12 | 21 | 20 | 40 | 48 |
| **Berberidaceae** | | | | | |
| Berberis vulgaris, L. | Sept. 8 | 56 | 38 | 2 | 19 |
| **Cruciferae** | | | | | |
| Sisymbrium officinale, (L.) Scop. | June 23 | * | 21 | 0 | 40 |

Table 6—Continued

| Species | Date collected | Number of days required for germination | | Total percentage of germination | |
|---|---|---|---|---|---|
| | | Mature seeds | Dry seeds | Mature seeds | Dry seeds |
| **Leguminosae** | | | | | |
| Baptisia australis, (L.) R. Br..... | June 26 | 14 | 27 | 34 | 28 |
| Trifolium pratense, L..... | June 12 | 33 | * | 2 | .. |
| Caragana aborescens, Lam..... | June 12 | 10 | 7 | 96 | 78 |
| Pisum sativum, L..... | June 22 | 3 | 2 | 61 | 52 |
| Medicago sativa, L..... | July 13 | 8 | 8 | 69 | 71 |
| Lathyrus latifolius, L..... | July 14 | 6 | 14 | 60 | 79 |
| Melilotus alba, Desr..... | July 19 | 8 | * | 4 | 0 |
| Gymnocladus dioica, (L.) Koch... | Aug. 3 | 10 | 20 | 85 | 85 |
| Robinia Pseudo-acacia, L..... | Aug. 25 | 9 | * | 1 | 0 |
| Gleditsia triacanthos, L..... | Aug. 3 | 6 | 11 | 25 | 22 |
| **Oxalidaceae** | | | | | |
| Oxalis Acetosella, L..... | June 22 | * | 47 | 0 | 4 |
| **Geraniaceae** | | | | | |
| Geranium carolinianum, L..... | June 9 | 88 | 37 | 13 | 35 |
| **Celastraceae** | | | | | |
| Celastrus scandens, L..... | Aug. 30 | 6 | .. | 3 | 0 |
| **Malvaceae** | | | | | |
| Malva rotundifolia, L..... | June 22 | * | 45 | 0 | 1 |
| Althaea rosea, Cav..... | June 29 | 6 | 6 | 73 | 72 |
| Abutilon Theophrasti, Medic..... | Aug. 3 | 16 | 24 | 7 | 15 |
| Hibiscus Moscheutos, L..... | Aug. 3 | 6 | * | 69 | 0 |
| **Umbelliferae** | | | | | |
| Pastinaca sativa, L..... | June 30 | 66 | 18 | 3 | 4 |
| **Solanaceae** | | | | | |
| Solanum Dulcamara, L..... | Sept. 14 | 9 | 19 | 70 | 46 |
| Datura Stramonium, L..... | Sept. 14 | 30 | 17 | 22 | 90 |
| **Bignoniaceae** | | | | | |
| Tecoma radicans, (L.) Juss..... | Sept. 12 | 20 | 44 | 33 | 8 |
| **Plantaginaceae** | | | | | |
| Plantago virginica, L..... | June 19 | 30 | * | 3 | 0 |
| Plantago lanceolata, L..... | June 30 | 8 | 6 | 20 | 33 |
| **Caprifoliaceae** | | | | | |
| Lonicera tatarica, L..... | June 20 | 66 | 18 | 2 | 30 |

* No Germination up to October 15.

Table 6—Continued

| Species | Date collected | Number of days required for germination | | Total percentage of germination | |
|---|---|---|---|---|---|
| | | Mature seeds | Dry seeds | Mature seeds | Dry seeds |
| **Cucurbitaceae** | | | | | |
| Citrullus vulgaris, Schrad..... | Aug. 26 | 7 | 6 | 18 | 35 |
| **Compositae** | | | | | |
| Taraxacum officinale, Weber..... | May 20 | 70 | * | 7 | 0 |
| Lactuca Scariola, L..... | June 8 | 21 | 9 | 14 | 21 |
| Chrysanthemum Leucanthemum, L..... | June 21 | * | 42 | 0 | 1 |
| Gaillardia sp..... | June 22 | 75 | 27 | 2 | 5 |
| Centaurea grandiflora, Hort..... | June 28 | 17 | 10 | 28 | 27 |
| Rudbeckia hirta, L..... | July 20 | * | 10 | 0 | 22 |
| Zinnia elegans, Jacq..... | July 24 | 8 | 4 | 23 | 52 |
| Echinops sphaerocephalus, L..... | Aug. 8 | 17 | 10 | 8 | 2 |
| Arctium minus, Bernh..... | Aug. 29 | 14 | 9 | 4 | 68 |
| Helianthus annuus, L ..... | Sept. 6 | * | 9 | 0 | 40 |
| Average for all species in Table 6... | ..... | 22.2 | 17.8 | 33.3 | 40.9 |

* No Germination up to October 15.

The following list includes those species from which no germination was secured:

**Gramineae**

*Poa pratensis*, L.
*Eragrostis major*, L.

**Cyperaceae**

*Carex* sp.
*Carex* sp.
*Carex Frankii*, Kunth.
*Cyperus strigosus*, L.

**Betulaceae**

*Ostrya virginiana*, (Mill.) K. Koch.

**Polygonaceae**

*Rumex Acetosella*, L.

**Amaranthaceae**

*Amaranthus spinosus*, L.
*Amaranthus* sp.

**Caryophyllaceae**

*Silene antirrhina*, L.

**Portulaceae**

*Portulaca oleracea*, L.

**Cruciferae**

*Capsella bursa-pastoris*, (L.) Medic.
*Lepidium virginicum*, L.

**Saxifragaceae**

*Ribes nigrum*, L.
*Ribes gracile*, Michx.

**Rosaceae**

*Agrimonia microcarpa*, Wallr.
*Fragaria virginiana*, Duchesne.
*Rubus occidentalis*, L.
*Rubus villosus*, Ait.
*Prunus Persica*, (L.) Stokes.
*Prunus Cerasus*, L.
*Prunus hortulana*, Bailey.
*Amelanchier canadensis*, (L.) Medic.
*Pyrus Malus*, L.
*Rosa rugosa*, L.
*Physocarpus opulifolius*, (L.) Maxim.
*Crataegus* sp.

**Leguminosae**

*Trifolium repens*, L.
*Cercis canadensis*, L.

**Rutaceae**

*Ptelea trifoliata*, L.
*Xanthoxylum americanum*, Mill.

**Anacardaceae**

*Rhus canadensis*, Marsh.
*Rhus glabra*, L.
*Rhus Toxicodendron*, L.

**Staphyleaceae**

*Staphylea trifolia*, L.

**Sapindaceae**

*Koelreuteria paniculata*, Laxm.

**Rhamnaceae**

*Rhamnus cathartica*, L.

**Vitaceae**

*Vitis labrusca*, L.
*Vitis riparia*, Michx.
*Ampelopsis quinquefolia*, Michx.

**Tiliaceae**

*Tilia americana*, L.

**Elaeagnaceae**

*Elaeagnus argentia*, Pursh.
*Elaeagnus multiflora*, Thunb.

**Umbelliferae**

*Chaerophyllum procumbens*, (L.) Crantz.
*Osmorhiza longistylis*, (Torr) DC.

**Cornaceae**

*Cornus stolonifera*, Michx.
*Cornus Baileyii*, Coult. & Evans.

**Ebenaceae**

*Diospyros virginiana*, L.

**Oleaceae**

*Chionanthus virginica*, L.
*Fraxinus americana*, L.

**Asclepiadaceae**

*Asclepias* sp.

**Labiatae**

*Blephilia ciliata*, (L.) Raf.

**Solanaceae**

*Solanum carolinense*, L.
*Solanum Melongena*, L.

**Scrophulariaceae**

*Verbascum Blattaria*, L.

**Plantaginaceae**

*Plantago major*, L.
*Plantago aristata*, Michx.

**Rubiaceae**

*Galium Aparine*, L.

**Caprifoliaceae**

*Sambucus canadensis*, L.

**Compositae**

*Cirsium pumilum*, (Nutt) Spreng.
*Coreopsis* sp.
*Helianthus laevigatus*, T. & G.
*Bidens bipinnata*, L.

On October 15 the greenhouse bench was required for other purposes so that observations on the plantings had to cease on this date. At that time more than one-half of the species planted had made no growth. Whether they would have grown later is a question that cannot be answered. However, the seeds remained in the bed long enough to answer the main questions at issue, namely, which species were able to germinate within a reasonable time after being planted immediately following maturity, and after being dried for a month. The species included in the list which follows the table were the ones that failed to germinate at all up to the time the seed bed was destroyed.

A study of Table 6 discloses some interesting facts. One fact that is very prominent is that many species seem to possess the capacity for prompt germination immediately after ripening, while others apparently must pass through a period of dormancy before they will grow. Less than 50 per cent of the species planted made any growth at all.

Among the orders to which belong species which germinated readily as soon as mature were *Gramineae, Liliaceae, Caryophyllaceae, Malvaceae,* and *Compositae,* while those which seemed to have a delayed germination included *Cyperaceae, Rosaceae, Anacardaceae* and *Vitaceae.* The fresh seeds of *Liliaceae* and *Leguminosae,* as a general rule, germinated quicker and gave a higher percentage of germination than the dried seeds while the results from plantings of *Compositae* and *Gramineae* were exactly the reverse. These two instances would seem to indicate that the seeds of the various species in an order are somewhat similar as regards their requirements for germination.

Of the fifty-eight species which were able to germinate at all, nine failed to grow from the first planting (fresh seed), and nine in the second planting (dried seed). Twenty-six of the species that grew germinated more quickly where seeds had been dried, indicating that they have a very short rest period, less than one month in extent. In fact a majority of the species studied seemed to require an interval of rest after maturity before they would sprout. The figures also show that seeds which had been dried for a month germinated in a much shorter time after planting than seeds planted immediately after they were collected. This apparently shows that the hindrances to germination due to hardness of the seed coat from drying out are much over-balanced by the beneficial effects on germination caused by allowing the seeds to pass thru a month of dormancy before being planted. Seemingly then, the assumption that seeds which fail to grow immediately after maturity are possessed of a rest period is incorrect, as the rest period may set in several days after maturity. In fact the process of maturity itself—that is, the loss of moisture by the seed—seems to bring on the rest period in the majority of cases.

The average time required for germination to take place for all species was: for the mature seeds, 22.2 days; dried seeds, 17.8 days; total germination, mature seeds, 33.3 per cent; dried seeds, 40.9 per cent. In twenty-six species the dried seeds gave a higher total germination, while only thirteen species gave the highest percentage of germination where seeds were planted immediately after maturity. The average increase in total germination, due to drying out, was 6.6 per cent. In nearly every case the higher percentage of total germination was correlated with the shorter time required for germination to begin.

**Second Season's Work, 1912.** The seed investigation during the summer and fall of 1912 consisted of the following experiments:

1. Planting a large number of species of seeds which were collected when first mature, some being planted at once, while the others (set incomplete), were air-dried before planting.

2. Collecting a comparatively short list of species while the seeds were still in the "dough" stage—that is, quite immature—and planting some at once, and air-drying a similar set before planting. These were compared with freshly ripened seeds in a germination test.

During the fall of 1912 and winter of 1912-13, additional tests consisted of the following:

1. Seeds of woody and herbaceous plants were subjected to various treatments designed to force them into growth.

2. A few species of seeds (mostly vegetables), were subjected to a long list of treatments designed to show their effects in a comparative way on the seeds when dry and when moist.

While the tests made during the season of 1911 yielded some very interesting results, it was desired if possible, to confirm them by studying a larger number of species. Also the scope of the investigation was to be enlarged by including several additional experiments. Special efforts were made to secure a large collection of species. The experience of the previous year was very helpful in enabling the collector to locate many new plants at the right time and to quickly and correctly classify the species. With more time to devote to the work, the collecting began early in the spring and was carried on with more thoroness than was possible the previous year. Unfortunately the work of collecting was interrupted by illness on the part of the collector about the middle of July. However, up to that time ninety-one species had been already collected. The work was resumed again in late September. As in 1911, seeds were again collected as nearly as possible exactly at ripening time. In addition a set of immature seeds was gathered. These were taken while in the condition usually spoken of as the "dough" stage. Nearly all of the green seeds were from trees and shrubs—that is, woody forms.

Of the ripe seeds collected, one-half were planted at once and the remainder allowed to become air-dry before planting. Two plantings also were made of the immature seeds, one set immediately after collecting and the other after becoming air-dry. The latter made no growth whatever.

It should be explained here that the incomplete set of newly ripened seeds which were alowed to become air-dry before planting gave about the same results as the seeds did the year before (Table

6) that were similarly treated, so the 1912 figures are not given here as they would be only a repetition.

In 1912 the seeds were planted in specially constructed beds in the garden, a well-drained soil being used instead of sand. The beds were equipped with cloth screens as a protection against the sun, and also to enable the soil to better retain its moisture. The object of planting out-of-doors was two-fold; first, to as nearly as possible imitate natural conditions, and second, to avoid having the beds disturbed by being used for other purposes. Such seeds as failed to grow during the summer and fall were thus enabled to remain in the soil where they would have an opportunity to grow the following spring. This was thought to be one serious defect in the first year's test. In 1911 the plantings were all destroyed when the sand bed was used for other purposes on October 15. In 1912 the seeds were planted and allowed to stay in the ground until they germinated or decayed. At the approach of winter a thick mulch of grass and leaves was spread over the seed bed. This material was removed early in the spring before growing time.

The main test in 1912 was with the seeds that were collected at maturity and planted immediately. This set of seeds consisted of seventy-six species representing thirty-two orders. Some of these seeds grew at once—within from one to three weeks—while others did not grow until fall, and still others (the latter group being far larger than either of the other two) did not grow until spring. For convenience the results of this germination test with mature, untreated seeds will be grouped under three separate heads, namely: Table 7, those showing immediate germination; Table 8, those that germinated in the fall; and Table 9, those that germinated in the spring. The list which follows Table 9 shows the species planted at maturity, which failed to germinate after being in the soil for ten months. Table 10 shows the results of planting green or immature seeds as compared with similar kinds that were harvested at maturity. The green seeds that were air-dried before planting made absolutely no germination.

In Tables 7, 8 and 9 are shown the number of days required for growth to begin in the various species that grew and also the total percentage of germination for each.

Besides the species accounted for in the three foregoing tables, a large number failed to show any germination, altho observations were kept up for ten months after planting. The following species were

TABLE 7. SEEDS COLLECTED WHEN RIPE OR MATURE AND PLANTED AT ONCE, BETWEEN MAY 9 AND JULY 14, 1912. ALL SHOWED "IMMEDIATE" GERMINATION

| Species | Date collected | Number of days required for germination | Total percentage of germination |
|---|---|---|---|
| **Gramineae** | | | |
| Secale cereale, L. | July 1 | 7 | 29 |
| Triticum vulgare, Vill. | July 2 | 7 | 30 |
| Avena sativa, L. | July 12 | 24 | 34 |
| Bromus ciliatus, L. | July 13 | 11 | 24 |
| Hordeum sativum, Jess. | July 13 | 6 | 36 |
| Lolium perenne, L. | July 13 | 11 | 37 |
| **Liliaceae** | | | |
| Asparagus officinale, L. | July 3 | 26 | 46 |
| **Urticaceae** | | | |
| Ulmus scabra, Mill. | May 9 | 14 | 18 |
| Ulmus fulva, Michx. | May 15 | 17 | 2 |
| Ulmus americana, L. | May 9 | 13 | 15 |
| Morus alba, L. | June 15 | 17 | 2 |
| **Leguminosae** | | | |
| Caragana aborescens, Lam. | July 2 | 8 | 81 |
| **Aceraceae** | | | |
| Acer saccharinum, L. | May 15 | 9 | 55 |
| **Malvaceae** | | | |
| Althaea rosea, Cav. | July 20 | 4 | 53 |
| **Umbelliferae** | | | |
| Pastinaca sativa, L. | July 6 | 18 | 3 |
| **Solanaceae** | | | |
| Solanum Dulcamara, L. | July 15 | 9 | 51.5 |
| **Cucurbitaceae** | | | |
| Cucumis Melo, L. | July 18 | 6 | 97 |
| **Compositae** | | | |
| Centaurea grandiflora, Hort. | July 5 | 19 | 5.5 |

collected when ripe or mature, from June to September, and planted at once. All failed to sprout.

**Gramineae**

*Bromus hordeacus*, L.

**Cyperaceae**

*Carex Shortiana*, Dewey.
*Carex gravida*, Bailey.
*Carex Muhlenbergii*, Schkuhr.

**Liliaceae**

*Allium canadense*, L.

**Betulaceae**

*Betula alba*, L.
*Betula nigra*, L.

**Nyctaginaceae**

*Oxybaphys floribundus*, Chois.

**Ranunculaceae**

*Aquilegia* sp.
*Aquilegia canadensis*, L.

**Anonaceae**

*Asimina triloba*, Dunal.

**Berberidaceae**

*Podophyllum peltatum*, L.

**Cruciferae**

*Lepidium virginicum*, L.
*Arabis canadensis*, L.

**Rosaceae**

*Potentilla monspliensis*, L.
*Prunus Cerasus*, L.
*Prunus virginiana*, L.
*Rubus strigosus*, Michx.
*Rubus occidentalis*, L.
*Rubus nigrobaccus*, Bailey.

**Leguminosae**

*Strophostyles helvola*, (L.) BSP.

**Staphyleaceae**

*Staphylea trifolia*, L.

**Malvaceae**

*Abutilon Theophrasti*, Medic.

**Plantaginaceae**

*Plantago virginica*, L.
*Plantago aristata*, Michx.

**Caprifoliaceae**

*Lonicera tatarica*, L.

**Compositae**

*Taraxacum officinale*, Weber.
*Sonchus asper*, (L.) Hill.

The following list of species includes those from which no germination was secured from either green or ripe seeds:

**Liliaceae**

*Polygonatum biflorum*, (Walt) Ell.

**Betulaceae**

*Ostrya virginiana*, (Mill) K. Koch.

**Urticaceae**

*Celtis occidentalis*, L.

**Rosaceae**

*Rosa rugosa*, Thunb.
*Physocarpus opulifolius*, (L.) Maxim.

**Rutaceae**

*Xanthoxylum americanum*, Mill.
*Ptelea trifoliata*, L.

**Aceraceae**

*Acer saccharum*, Marsh.

**Oleaceae**

*Fraxinus americana*, L.

TABLE 8. SPECIES COLLECTED WHEN RIPE OR MATURE AND PLANTED IMMEDIATELY, BETWEEN JUNE 8 AND JUNE 21, 1912, DID NOT BEGIN GERMINATING UNTIL FALL, AND GERMINATION WAS NOT COMPLETE UNTIL OCTOBER 30

| Species | Date collected | Total percentage of germination |
|---|---|---|
| **Geraniaceae** | | |
| Geranium carolinianum, L. | June 8 | 22 |
| **Rubiaceae** | | |
| Galium Aparine, L. | June 20 | 81 |
| **Compositae** | | |
| Lactuca Scariola, L. | June 21 | 5 |

TABLE 9. LIST OF SEEDS COLLECTED WHEN RIPE, OR MATURE, AND PLANTED AT ONCE BETWEEN JUNE 8 AND JULY 14, 1912, BUT WHICH DID NOT SHOW ANY GERMINATION UNTIL THE SPRING OF 1913 (APRIL 16)

| Species | Date collected | Total percentage of germination |
|---|---|---|
| **Gramineae** | | |
| Melica mutica, Walt | June 25 | 25.0 |
| Dactylis glomerata, L | June 27 | 47.5 |
| Phleum pratense, L | July 13 | 9.0 |
| Hordeum nodosum, L | June 8 | 8.5 |
| **Commelinaceae** | | |
| Tradescantia reflexa, Raf | June 24 | 7.5 |
| **Liliaceae** | | |
| Trillium sessile, L | July 1 | 50.0 |
| **Polygonaceae** | | |
| Rumex obtusifolius, L | July 2 | 48.0 |
| Rumex crispus, L | June 19 | 12.5 |
| **Saxifragaceae** | | |
| Ribes gracile, Michx | July 5 | 13.5 |
| **Rosaceae** | | |
| Prunus hortulana, Bailey | July 19 | 5.0 |
| **Leguminosae** | | |
| Trifolium pratense, L | June 25 | 40.0 |
| Trifolium repens, L | July 2 | 57.0 |
| **Anacardaceae** | | |
| Rhus canadensis, Marsh | June 20 | 5.0 |
| **Balsaminaceae** | | |
| Impatiens pallida, Nutt | June 22 | 78.0 |
| Impatiens biflora, Walt | July 9 | 28.0 |
| **Violaceae** | | |
| Viola pubescens, Ait | June 21 | 20.8 |
| Viola papilionacea, Pursh | June 21 | 65.0 |
| Hybanthus concolor, (Forster) Spreng | June 26 | 27.0 |
| **Umbelliferae** | | |
| Osmorhiza longistylis, (Torr) DC | July 5 | 40.0 |
| Pimpinella Saxifraga, L | July 12 | 11.0 |
| **Oleaceae** | | |
| Fraxinus quadrangulata, Michx | June 25 | 4.0 |

Table 9—Continued

| Species | Date collected | Total percentage of germination |
|---|---|---|
| **Hydrophyllaceae** | | |
| Ellisia Nyctelea, L. | June 8 | 31.5 |
| **Boraginaceae** | | |
| Cynoglossum officinale, L. | June 28 | 36.0 |
| **Plantaginaceae** | | |
| Plantago lanceolata, L. | July 14 | 40.0 |
| **Compositae** | | |
| Centaurea grandiflora, Hort. | July 5 | 23.5 |
| Coreopsis lanceolata, L. | July 5 | 10.0 |
| Gaillardia pulchella, Fouq. | July 5 | 17.0 |

Tables 7, 8 and 9 bring out some of the same facts deduced from Table 6. In the first place it seems certain that seeds of a large number of species will not germinate immediately after maturity. Also it appears that the species of a single order show more or less the same characteristics as regards time and percentage of germination.

Tables 7, 8 and 9 probably supply the explanation as to why so many of the species in the first year's test showed no germination. An examination of Tables 7 to 9 inclusive show that only eighteen species out of forty-eight showing germination were able to grow immediately after maturity, while twenty-seven species were able to germinate only after intervals of eight to ten months. During this period of quiescence the seeds were exposed to the influence of freezing and undoubtedly this had some effect in bringing about germination in the spring, but evidently these species possess a long rest period, or some of them would have shown signs of growth during the summer or fall of 1912.

Four species showed a capacity for germination in the fall. It is possible that these species require a cool temperature for growth, and since such conditions are present only during the spring and autumn may be the reason why they made no growth during the summer.

Table 10 shows quite clearly that green or immature seeds, at least from woody plants, for the most part are unable to germinate, or at least they did not germinate nearly so freely as mature seeds of the same species. The set of green seeds that had been allowed to

dry out after harvesting was also planted, but none of them grew. Unfortunately not enough species of immature seeds were used to be able to obtain any conclusive results, but apparently from the two species which grew, green seeds, if they germinate at all, will grow very much more quickly than ripe seeds. Also it is apparently true that immature seeds of woody plants are easily killed if they are allowed to become dry before planting.

TABLE 10. COMPARISON OF GERMINATION IN SEEDS OF WOODY SPECIES, ONE SET COLLECTED AND PLANTED WHILE GREEN OR IMMATURE AND THE OTHER IMMEDIATELY AFTER RIPENING

| Species | Number of days required for germination | | Total percentage of germination | |
|---|---|---|---|---|
| | Green seeds | Ripe seeds | Green seeds | Ripe seeds |
| **Rosaceae** | | | | |
| Pyrus Malus, L. | * | 57 | 0 | 1 |
| **Saxifragaceae** | | | | |
| Ribes gracile, Michx. | * | 200 | 0 | 13.5 |
| **Leguminosae** | | | | |
| Gymnocladus dioica, (L.) Koch | * | 12 | 0 | 46 |
| Robinia Pseudo-acacia, L. | 6 | 6 | 32 | 25 |
| Caragana aborescens, Lam. | 14 | 10 | 9.5 | 81 |
| **Rhamnaceae** | | | | |
| Rhamnus cathartica, L. | * | 21 | 0 | 56 |

* No Germination.

## EXPERIMENTS IN TREATING SEEDS TO FORCE GROWTH, WINTER OF 1912-13

**Seeds of Woody Plants.** The results of planting seeds during the seasons of 1911-12 seemed to show that seeds of woody plants have a longer rest period, sprout more slowly, and show a lower percentage of germination than herbaceous species. Practically all of the seeds used during the experiments in forcing during the winter of 1912-13 were woody species. However, a few herbaceous species were used. While a larger number of the woody species were employed, these were not subjected to very many treatments. Only nine species of non-woody forms were experimented with. These were each subjected to about twenty different treatments. The treatments of the woody species consisted of drying, soaking, etherizing, stratifying, and combinations of these treatments.

The seeds were gathered late in the fall of 1912. One set was planted at once and another thoroly dried. The latter were then stored in cardboard boxes on shelves in a basement room where the atmosphere was fairly uniform, being neither too hot nor too dry. A set of the dried seeds was planted about one month after they were gathered. At the time the dried seeds were planted, another set of the dried seeds was soaked in tap water for three hours and then etherized for twelve hours just before planting. The seeds were etherized by placing under a bell-jar with a quantity of liquid ether amounting to 1 cc. for each 25 liters of air space. The bell-jar was sealed to a glass plate by means of vaseline. The temperature usually ranged between 22° and 25° Centigrade.

All plantings were made in a sand bed in the greenhouse, the etherized seeds being planted immediately after removing from beneath the bell-jar. The sand was kept thoroly moist and the atmosphere of the greenhouse kept as uniform as possible both as regards temperature and humidity.

A variation in the experiment was started December 17, 1912, by stratifying and freezing some of the seeds from each species. The seeds were placed between folds of cheesecloth and buried in a box of sand. The box was then left exposed to the varying conditions of out-door temperature until February 17, 1913, when it was brought in. Hard freezing weather occurred during January so that the stratified seeds were thoroly frozen. One sample of each species was planted immediately, while another sample was etherized for twelve hours, and still another was etherized for twenty-hours immediately before planting. These three sets of seeds were planted in a moist sand bed and otherwise treated like those that were planted during the fall and early winter.

The following summary shows the treatments the seeds received before being planted:

1. Planted in fall immediately after maturity, without any treatment.
2. Air-dried for one month before planting.
3. Dried one month, soaked three hours, then etherized twelve hours.
4. Dried one month, then etherized twenty-four hours.
5. Dried one month, then frozen in stratification.
6. Dried one month, frozen in stratification, then etherized twelve hours.
7. Dried one month, frozen in stratification, then etherized twenty-four hours.

The results of these experiments are set forth in Tables 11 and 12, together with the summaries of these in Table 13.

TABLE 11. EFFECTS OF VARIOUS TREATMENTS USED FOR BREAKING THE REST PERIOD OF SEEDS OF WOODY PLANTS

| Species | Number of days required ofr germination to begin | | | | | | |
|---|---|---|---|---|---|---|---|
| | Planted at maturity | Dried one month | Dried, soaked 3 hours, etherized 12 hours | Dried, etherized 24 hours | Dried, frozen in stratification | Dried, frozen in stratification, etherized 12 hours | Dried, frozen in stratification, etherized 24 hours |
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) |
| **Liliaceae** | | | | | | | |
| Smilax rotundifolia, L. | 34 | 110 | 75 | 109 | 38 | 52 | 37 |
| **Rosaceae** | | | | | | | |
| Pyrus Malus, L. | 57 | * | * | * | 13 | 15 | 10 |
| Crataegus Marshallii, Eggleston | * | * | 59 | * | * | * | * |
| Rosa Carolina, L. | 150 | * | * | * | 21 | * | * |
| **Leguminosae** | | | | | | | |
| Cercis canadensis, L. | 127 | 105 | 47 | 137 | 11 | * | * |
| Gleditsia triacanthos, L. | 11 | 8 | 7 | 7 | 59 | 58 | 58 |
| Gymnocladus dioica, (L.) Koch | 12 | 67 | 24 | 13 | * | 44 | * |
| **Anacardaceae** | | | | | | | |
| Rhus glabra, L. | * | 52 | 102 | 113 | * | * | 30 |
| **Celastraceae** | | | | | | | |
| Celastrus scandens, L. | * | * | 107 | * | * | * | * |
| **Aceraceae** | | | | | | | |
| Acer Negundo, L. | * | * | 70 | * | 7 | 7 | 6 |
| Acer saccharum, Marsh. | * | * | * | * | 13 | * | 18 |
| Acer platanoides, L. | * | * | * | * | 16 | * | * |
| **Rhamnaceae** | | | | | | | |
| Rhamnus cathartica, L. | 21 | 62 | 79 | 63 | * | 14 | * |
| **Vitaceae** | | | | | | | |
| Ampelopsis quinquefolia, Michx. | 89 | * | 117 | 34 | 21 | 18 | 18 |
| Ampelopsis tricuspidata, Sieb. and Zucc. | * | * | 70 | 73 | 23 | 18 | 26 |
| Vitis riparia, Michx. | 25 | 57 | 40 | 48 | 19 | 18 | 18 |
| Menispermum canadense, L. | 22 | 46 | 40 | 44 | 20 | 22 | 18 |
| **Ebenaceae** | | | | | | | |
| Diospyros virginiana, L. | 31 | 45 | 71 | 63 | 37 | 45 | * |
| **Oleaceae** | | | | | | | |
| Ligustrum vulgare, L. | * | 33 | 29 | 31 | * | 26 | * |
| **Bignonaceae** | | | | | | | |
| Tecoma radicans, (L.) Juss. | 23 | 37 | 23 | 21 | 12 | 12 | 10 |

* No germination up to May 1, 1913.

TABLE 12. GERMINATION TESTS OF WOODY PLANTS TREATED IN VARIOUS WAYS TO HASTEN GROWTH

| Species | Percentage of germination of seeds from the following treatments | | | | | | |
|---|---|---|---|---|---|---|---|
| | Mature seed, no treatment | Dried one month | Dried one month, soaked 3 hours, etherized 12 hours | Dried one month, etherized 24 hours | Dried one month, frozen in stratification | Dried one month, frozen in stratification, etherized 12 hrs. | Dried one month, frozen in stratification, etherized 24 hrs. |
| **Liliaceae** | (1) | (2) | (3) | (4) | (5) | (6) | (7) |
| Smilax rotundifolia, L. | 7 | 9 | 7 | 12 | 51.4 | 45.7 | 48.5 |
| **Rosaceae** | | | | | | | |
| Pyrus Malus, L. | 1 | 0 | 0 | 0 | 3.1 | 3.1 | 3.1 |
| Crataegus Marshallii, Eggleston | 0 | 0 | 2 | 0 | 0 | 0 | 0 |
| Rosa Carolina, L. | 1 | 0 | 0 | 0 | 1 | 0 | 0 |
| **Leguminosae** | | | | | | | |
| Cercis canadensis, L. | 3 | 5 | 5 | 2 | 1 | 0 | 0 |
| Gleditsia triacanthos, L. | 6 | 13 | 11.5 | 10 | 2.6 | 5.2 | 5.2 |
| Gymnocladus dioica, (L.) Koch | 46 | 2 | 26 | 22 | 0 | 5.5 | 0 |
| **Anacardaceae** | | | | | | | |
| Rhus glabra, L. | 0 | 2 | 1 | 1 | 0 | 0 | 1 |
| **Celastraceae** | | | | | | | |
| Celastrus scandens, L. | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| **Aceraceae** | | | | | | | |
| Acer Negundo, L. | 0 | 0 | 1 | 0 | 76.6 | 80 | 83.3 |
| Acer saccharum, Marsh. | 0 | 0 | 0 | 0 | 15.7 | 0 | 21 |
| Acer platanoides, L. | 0 | 0 | 0 | 0 | 2.2 | 0 | 0 |
| **Rhamnaceae** | | | | | | | |
| Rhamnus cathartica, L. | 56 | 17 | 12 | 11 | 0 | 9 | 0 |
| **Vitaceae** | | | | | | | |
| Ampelopsis quinquefolia, Michx. | 1.5 | 4 | 5 | 3 | 49 | 68 | 52 |
| Ampelopsis tricuspidata, S, & Z. | 0 | 0 | 1 | 1 | 72 | 80 | 62.6 |
| Vitis riparia, Michx. | 7 | 22 | 27 | 13 | 57.3 | 78.6 | 56 |
| Menispermum canadense, L. | 34 | 24 | 31 | 25 | 70 | 72.5 | 72.5 |
| **Ebenaceae** | | | | | | | |
| Diospyros virginiana, L. | 1 | 52 | 37 | 51 | 11.7 | 17.6 | 0 |
| **Oleaceae** | | | | | | | |
| Ligustrum vulgare, L. | 0 | 13 | 27 | 16 | 0 | 2 | 0 |
| **Bignonaceae** | | | | | | | |
| Tecoma radicans, (L.) Juss. | 11 | 47 | 65 | 54 | 69 | 86 | 77 |

0 No germination

**Results of Forcing Seeds of Woody Plants.** Seeds of woody plants were treated in various ways for three general purposes: first, to find what species seem to have a rest period; second, to test the various treatments used for breaking the rest (Table 11); and, third, for testing effects of treatments on total percentage of germination (Table 12). The results shown in the two tables were then summarized in Table 13. A review of the experiments and summary will be of interest.

TABLE 13. SUMMARY OF TABLE 11, EFFECTS OF TREATMENTS ON THE REST PERIOD, AND TABLE 12, EFFECTS OF TREATMENTS ON TOTAL GERMINATION

| Treatment | Average length of dormant period in days | Percentage of Germination |
|---|---|---|
| (1) Planted at maturity, no treatment.. | 50.1 | 14.5 |
| (2) Dried one month..... | 56.5 | 17.5 |
| (3) Dried one month, soaked 3 hrs., etherized 12 hrs..... | 60.0 | 16.2 |
| (4) Dried one month, etherized 24 hrs... | 58.1 | 17.0 |
| (5) Dried one month, frozen in stratification..... | 22.1 | 34.4 |
| (6) Dried one month, frozen in stratification, etherized 12 hrs..... | 26.8 | 42.5 |
| (7) Dried one month, frozen in stratification, etherized 24 hrs..... | 22.6 | 43.8 |

Of the 31 species tested (Tables 11 and 12), the following 11 failed to make any germination whatever:

**Betulaceae**

*Ostrya virginiana*, L.
*Carpinus caroliniana*, L.

**Rosaceae**

*Prunus Persica*, (L.) Stokes.
*Crataegus coccinea*, L.
*Pyrus Scheideckeri*, Hort.
*Pyrus fastigiata bifers*, Hort.

**Leguminosae**

*Robinia Pseudo-acacia*, L.

**Rutaceae**

*Ptelea trifoliata*, L.

**Celastraceae**

*Euonymus atropurpureus*, Jacq.

**Cornaceae**

*Cornus asperifolia*, Michx.

**Caprifoliaceae**

*Symphoricarpos vulgaris*, Michx.

Those species requiring more than two weeks for germination, or which made no growth, where planted at maturity (Table 11, column 1), evidently have a rest period. Also those that showed no growth at all (see list following Table 12) may be counted as having a period of rest. Apparently, then, 93.5 per cent of the list of species tested have a rest period.

The treatment that produced the earliest growth in seeds was the freezing in stratification followed by etherizing twenty-four hours.

This treatment shortened the dormant period (as compared with seeds planted at maturity without treatment) in five species out of the eleven that grew. The average shortening of the rest period by this treatment was nearly twenty-eight days. The other two treatments making use of stratification did almost as well. The highest germination followed drying, freezing in stratification and etherizing for twenty-four hours, which was nearly 30 per cent better than seeds planted at maturity without treatment.

Drying seeds for a month seemed to greatly retard germination, as compared with seeds planted immediately after ripening (Table 13, lines 1 and 2). Etherizing the dried seeds for twenty-four hours or soaking for three hours followed by twelve hours of ether gave about the same results. The average retardation in all dried seeds (except those that were stratified) was from 6.4 to 9.9 days. However, the drying appeared to increase the total germination by from 1.7 to 3 per cent. (Table 13, lines 1 to 4).

Comparing the seeds that were dried one month with those that were planted immediately after maturity, Table 13 shows that about 3 per cent more of the latter grew. However, on the average the dried seeds required 56.5 days for germination to begin, while those planted at maturity on the average began to germinate in 50.1 days. Evidently the rest period, or the length of time required for germination after planting, is somewhat increased by the drying process; or perhaps the rest period does not set in until a few days after seeds are ripe or until after they have undergone a few days of drying. This change that takes place in seeds corresponds to what is popularly known among gardeners and others as the "curing process," thru which they say seeds must pass before they will do to plant, if best results are to be expected.

Comparing dried seeds with similar species that were soaked three hours in water and then etherized for twelve hours, it is seen by reference to columns 2 and 3 in Table 11 that the ether treatment shortened the dormant period in nine species out of twelve that grew, or where there was any difference. The average shortening of the rest period amounted to 3.5 days. The ether treatment brought about germination in six species where the checks (the dried seeds) refused to germinate, but in no case was germination prevented by the treatment. In six species out of twelve, however, the percentage of germination was decreased by the ether treatment. An average of all percentages shows that there was a decrease of 1.3 per cent in germination in seeds that were etherized twelve hours.

A comparison of the results obtained from treating dried seeds with ether for twenty-four hours, and similar species of dried seeds

with no other treatment (columns 4 and 2, Table 11) shows that the ether apparently had no influence of any consequence on either the time required for growth to begin, or total germination (lines 2 and 4, Table 13).

Comparing dried seeds that were stratified and frozen with similar species of dried seeds untreated, it will be seen from columns 5 and 2 in Table 11, that fourteen of the former grew while only eleven of the latter germinated. Twenty species of each were planted. The stratified seeds, however, made a much earlier growth than the dried ones, the average length of time required for growth to begin being 22.1 days, while the dried seeds on the average required 56.5 days. Comparing the extent of germination in the two it is seen that 34.4 per cent of the stratified seeds germinated while only 17.5 per cent of the dried seeds grew. (Table 13, lines 2 and 5). It is evident from this that the custom of stratifying seeds after they have once been allowed to dry out, is a very necessary practice.

One lot of seeds of all species was etherized for twelve hours after being dried, and then frozen while stratified. Comparing these with similarly stratified seeds receiving no ether treatment (columns 6 and 5, Table 11), we learn that the ether treatment caused varying results. In some cases the dormant period apparently was shortened, while in other cases it was seemingly lengthened. In other words the ether seemed to force certain species into an early growth, while it hindered the growth in others. However, the percentage of germination was very markedly increased by the ether treatment, the average increase being 8.1 per cent. The average time required for germination to begin in the etherized seeds was 26.8 days, which was, on the average, 4.7 days longer than required for growth to begin in similarly stratified and frozen seeds that received no ether. The ether treatment seemed to cause germination to take place in three species that did not germinate where similar seeds were stratified only, and in four species the treatment apparently prevented germination, because the same species without treatment grew. However, the ether increased the total germination, as stated above, to the extent of 8.1 per cent. (Table 13, lines 5 to 7).

The final comparison is between seeds stratified and frozen and then etherized for twenty-four hours, and similar stratified seeds receiving no ether treatments. (Columns 7 and 5, Table 11.) The ether treatment increased the total germination by 9.4 per cent, but did not shorten the rest period.

It is interesting to compare all of the treatments as regards the average length of time required for germination to take place. The shortest time required for growth to begin (Table 13, line 5) was

22.1 days from those that were frozen in stratification. The next quickest growth took place in those seeds that were dried, frozen in stratification and etherized twenty-four hours—22.6 days. (Table 13, line 7.) Those that were dried, frozen in stratification and etherized for twelve hours, made the third quickest growth—that is, in 26.8 days on the average. (Table 13, line 6.) Seeds planted at maturity without treatment were the fourth to grow, the average time of germination being 50.1 days. Those that were dried one month before planting; dried and etherized for twenty-four hours; and dried, soaked three hours and etherized for twelve hours grew in 56.5, 58.1 and 60 days, respectively. (Table 13, lines 2, 4 and 3.)

The highest percentage of germination secured—43.8 per cent on the average—was from seeds that were dried one month, frozen in stratification and etherized for twenty-four hours. The other stratification treatment, where twelve hours of ether was given, did almost as well, the total being 42.5 per cent, while those stratified but not etherized, showed only 34.4 per cent. The total germination from the remaining four plantings ranged from 14.5 to 17.5 per cent. (Table 13.) The influence of the stratification alone, wherever used, more than doubled the total percentage of germination. Apparently then, it would be good practice to stratify seeds of woody plants when harvested, or shortly afterward.

At first sight it might seem that seeds planted as soon as ripe and given no chance to dry out ought to have germinated on the average in less than fifty days, and made a higher germination than 14 per cent. However, it should be remembered that these seeds were planted in September and practically all germinated before freezing weather came, while the stratified seeds were severely frozen before being planted.

The following general conclusions may be drawn from the experiments in treating seeds during the winter of 1912-13: Seeds that are planted after being kept in stratification, germinate much more readily and produce a much higher percentage of germination than similar seeds that are kept in dry storage before planting. The effects of treating seeds with ether are much more marked on the subsequent growth of stratified seeds than on unstratified seeds. In general the ether treatments shortened the dormant period of seeds and increased the percentage of germination, but the different species reacted quite differently to this kind of treatment. Twenty-four hours of ether seemed to be more effective than the 12-hour dose, both as regards reducing the length of the dormant period, and increasing the percentage of germination, altho here again the species were found to vary considerably. In several instances the 24-hour ether treatment

was apparently too severe, and this tended to reduce the total percentage of germination so that it was only slightly greater than that following the 12-hour treatment. This principle holds good in etherizing both woody and herbaceous plants. If the dose is severe enough to be injurious, growth is quick but the percentage is apt to be low.

**Treatment of Seeds of Herbaceous Plants.** During the winter of 1912-13, while working with seeds of woody plants, some additional experiments were carried out with seeds of herbaceous plants. The seeds used were mostly those of common vegetables which had been purchased from a commercial seed house and kept in ordinary storage until January. The treatments were made during the months of January and February. Since a large number of treatments were to be given, only a comparatively few species could be used. The species employed were: Indian corn (*Zea Mays,* L.), Lima bean (*Phaseolus lunatus,* L. var. *Macrocarpus,* Benth.), kidney bean (*Phaseolus vulgaris,* L.), watermelon (*Citrullus vulgaris,* Schrad.), squash (*Cucurbita maxima,* Duchesne), spinach (*Spinacia Oleracea,* L.), radish (*Raphanus sativus,* L.), okra (*Hibiscus esculentus,* L.), and onion (*Allium Cepa,* L.). The agents used for forcing growth were ether, freezing, soaking, and combinations of these treatments. Whenever ether was used in a combination treatment, it was always the last treatment preceding planting. The quantity of ether used per unit of space and the methods of making the treatments were the same as described under the head of "seeds of woody plants," (page 26.) The freezing was done with a salt and ice mixture, the temperature being lowered to —5° to —10° Centigrade, and the seeds exposed to this temperature for twenty-four hours. The soaking was done in tap water at room temperature.

All germination tests in this series of experiments were carried out by spreading the seeds between sheets of filter paper in wooden plates. These plates were kept in an enclosed space (moist chamber) over a sand bench in the greenhouse. The approximate temperature was 22° C altho the actual temperature at times varied considerably from this figure.

The object of the test was not only to find out the general effects of ether and frost on different kinds of vegetable seeds and to what extent germination is hastened by them, but by means of combinations of the treatments to find out to what extent germination may be influenced by varying the conditions under which the ether and frost are applied.

The following review shows in detail the exact treatments to which each set of seeds of the different species was subjected.

1. Dry seeds. Untreated. (To check treatments 2 to 12 inclusive.)
2. Dry, etherized 12 hours.
3. Dry, etherized 24 hours.
4. Dry, frozen 24 hours. (To check 5 and 6.)
5. Dry, frozen 24 hours, then etherized 12 hours.
6. Dry, frozen 24 hours, then etherized 24 hours.
7. Dry, frozen 24 hours, then soaked in water 3 hours. (To check 8 and 9.)
8. Dry, frozen 24 hours, soaked 3 hours, then etherized 12 hours.
9. Dry, frozen 24 hours, soaked 3 hours, then etherized 24 hours.
10. Dry, frozen 24 hours, soaked 6 hours. (To check 11 and 12.)
11. Dry, frozen 24 hours, soaked 6 hours, then etherized 12 hours.
12. Dry, frozen 24 hours, soaked 6 hours, then etherized 24 hours.
13. Soaked 3 hours. (To check treatments 14 to 18 inclusive).
14. Soaked 3 hours, then etherized 12 hours.
15. Soaked 3 hours, then etherized 24 hours.
16. Soaked 3 hours, then frozen 24 hours. (To check 17 and 18.)
17. Soaked 3 hours, frozen 24 hours, then etherized 12 hours.
18. Soaked 3 hours, frozen 24 hours, then etherized 24 hours.
19. Soaked 6 hours. (To check treatments 20 to 24 inclusive).
20. Soaked 6 hours, then etherized 12 hours.
21. Soaked 6 hours, then etherized 24 hours.
22. Soaked 6 hours, then frozen 24 hours. (To check 23 and 24.)
23. Soaked 6 hours, frozen 24 hours, then etherized 12 hours.
24. Soaked 6 hours, frozen 24 hours, then etherized 24 hours.

The seeds were examined each day and notes taken showing the percentage of germination. The tables show the extent of the growth following each of the treatments by days for one week. As a rule all of the seeds that were capable of germinating had sprouted at the end of 7 days. Occasionally later germination occurred. In the last column of each table is shown the total germination that resulted from each treatment. Table 14 shows the results secured from treating Indian corn (*Zea Mays* L.)

An analysis of Tables 14 to 22 inclusive brings out the fact that etherizing old, dry seeds has but little effect on their germination. The ether treatment with such seeds certainly did not hasten the germination very much, and in some cases there were indications that the ether had exerted a detrimental effect on the total germination that occurred.

TABLE 14. EFFECTS OF VARIOUS TREATMENTS ON GERMINATION OF SEEDS KEPT IN COMMON STORAGE UNTIL MID-WINTER. TREATMENTS MADE IN JANUARY AND FEBRUARY, 1913. SPECIES, *Zea Mays*, L.

| Treatments | | | | | Percentage of germination by days | | | | | | | Total percentage of germination |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Kind of treatment * | Frozen (before soaking) hours | Soaked hours | Frozen (after soaking) hours | Etherized hours | 1st day | 2nd day | 3rd day | 4th day | 5th day | 6th day | 7th day | |
| 1 | ... | ... | ... | ... | | | | 18 | 60 | 68 | 68 | 68 |
| 2 | ... | ... | ... | 12 | | | | 41 | 78 | 91 | 91 | 97 |
| 3 | ... | ... | ... | 24 | | | | 58 | 94 | 97 | 97 | 100 |
| 4 | 24 | ... | ... | ... | | | 40 | 74 | 100 | 100 | 100 | 100 |
| 5 | 24 | ... | ... | 12 | | | 14 | 48 | 92 | 92 | 92 | 92 |
| 6 | 24 | ... | ... | 24 | | | 12 | 78 | 96 | 98 | 98 | 98 |
| 7 | 24 | 3 | ... | ... | | | | 50 | 60 | 60 | 60 | 64 |
| 8 | 24 | 3 | ... | 12 | | 8 | 67 | 95 | 98 | 98 | 98 | 99 |
| 9 | 24 | 3 | ... | 24 | | | 16 | 80 | 96 | 97 | 97 | 97 |
| 10 | 24 | 6 | ... | ... | | | | 48 | 74 | 74 | 78 | 80 |
| 11 | 24 | 6 | ... | 12 | | 10 | 50 | 92 | 98 | 98 | 98 | 98 |
| 12 | 24 | 6 | ... | 24 | | | 18 | 78 | 98 | 98 | 100 | 100 |
| 13 | ... | 3 | ... | ... | | | | 50 | 60 | 60 | 60 | 64 |
| 14 | ... | 3 | ... | 12 | | 12 | 80 | 90 | 98 | 100 | 100 | 100 |
| 15 | ... | 3 | ... | 24 | | | | | 46 | 70 | 90 | 94 |
| 16 | ... | 3 | 24 | ... | | 4 | 16 | 18 | 22 | 24 | 30 | 30 |
| 17 | ... | 3 | 24 | 12 | | | | 22 | 30 | 38 | 40 | 40 |
| 18 | ... | 3 | 24 | 24 | | | 12 | 22 | 28 | 30 | 30 | 30 |
| 19 | ... | 6 | ... | ... | | | | 48 | 74 | 74 | 78 | 80 |
| 20 | ... | 6 | ... | 12 | | 2 | 36 | 74 | 88 | 88 | 88 | 88 |
| 21 | ... | 6 | ... | 24 | | | | 32 | 84 | 98 | 100 | 100 |
| 22 | ... | 6 | 24 | ... | | 4 | 8 | 12 | 12 | 14 | 16 | 16 |
| 23 | ... | 6 | 24 | 12 | | | 4 | 12 | 20 | 22 | 22 | 22 |
| 24 | ... | 6 | 24 | 24 | | | 4 | 4 | 6 | 6 | 10 | 10 |

*See page 34 for detailed treatments.

Freezing dry seeds apparently had but little effect on either the time or the percentage of germination. However, etherizing for twelve hours seeds that had been previously frozen quite materially hastened the germination in some species, while others were uninfluenced in this respect. In the main, the 12-hour ether treatment was more effective in hastening germination than the 24-hour dose.

One surprising result noticed was that Indian corn (Table 14), made 100 per cent of germination in five days where dry seeds had been frozen for twenty-four hours, while similar dry seeds, not frozen, made only 68 per cent germination. Just why freezing should apparently have been beneficial to germination is not clear. Seeds that

TABLE 15. EFFECTS OF VARIOUS TREATMENTS ON GERMINATION OF SEEDS KEPT IN COMMON STORAGE UNTIL MID-WINTER. TREATMENTS MADE IN JANUARY AND FEBRUARY, 1913. SPECIES, *Phaseolus Lunatus*, L. VAR, *Macrocarpus*, BENTH.

| Treatments | | | | | Percentage of germination by days | | | | | | | Total percentage of germination |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Kind of treatment | Frozen (before soaking) hours | Soaked hours | Frozen (after soaking) hours | Etherized hours | 1st day | 2nd day | 3rd day | 4th day | 5th day | 6th day | 7th day | |
| 1 | ... | ... | ... | ... | | | 4 | 18 | 38 | 42 | 54 | 84 |
| 2 | ... | ... | . | 12 | | | 19 | 39 | 53 | 54 | 55 | 71 |
| 3 | ... | ... | ... | 24 | | | 25 | 52 | 58 | 62 | 66 | 75 |
| 4 | 24 | . | ... | ... | | 2 | 10 | 14 | 22 | 22 | 22 | 42 |
| 5 | 24 | ... | ... | 12 | | | 12 | 28 | 32 | 34 | 40 | 60 |
| 6 | 24 | ... | . | 24 | | | 12 | 22 | 42 | 56 | 58 | 84 |
| 7 | 24 | 3 | ... | ... | | 10 | 24 | 40 | 48 | 48 | 50 | 88 |
| 8 | 24 | 3 | | 12 | 2 | 6 | 14 | 36 | 58 | 62 | 70 | 82 |
| 9 | 24 | 3 | . | 24 | | | 18 | 36 | 50 | 62 | 72 | 90 |
| 10 | 24 | 6 | ... | ... | | 20 | 28 | 54 | 58 | 62 | 62 | 70 |
| 11 | 24 | 6 | ... | 12 | 12 | 24 | 38 | 52 | 56 | 56 | 58 | 74 |
| 12 | 24 | 6 | ... | 24 | 2 | 4 | 20 | 36 | 56 | 66 | 78 | 96 |
| 13 | ... | 3 | ... | ... | | | | 44 | 52 | 56 | 62 | 78 |
| 14 | ... | 3 | ... | 12 | 5 | 8 | 25 | 45 | 64 | 69 | 71 | 95 |
| 15 | ... | 3 | ... | 24 | | 3 | 25 | 49 | 55 | 59 | 63 | 82 |
| 16 | ... | 3 | 24 | ... | | 2 | 4 | 22 | 24 | 30 | 38 | 50 |
| 17 | ... | 3 | 24 | 12 | | | | 12 | 24 | 34 | 38 | 40 |
| 18 | ... | 3 | 24 | 24 | | | 2 | 14 | 24 | 36 | 46 | 54 |
| 19 | ... | 6 | ... | ... | | | 12 | 40 | 54 | 56 | 66 | 82 |
| 20 | ... | 6 | ... | 12 | 4 | 8 | 20 | 32 | 44 | 56 | 66 | 86 |
| 21 | ... | 6 | ... | 24 | | | 12 | 44 | 54 | 58 | 60 | 86 |
| 22 | ... | 6 | 24 | ... | | 2 | 8 | 14 | 20 | 22 | 24 | 26 |
| 23 | ... | 6 | 24 | 12 | | | 2 | 4 | 20 | 28 | 40 | 46 |
| 24 | ... | 6 | 24 | 24 | | | | 12 | 16 | 20 | 24 | 30 |

*See page 34 for detailed treatments.

were frozen, soaked six hours and etherized twenty-four hours also made 100 per cent germination, while only 80 per cent grew where similarly frozen and soaked but not etherized. Others that had the same preliminary treatment but etherized for only twelve hours, showed 98 per cent of germination. Thus it would seem that the ether treatment increased the amount of germination, and a study

of these treatments in Table 14 would seem to indicate that germination also was hastened by the ether treatment.

It is interesting to note in the same table that it makes quite a difference on the germination of the seeds as to whether they are frozen when dry or after being soaked. In treatments 8 to 12 the seeds were frozen while dry, then soaked and etherized. In the main,

TABLE 16. EFFECTS OF VARIOUS TREATMENTS ON GERMINATION OF SEEDS KEPT IN COMMON STORAGE UNTIL MID-WINTER. TREATMENTS MADE IN JANUARY AND FEBRUARY, 1913. SPECIES, *Phaseolus Vulgaris*, L.

| Treatments | | | | | Percentage of germination by days | | | | | | | Total percentage of germination |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Kind of treatment | Frozen (before soaking) hours | Soaked hours | Frozen (after soaking) hours | Etherized hours | 1st day | 2nd day | 3rd day | 4th day | 5th day | 6th day | 7th day | |
| 1.. | ..... | ..... | ..... | ... | | | | 2 | 2 | 2 | 6 | 10 |
| 2.. | ..... | ..... | ... | 12 | | | | 1 | 2 | 4 | 4 | 4 |
| 3.. | ..... | ..... | ... | 24 | | | | 2 | 3 | 8 | 8 | 11 |
| 4 | 24.. | ..... | ... | | | | | 2 | 4 | 8 | 8 | 8 |
| 5 | 24.. | ..... | ... | 12 | | | | | 2 | 2 | 6 | 6 |
| 6 | 24.. | ..... | ... | 24 | | | | | 2 | 2 | 2 | 6 |
| 7 | 24 | 3.. | ..... | . | | | 2 | 4 | 4 | 6 | 6 | 6 |
| 8 | 24 | 3 | ... | 12 | | | | 4 | 8 | 12 | 24 | 26 |
| 9 | 24 | 3.. | ... | 24 | | | 2 | 4 | 8 | 10 | 10 | 12 |
| 10 | 24 | 6.. | ..... | ... | | 2 | 2 | 8 | 12 | 14 | 16 | 18 |
| 11 | 24 | 6.. | ... | 12 | | | | | 4 | 6 | 8 | 12 |
| 12 | 24 | 6.. | ... | 24 | | | | | 2 | 10 | 10 | 12 |
| 13.. | ... | 3.. | ..... | ... | | | 2 | 6 | 10 | 10 | 10 | 12 |
| 14.. | ... | 3.. | ... | 12 | | | | 4 | 7 | 12 | 13 | 15 |
| 15.. | ... | 3.. | ... | 24 | | | | | 2 | 9 | 10 | 11 |
| 16 | ... | 3.. | 24 | ... | | | | 8 | 8 | 8 | 8 | 8 |
| 17.. | ... | 3 | 24 | 12 | | | | 4 | 6 | 16 | 18 | 18 |
| 18 | ... | 3 | 24 | 24 | | | 6 | 12 | 14 | 16 | 22 | 22 |
| 19.. | ... | 6.. | ..... | ... | | | | 2 | 8 | 12 | 12 | 16 |
| 20.. | ... | 6.. | ... | 12 | | | | 2 | 2 | 6 | 12 | 12 |
| 21.. | ... | 6.. | ... | 24 | | | 2 | 6 | 6 | 6 | 8 | 12 |
| 22.. | ... | 6 | 24 | ... | | | 6 | 6 | 10 | 14 | 14 | 16 |
| 23.. | ... | 6 | 24 | 12 | | | | 4 | 10 | 14 | 14 | 14 |
| 24.. | ... | 6 | 24 | 24 | | | 2 | 2 | 4 | 6 | 10 | 10 |

*See page 34 for detailed treatments.

all of them show a high percentage of germination, while in treatments 16 to 18 inclusive, the seeds were soaked three hours before freezing and etherizing, and there germination was very low. To find the full effects of freezing seeds of this kind, a comparison should be made of treatment 4 with Nos. 16 and 22 in Table 14. Treatment 4, where dry seeds were frozen, shows 100 per cent of germination.

Treatment 17, where seeds were soaked three hours and then frozen, shows 40 per cent of germination; and 22, where seeds were soaked 24 hours then frozen shows 16 per cent of germination. This is good argument in support of the advice which is frequently given that while seed corn will stand considerable freezing in storage if dry, it is badly injured by freezing, if moist.

TABLE 17. EFFECTS OF VARIOUS TREATMENTS ON GERMINATION OF SEEDS KEPT IN COMMON STORAGE UNTIL MID-WINTER. TREATMENTS MADE IN JANUARY AND FEBRUARY, 1913. SPECIES, *Citrullus Vulgaris*, SCHRAD

| Treatments | | | | | Percentage of germination by days | | | | | | | Total percentage of germination |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Kind of treatment | Frozen (before soaking) hours | Soaked hours | Frozen (after soaking) hours | Etherized hours | 1st day | 2nd day | 3rd day | 4th day | 5th day | 6th day | 7th day | |
| 1.. | ..... | ..... | ..... | ... | | | | | | | | 82 |
| 2.. | ..... | ..... | ... | 12 | | | | | | | | 77 |
| 3.. | ..... | ..... | ... | 24 | | | | | | | 1 | 66 |
| 4 | 24.. | ..... | ..... | ... | | | | | | | 2 | 62 |
| 5 | 24.. | ..... | ... | 12 | | | | | 2 | 28 | 60 | 84 |
| 6 | 24.. | ..... | ... | 24 | | | | | 4 | 12 | 24 | 72 |
| 7 | 24 | 3.. | ..... | ... | | | | | | | 2 | 82 |
| 8 | 24 | 3.. | ... | 12 | | | | | 2 | 8 | 50 | 74 |
| 9 | 24 | 3 | | 24 | | | | | 8 | 20 | 52 | 86 |
| 10 | 24 | 6.. | ..... | ... | | | | | 2 | 16 | 38 | 78 |
| 11 | 24 | 6.. | ... | 12 | | | | | 2 | 28 | 52 | 78 |
| 12 | 24 | 6.. | ... | 24 | | | | 2 | 2 | 18 | 60 | 82 |
| 13.. | ... | 3.. | ..... | ... | | | | | | | | 76 |
| 14.. | ... | 3.. | ... | 12 | | | | | | | 4 | 52 |
| 15.. | ... | 3.. | ... | 24 | | | | | | 2 | 6 | 25 |
| 16 | ... | 3.. | 24 | ... | | | | | | | | 0 |
| 17.. | ... | 3 | 24 | 12 | | | | | | | | 2 |
| 18.. | ... | 3 | 24 | 24 | | | | | | | | 0 |
| 19.. | ... | 6.. | ..... | ... | | | | | | | | 48 |
| 20.. | ... | 6.. | ... | 12 | | | | | | 6 | 48 | 82 |
| 21.. | ... | 6.. | ... | 24 | | | | | | | | 82 |
| 22.. | ... | 6.. | .24 | ... | | | | | | | | 0 |
| 23.. | ... | 6 | 24 | 12 | | | | | | | | 0 |
| 24 | ... | 6 | 24 | 24 | | | | | | | | 0 |

*See page 34 for detailed treatments.

In Table 15 it is seen that Lima beans even when dry, are badly injured by freezing, while if they are moist (treatment 17) they are slightly more injured, but if thoroly wet (treatment 22) freezing will greatly reduce germination. In these three instances the total percentages of germination were 42, 40 and 26 respectively. Ether apparently had little effect in either hastening growth or bringing about a higher percentage of germination.

By consulting Table 17 it is seen that watermelon seeds are apparently slightly injured by freezing, even when they are dry, while if they are frozen after being soaked, either for three or six hours, all are killed. The effects of the ether on watermelon seeds were somewhat irregular. In treatments 2 and 3, dry seeds were etherized for twelve and twenty-four hours. The total germination was 77 and 76

TABLE 18. EFFECTS OF VARIOUS TREATMENTS ON GERMINATION OF SEEDS KEPT IN COMMON STORAGE UNTIL MID-WINTER. TREATMENTS MADE IN JANUARY AND FEBRUARY, 1913. SPECIES, *Cucurbtia Maxima*, DUCHESNE

| Treatments | | | | | Percentage of germination by days | | | | | | | Total percentage of germination |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Kind of treatment | Frozen (before soaking) hours | Soaked hours | Frozen (after soaking) hours | Etherized hours | 1st day | 2nd day | 3rd day | 4th day | 5th day | 6th day | 7th day | |
| 1.. | ..... | ..... | ..... | ... | | | | | 12 | 16 | 28 | 40 |
| 2.. | ..... | ..... | ... | 12 | | | | 4 | 20 | 29 | 29 | 62 |
| 3.. | ..... | ..... | ... | 24 | | | | 4 | 11 | 19 | 28 | 53 |
| 4 | 24.. | ..... | ..... | ... | | | | 6 | 20 | 26 | 46 | 68 |
| 5 | 24.. | ..... | ... | 12 | | | | | 30 | 50 | 64 | 66 |
| 6 | 24.. | ..... | ... | 24 | | | | 10 | 30 | 50 | 70 | 74 |
| 7 | 24 | 3.. | ..... | ... | | | | 4 | 14 | 28 | 54 | 72 |
| 8 | 24 | 3.. | ... | 12 | | | | 20 | 38 | 52 | 52 | 54 |
| 9 | 24 | 3.. | ... | 24 | | | 6 | 20 | 48 | 66 | 70 | 76 |
| 10 | 24 | 6.. | ..... | ... | | | 10 | 22 | 38 | 56 | 62 | 74 |
| 11 | 24 | 6.. | ... | 12 | | | | 6 | 32 | 54 | 68 | 74 |
| 12 | 24 | 6.. | ... | 24 | | | 1 | 18 | 38 | 50 | 52 | 58 |
| 13.. | ... | 3.. | ..... | ... | | | | | 4 | 8 | 22 | 88 |
| 14.. | ... | 3.. | ... | 12 | | | 5 | 20 | 47 | 64 | 66 | 96 |
| 15.. | ... | 3.. | ... | 24 | | 2 | 10 | 27 | 44 | 49 | 54 | 77 |
| 16 | ... | 3.. | 24 | ... | | | 4 | 16 | 28 | 36 | 38 | 40 |
| 17.. | ... | 3 | 24 | 12 | | | | 14 | 36 | 36 | 38 | 54 |
| 18.. | ... | 3 | 24 | 24 | | | 10 | 24 | 30 | 36 | 40 | 42 |
| 19.. | ... | 6.. | ..... | ... | | | | | | 12 | 22 | 60 |
| 20.. | ... | 6.. | ... | 12 | | | 2 | 6 | 28 | 54 | 64 | 66 |
| 21.. | ... | 6.. | ... | 24 | | | | | 12 | 22 | 34 | 66 |
| 22.. | ... | 6 | 24 | ... | | | | 4 | 10 | 14 | 14 | 14 |
| 23.. | ... | 6 | 24 | 12 | | | | 8 | 16 | 20 | 20 | 24 |
| 24.. | ... | 6 | 24 | 24 | | | 10 | 10 | 18 | 18 | 20 | 22 |

*See page 34 for detailed treatments.

per cent respectively. Treatments 14 and 15 consisted of etherizing soaked seeds (three hours) for twelve and twenty-four hours. The total percentage of germination was 52 and 25 respectively, while in treatments 20 and 21, seeds soaked six hours received the same ether treatments, and the germination in both cases was 82 per cent. It thus appears that if seeds are thoroly moist (as they were when soaked

six hours), that the ether is able to exert its full effects. However, the highest total percentage of germination in even thoroly moist seeds that were etherized, was only equal to the total germination in the same kind of seeds which were planted when dry, receiving no treatment whatever. Apparently, then, freezing is injurious to watermelon seeds, and ether also is detrimental except when used on seeds that are thoroly moist.

TABLE 19. EFFECTS OF VARIOUS TREATMENTS ON GERMINATION OF SEEDS KEPT IN COMMON STORAGE UNTIL MID-WINTER. TREATMENTS MADE IN JANUARY AND FEBRUARY, 1913. SPECIES, *Spinacia Oleracea*, L

| Treatments | | | | | Percentage of germination by days | | | | | | | Total percentage of germination |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Kind of treatment | Frozen (before soaking) hours | Soaked hours | Frozen (after soaking) hours | Etherized hours | 1st day | 2nd day | 3rd day | 4th day | 5th day | 6th day | 7th day | |
| 1 | ... | ... | ... | ... | | | 6 | 6 | 22 | 46 | 58 | 88 |
| 2 | ... | ... | ... | 12 | | 4 | 17 | 29 | 39 | 54 | 54 | 74 |
| 3 | ... | ... | ... | 24 | | | 23 | 43 | 51 | 51 | 56 | 69 |
| 4 | 24 | ... | ... | ... | | | 2 | 20 | 48 | 66 | 66 | 76 |
| 5 | 24 | ... | ... | 12 | | 2 | 12 | 44 | 66 | 70 | 72 | 90 |
| 6 | 24 | ... | ... | 24 | | | 18 | 44 | 66 | 66 | 70 | 82 |
| 7 | 24 | 3 | ... | ... | | 2 | 6 | 22 | 54 | 62 | 64 | 66 |
| 8 | 24 | 3 | ... | 12 | | | 10 | 50 | 60 | 64 | 72 | 78 |
| 9 | 24 | 3 | ... | 24 | | | 24 | 50 | 58 | 62 | 62 | 74 |
| 10 | 24 | 6 | ... | ... | | | 10 | 20 | 42 | 44 | 50 | 60 |
| 11 | 24 | 6 | ... | 12 | | 8 | 20 | 56 | 66 | 74 | 74 | 80 |
| 12 | 24 | 6 | ... | 24 | | | 24 | 42 | 48 | 54 | 58 | 66 |
| 13 | ... | 3 | ... | ... | | 2 | 24 | 26 | 54 | 66 | 74 | 84 |
| 14 | ... | 3 | ... | 12 | 11 | 24 | 50 | 60 | 68 | 74 | 74 | 95 |
| 15 | ... | 3 | ... | 24 | 13 | 33 | 49 | 68 | 71 | 77 | 79 | 89 |
| 16 | ... | 3 | 24 | ... | | | 4 | 10 | 12 | 12 | 14 | 18 |
| 17 | ... | 3 | 24 | 12 | 2 | 10 | 14 | 36 | 46 | 48 | 48 | 54 |
| 18 | ... | 3 | 24 | 24 | | | 8 | 24 | 40 | 40 | 50 | 66 |
| 19 | ... | 6 | ... | ... | | 4 | 4 | 14 | 36 | 46 | 60 | 72 |
| 20 | ... | 6 | ... | 12 | 6 | 22 | 38 | 58 | 66 | 70 | 74 | 86 |
| 21 | ... | 6 | ... | 24 | | | 18 | 36 | 54 | 70 | 80 | 86 |
| 22 | ... | 6 | 24 | ... | | 2 | 6 | 10 | 16 | 16 | 18 | 22 |
| 23 | ... | 6 | 24 | 12 | | 8 | 16 | 34 | 34 | 34 | 46 | 56 |
| 24 | ... | 6 | 24 | 24 | | | 4 | 12 | 28 | 34 | 34 | 52 |

*See page 34 for detailed treatments.

The most striking results from treatments of okra seed were from soaking. (In Table 21, treatments 13 and 19, soaking three and six hours.) The first made only 4 per cent of germination while the second made only 6 per cent. Freezing the dry seed apparently had no effect on the germination. In treatment 7 where seeds were frozen

and then soaked for three hours, the germination was only 2 per cent. Evidently the injury was from the soaking as was shown in treatments 13 and 19. The highest percentages of germination followed the 12-hour ether treatments—viz., where seeds were dry, where they had been soaked three hours, and soaked six hours, the percentages being 25, 29 and 26 respectively. These were from 7 to 9 per cent

TABLE 20. EFFECTS OF VARIOUS TREATMENTS ON GERMINATION OF SEEDS KEPT IN COMMON STORAGE UNTIL MID-WINTER. TREATMENTS MADE IN JANUARY AND FEBRUARY, 1913. SPECIES, *Raphanus Sativus*, L

| Treatments | | | | | Percentage of germination by days | | | | | | | Total percentage of germination |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Kind of treatment | Frozen (before soaking) hours | Soaked hours | Frozen (after soaking) hours | Etherized hours | 1st day | 2nd day | 3rd day | 4th day | 5th day | 6th day | 7th day | |
| 1 | ... | ... | ... | ... | 14 | 62 | 70 | 80 | 80 | 80 | 80 | 80 |
| 2 | ... | ... | ... | 12 | | 40 | 58 | 74 | 76 | 78 | 82 | 82 |
| 3 | ... | ... | ... | 24 | | 4 | 38 | 44 | 48 | 50 | 50 | 56 |
| 4 | 24 | ... | ... | ... | | 64 | 68 | 76 | 76 | 76 | 76 | 76 |
| 5 | 24 | ... | ... | 12 | 16 | 58 | 68 | 74 | 82 | 82 | 82 | 86 |
| 6 | 24 | ... | ... | 24 | 12 | 66 | 76 | 80 | 84 | 84 | 86 | 86 |
| 7 | 24 | 3 | ... | ... | | 20 | 48 | 76 | 76 | 84 | 86 | 88 |
| 8 | 24 | 3 | ... | 12 | 20 | 68 | 68 | 74 | 74 | 76 | 76 | 80 |
| 9 | 24 | 3 | ... | 24 | 16 | 66 | 74 | 76 | 76 | 82 | 82 | 82 |
| 10 | 24 | 6 | ... | ... | | 28 | 60 | 76 | 76 | 82 | 84 | 86 |
| 11 | 24 | 6 | ... | 12 | 50 | 72 | 78 | 78 | 78 | 80 | 80 | 80 |
| 12 | 24 | 6 | ... | 24 | 42 | 72 | 78 | 84 | 84 | 84 | 84 | 88 |
| 13 | ... | 3 | ... | ... | | 42 | 78 | 84 | 84 | 84 | 88 | 88 |
| 14 | ... | 3 | ... | 12 | | 60 | 86 | 90 | 90 | 92 | 92 | 92 |
| 15 | ... | 3 | ... | 24 | | 24 | 74 | 80 | 82 | 82 | 84 | 86 |
| 16 | ... | 3 | 24 | ... | 10 | 28 | 38 | 38 | 42 | 42 | 42 | 44 |
| 17 | ... | 3 | 24 | 12 | 8 | 48 | 78 | 80 | 86 | 88 | 88 | 90 |
| 18 | ... | 3 | 24 | 24 | | | 14 | 20 | 30 | 30 | 30 | 44 |
| 19 | ... | 6 | ... | ... | | 42 | 76 | 82 | 88 | 90 | 92 | 96 |
| 20 | ... | 6 | ... | 12 | 54 | 84 | 84 | 84 | 84 | 84 | 88 | 88 |
| 21 | ... | 6 | ... | 24 | | 36 | 58 | 70 | 72 | 72 | 78 | 78 |
| 22 | ... | 6 | 24 | ... | 2 | 30 | 38 | 40 | 46 | 46 | 46 | 50 |
| 23 | ... | 6 | 24 | 12 | 6 | 38 | 70 | 78 | 80 | 82 | 82 | 88 |
| 24 | ... | 6 | 24 | 24 | | | 18 | 28 | 34 | 38 | 38 | 44 |

*See page 34 for detailed treatments.

better than the germination shown by check or untreated seeds. If the two latter are compared with seeds that were soaked three and six hours, but with no further treatment, the differences in total germination are found to be 25 and 20 per cent respectively, in favor of the etherized seeds.

With onion seed the effects of freezing were contradictory. Freezing dry seeds appeared to increase the total percentage of germination.

while freezing seeds that were soaked three and six hours respectively greatly reduced the total; the 3-hour soaking far worse than the 6-hour soaking. Etherizing dry seeds and etherizing those soaked three hours seemed to give about the same results in germination, while etherizing seeds that had been soaked six hours seemed to reduce the amount of germination. However, the best results were only equal to the check or

TABLE 21. EFFECTS OF VARIOUS TREATMENTS ON GERMINATION OF SEEDS KEPT IN COMMON STORAGE UNTIL MID-WINTER. TREATMENTS MADE IN JANUARY AND FEBRUARY, 1913. SPECIES, *Hibiscus Esculentus*, L

| Treatments | | | | | Percentage of germination by days | | | | | | | Total percentage of germination |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Kind of treatment | Frozen (before soaking) hours | Soaked hours | Frozen (after soaking) hours | Etherized hours | 1st day | 2nd day | 3rd day | 4th day | 5th day | 6th day | 7th day | |
| 1.. | ..... | ..... | ..... | ... | | | | 4 | 4 | 10 | 10 | 18 |
| 2.. | ..... | ..... | ... | 12 | | | 4 | 14 | 20 | 21 | 21 | 25 |
| 3.. | ..... | ..... | ... | 24 | | | 7 | 15 | 17 | 17 | 17 | 20 |
| 4 | 24.. | ..... | ..... | ... | | | | 6 | 12 | 12 | 12 | 18 |
| 5 | 24.. | ..... | ... | 12 | 2 | 4 | 6 | 6 | 10 | 10 | 10 | 18 |
| 6 | 24.. | ..... | ... | 24 | | | | 8 | 10 | 10 | 10 | 12 |
| 7 | 24 | 3.. | ..... | ... | | | | | 2 | 2 | 2 | 2 |
| 8 | 24 | 3.. | ... | 12 | | | | 6 | 6 | 6 | 6 | 6 |
| 9 | 24 | 3.. | ... | 24 | | | | | 4 | 6 | 8 | 10 |
| 10 | 24 | 6.. | ..... | ... | | | | | | | | 2 |
| 11 | 24 | 6.. | ... | 12 | | | | 2 | 4 | 6 | 10 | 12 |
| 12 | 24 | 6.. | ... | 24 | | | | 6 | 10 | 10 | 10 | 16 |
| 13.. | ... | 3.. | ..... | ... | | | | | | | | 4 |
| 14.. | ... | 3.. | ... | 12 | | 3 | 9 | 27 | 27 | 27 | 27 | 29 |
| 15.. | ... | 3.. | ... | 24 | | 3 | 27 | 37 | 38 | 38 | 38 | 41 |
| 16 | ... | 3.. | 24 | ... | | 4 | 6 | 10 | 12 | 12 | 12 | 14 |
| 17.. | ... | 3 | 24 | 12 | 2 | 10 | 14 | 22 | 22 | 22 | 22 | 24 |
| 18.. | ... | 3 | 24 | 24 | | | 4 | 12 | 12 | 14 | 14 | 14 |
| 19.. | ... | 6.. | ..... | ... | | | | | | 4 | 6 | 6 |
| 20.. | ... | 6.. | ... | 12 | 4 | 4 | 10 | 18 | 20 | 22 | 26 | 26 |
| 21.. | ... | 6.. | ... | 24 | | | | 6 | 8 | 12 | 16 | 20 |
| 22.. | ... | 6 | 24 | ... | | 8 | 8 | 8 | 8 | 8 | 8 | 10 |
| 23.. | ... | 6 | 24 | 12 | | 4 | 8 | 16 | 26 | 26 | 26 | 26 |
| 24.. | ... | 6 | 24 | 24 | | | 4 | 8 | 8 | 8 | 8 | 10 |

*See page 34 for detailed treatments.

untreated seeds, so apparently etherizing this species is neither beneficial nor particularly harmful.

Soaking dry-frozen seeds for six hours apparently has about the same effect as soaking alone for three hours. However, where such seeds were etherized for twelve hours, they gave a higher average total germination than similar seeds etherized for twenty-four hours.

This may perhaps be explained on the theory that growth had already begun in the 6-hour-soaked seeds, and consequently that the 24-hour ether treatment which followed was harmful to the growing parts. This is in accord with previous experiments in etherizing vegetative parts where buds were nearly always injured if treated with a strong dose of ether after they had begun to grow.

TABLE 22. EFFECTS OF VARIOUS TREATMENTS ON GERMINATION OF SEEDS KEPT IN COMMON STORAGE UNTIL MID-WINTER. TREATMENTS MADE IN JANUARY AND FEBRUARY, 1913. SPECIES, *Allium Cepa*, L

| Treatments | | | | | Percentage of germination by days | | | | | | | Total percentage of germination |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Kind of treatment | Frozen (before soaking) hours | Soaked hours | Frozen (after soaking) hours | Etherized hours | 1st day | 2nd day | 3rd day | 4th day | 5th day | 6th day | 7th day | |
| 1.. | ..... | ..... | ..... | ... | | 2 | 2 | 2 | 2 | 14 | 28 | 62 |
| 2.. | ..... | ..... | ... | 12 | | 2 | 5 | 8 | 15 | 19 | 20 | 40 |
| 3.. | ..... | ..... | ... | 24 | | | 4 | 23 | 37 | 40 | 43 | 62 |
| 4 | 24.. | ..... | ..... | ... | | | | 4 | 14 | 24 | 34 | 66 |
| 5 | 24.. | ..... | ... | 12 | | | 2 | 10 | 15 | 24 | 28 | 40 |
| 6 | 24.. | ..... | ... | 24 | 4 | 4 | 10 | 18 | 22 | 28 | 32 | 38 |
| 7 | 24 | 3.. | ..... | ... | | | 8 | 8 | 14 | 16 | 20 | 30 |
| 8 | 24 | 3.. | ... | 12 | | 8 | 16 | 16 | 28 | 34 | 46 | 52 |
| 9 | 24 | 3.. | ... | 24 | | | | 10 | 18 | 30 | 32 | 40 |
| 10 | 24 | 6.. | ..... | ... | | | 4 | 4 | 16 | 18 | 20 | 40 |
| 11 | 24 | 6.. | ... | 12 | | 2 | 2 | 10 | 20 | 32 | 42 | 52 |
| 12 | 24 | 6.. | ... | 24 | | | 2 | 10 | 18 | 22 | 22 | 26 |
| 13.. | ... | 3.. | ..... | ... | | 2 | 2 | 2 | 2 | 10 | 24 | 50 |
| 14.. | ... | 3.. | ... | 12 | | 3 | 7 | 28 | 40 | 49 | 53 | 63 |
| 15.. | ... | 3.. | ... | 24 | | 4 | 14 | 30 | 38 | 41 | 44 | 63 |
| 16 | ... | 3.. | 24 | ... | 6 | 10 | 12 | 12 | 12 | 12 | 12 | 18 |
| 17.. | ... | 3 | 24 | 12 | | | 4 | 8 | 8 | 8 | 16 | 26 |
| 18.. | ... | 3 | 24 | 24 | | | | 2 | 12 | 16 | 18 | 22 |
| 19.. | ... | 6.. | ..... | ... | | 2 | 2 | 2 | 6 | 8 | 26 | 46 |
| 20.. | ... | 6.. | ... | 12 | | 2 | 6 | 6 | 18 | 32 | 40 | 56 |
| 21.. | ... | 6.. | ... | 24 | | | 2 | 2 | 2 | 8 | 18 | 46 |
| 22.. | ... | 6 | 24 | ... | 2 | 6 | 14 | 16 | 18 | 26 | 32 | 38 |
| 23.. | ... | 6 | 24 | 12 | 4 | 6 | 10 | 12 | 12 | 14 | 22 | 32 |
| 24.. | ... | 6 | 24 | 24 | | | | 2 | 6 | 14 | 20 | 24 |

*See page 34 for detailed treatments.

In general, soaking dry seeds for three hours has a tendency to produce a hastened germination, but a 12-hour exposure to ether, in addition to the soaking, hastened it still more in many cases.

Seeds that were soaked for three hours and then frozen showed hastened germination in a few cases, but with practically every species a much lower total germination was secured. The ether treatment

apparently stimulated a higher percentage of germination, and in the majority of cases the 12-hour exposure caused germination to be hastened.

TABLE 23. SUMMARY OF RESULTS OF ALL TREATMENTS ON NINE SPECIES OF SEEDS KEPT IN COMMON STORAGE FROM HARVESTING TIME UNTIL MID-WINTER. (TABLES 14 TO 22 INCLUSIVE)

| Treatments | | | | | Total percentage of germination of the following species: | | | | | | | | | Average percentage of germination |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Kind of treatment | Frozen (before soaking) hours | Soaked hours | Frozen (after soaking) hours | Etherized hours | Zea Mays Table 9 | Phaseolus lunatus Table 10 | Phaesolus vulgaris Table 11 | Citrullus vulgaris Table 12 | Cucurbita maxima Table 13 | Spinacia oleracea Table 14 | Raphanus sativus Table 15 | Hibiscus esculentus Table 16 | Allium Cepa Table 17 | |
| 1 | ... | ... | ... | ... | 68 | 84 | 10 | 82 | 40 | 88 | 80 | 18 | 62 | 59.1 |
| 2 | ... | ... | ... | 12 | 92 | 71 | 4 | 77 | 62 | 74 | 82 | 25 | 40 | 58.5 |
| 3 | ... | ... | ... | 24 | 97 | 75 | 11 | 66 | 53 | 69 | 56 | 20 | 62 | 56.5 |
| 4 | 24 | ... | ... | ... | 100 | 42 | 8 | 62 | 68 | 76 | 76 | 18 | 66 | 57.3 |
| 5 | 24 | ... | ... | 12 | 92 | 60 | 6 | 84 | 66 | 90 | 86 | 18 | 40 | 60.2 |
| 6 | 24 | ... | ... | 24 | 98 | 84 | 6 | 72 | 74 | 82 | 86 | 12 | 38 | 61.3 |
| 7 | 24 | 3 | ... | ... | 64 | 88 | 6 | 82 | 72 | 66 | 88 | 2 | 30 | 55.3 |
| 8 | 24 | 3 | ... | 12 | 99 | 82 | 26 | 74 | 54 | 78 | 80 | 6 | 52 | 61.2 |
| 9 | 24 | 3 | ... | 24 | 97 | 90 | 12 | 86 | 76 | 74 | 82 | 10 | 40 | 63.0 |
| 10 | 24 | 6 | ... | ... | 80 | 70 | 18 | 78 | 74 | 60 | 86 | 2 | 40 | 56.4 |
| 11 | 24 | 6 | ... | 12 | 98 | 74 | 12 | 78 | 74 | 80 | 80 | 12 | 52 | 62.2 |
| 12 | 24 | 6 | ... | 24 | 100 | 96 | 12 | 82 | 58 | 66 | 88 | 16 | 26 | 60.4 |
| 13 | ... | 3 | ... | ... | 64 | 78 | 12 | 76 | 88 | 84 | 88 | 4 | 50 | 60.4 |
| 14 | ... | 3 | ... | 12 | 100 | 95 | 15 | 52 | 96 | 95 | 92 | 29 | 63 | 70.7 |
| 15 | ... | 3 | ... | 24 | 94 | 82 | 11 | 25 | 77 | 89 | 86 | 41 | 63 | 63.1 |
| 16 | ... | 3 | 24 | ... | 30 | 50 | 8 | 0 | 40 | 18 | 44 | 14 | 18 | 24.6 |
| 17 | ... | 3 | 24 | 12 | 40 | 40 | 18 | 2 | 54 | 54 | 90 | 24 | 26 | 38.6 |
| 18 | ... | 3 | 24 | 24 | 30 | 54 | 22 | 0 | 42 | 66 | 44 | 14 | 22 | 32.6 |
| 19 | ... | 6 | ... | ... | 80 | 82 | 16 | 48 | 60 | 72 | 96 | 6 | 46 | 56.2 |
| 20 | ... | 6 | ... | 12 | 88 | 86 | 12 | 82 | 66 | 86 | 88 | 26 | 56 | 65.4 |
| 21 | ... | 6 | ... | 24 | 100 | 86 | 12 | 82 | 66 | 86 | 78 | 20 | 46 | 64.0 |
| 22 | ... | 6 | 24 | ... | 16 | 26 | 16 | 0 | 14 | 22 | 50 | 10 | 38 | 21.3 |
| 23 | ... | 6 | 24 | 12 | 22 | 46 | 14 | 0 | 24 | 56 | 88 | 26 | 32 | 34.2 |
| 24 | ... | 6 | 24 | 24 | 10 | 10 | 10 | 0 | 22 | 52 | 44 | 10 | 24 | 20.2 |
| Average of all check plantings | | | | | 62.7 | 65.0 | 11.7 | 53.5 | 57.0 | 60.7 | 73.5 | 9.2 | 37.5 | 47.8 |
| Average of all 12 hour ether treatments | | | | | 78.8 | 69.2 | 13.3 | 56.1 | 62.0 | 76.6 | 85.7 | 20.7 | 44.8 | 56.3 |
| Average of all 24 hour ether treatments | | | | | 78.2 | 74.6 | 12.0 | 51.6 | 58.5 | 73.0 | 70.2 | 17.8 | 37.6 | 52.6 |

*See page 34 for detailed treatments.

Seeds soaked six hours did not show much advantage in either the time or amount of germination over those soaked for three hours. However, etherizing such seeds tends to hasten the germination and also to increase the total percentage that grow. The 12-hour treatment was more effective than the longer exposure.

Seeds soaked six hours and then frozen, were badly damaged by such treatment, but etherizing, especially for the 12-hour period, seemed to have the power of causing a greatly increased percentage of germination.

A summary of all of the treatments in each table shows that the average percentage of germination for all check seeds was 47.8; for all plantings after 12-hour ether treatment, was 56.3; and for all the 24-hour etherization treatments, 52.6 per cent. Comparing the checks with the ether treatments it is seen that former germinated in twenty-nine cases on the first day on which germination was recorded for that series; the 12-hour ether exposure in forty-seven cases; and the 24-hour ether treatments in only thirty cases. The 12-hour treatment, when compared with the check, shows a hastening of germination in thirty-six cases, and a retardation in only eighteen instances, while the 24-hour exposure hastened the germination in twenty-five instances, and retarded it in twenty-four.

## SUMMARY AND CONCLUSIONS

Seed studies carried on at the Missouri Agricultural Experiment Station were begun in 1907 and continued for seven years. Primarily these studies were conducted for the purpose of investigating the rest period.

Preliminary tests in 1907 and 1908 showed, first, that seeds of many annual plants are able to germinate while quite immature; and, second, that seeds of more than half of the species grown in Missouri have a pronounced rest period. Also that of the species having a rest period, by far the greater percentage are woody forms.

The chief purpose of the seed investigations carried on during the years 1911, 1912, and 1913, was to confirm the existence of a rest period in seeds, and to find to what extent the species are influenced by this phenomenon.

Other objects sought thru these later investigations were: If seeds have a rest period, when does the resting phase set in and can it be broken by treatments; what agents are most effective for breaking the rest; to what extent do seeds respond to treatments in general while dry and while moist; effects of treatments on germination aside from hastening or hindering the growth; and, a comparison of all of the foregoing with regard to the different species and orders.

Special efforts were put forth to secure as many different kinds of seeds as possible. Altogether, during the two seasons of 1912 and 1913, nearly 200 species, representing fifty-one orders, were collected. Each planting usually consisted of 100 seeds and there were more

than 900 separate plantings so that these investigations alone represented a total planting and study of nearly 100,000 seeds.

## EXPERIMENT 1

During the summer of 1911 the collection of seeds from wild and cultivated plants amounted to 122 species. These were harvested as nearly as possible immediately after ripening. From each species 200 seeds were counted out. One-half of each sample was planted at once in moist sand, and the other half dried at room temperature for one month before planting.

**Results from Experiment 1.** Up to October 15, when observations ceased, 23.1 per cent of the species had germinated in less than two weeks, 19.8 per cent after two weeks, and 57.1 per cent did not grow at all. The seeds planted at maturity, on the average, germinated in 22.2 days while the dried seeds required only 17.8 days. The total germination in the mature seeds was 33.3 per cent, dried seeds 40.9 per cent.

**Conclusions.** If two weeks is sufficient time to allow seeds for making "immediate" germination, then it must be concluded that fully 75 per cent of the species in the experiment have a rest period. Also the usual assumption that seeds which fail to grow immediately after maturity are possessed of a rest period apparently is incorrect, as the rest period may not set in at any time during several days after ripening. Finally, seeds dried for a month germinate quicker and better than when planted immediately after maturity, thus showing that the majority of seeds are greatly benefited by being allowed to pass thru a period of dormancy before being planted.

## EXPERIMENT 2

The seed collection of 1912 was intended to be quite complete for the entire season. However, the plans could not be carried out on account of illness. Collecting stopped July 20. Seeds were again gathered as near maturity as possible. One lot was planted at once, while a similar lot (set not complete) was dried out before planting.

**Results from Experiment 2.** The dried seeds gave approximately the same results as in the previous years' test, viz., that they germinated more quickly and better than those that were planted at once after maturity. The set of seeds planted immediately after ripening consisted of seventy-six species, representing thirty-two orders. Of these, 23.6 per cent grew in less than three weeks, 39.4 per cent in fall or the following spring, and 37 per cent did not grow at all.

**Conclusions.** These results are almost identical with those secured the previous year as regards the number of species that have a rest period, viz., a little more than 76 per cent.

The species of a single order are much alike as regards whether they have a rest period. Also in addition to exhibiting similar requirements for growth, they are apt to show about the same percentage of germination.

## EXPERIMENT 3

The seeds of fifteen species of woody plants, representing eleven orders, were gathered before maturity, that is, in the "dough" stage. Half of each was planted at once and the other half air-dried before planting. A set of freshly gathered, mature seeds was planted immediately after harvesting in order to check the results.

**Results from Experiment 3.** Only two species (13.3 per cent) of the freshly gathered, green seeds grew, while none of the immature dried seeds germinated. Forty per cent of the ripe seeds sprouted.

**Conclusions.** While the number of seeds in the experiment was small, it would appear for the most part, that immature seeds, particularly of woody plants, are unable to germinate. However, if they do grow, germination takes place much more quickly than in mature seeds. Finally, immature seeds of woody plants are easily killed if allowed to become air-dry.

## EXPERIMENT 4

In the fall of 1912, thirty-one species of woody plants, representing fifteen orders, were tested to find what species have a rest period, value of treatments for breaking the rest—that is, for producing quick germination—and also the effects of the treatments on total percentage of germination. The treatments consisted of drying, soaking in water, etherizing, stratifying, and combinations of these treatments. The seeds that were stratified were frozen in stratification.

**Results from Experiment 4.** Of the species planted at maturity, 6.5 per cent germinated within two weeks, 58 per cent grew after two weeks while 35.4 per cent did not grow at all.

The quickest germination resulted from freezing the seeds in stratification, then treating them with ether for twenty-four hours. These grew, on the average, in 22.6 days, while dry untreated seeds required, on the average 50.1 days. This treatment also gave the most complete germination, 43.8 per cent, as compared with 14.5 per cent for dry untreated seeds.

Drying seeds for one month had but little effect on the number that germinated, but they grew 6.4 days earlier on the average, apparently as a result of the drying. Etherizing dried seeds did not cause them to grow any earlier and neither did the treatment increase the percentage of germination.

Stratifying seeds and allowing them to freeze hastened the time of germination by 34.4 days, and increased the percentage of those that grew by 16.9 per cent. Etherizing after stratification gave varying results on the whole greatly increased the percentage of germination, but this treatment did not materially reduce the length of the rest period.

**Conclusions.** Of thirty-one species of woody plants tested, 93.5 per cent apparently have a pronounced rest period. Stratifying seeds of woody plants and letting them freeze while mixed with the moist sand proved to be the best treatment tried for hastening the sprouting and bringing about the highest percentage of germination. This shows that the common practice of stratifying forest tree seeds, after they have become dry, is a very necessary treatment.

Etherizing dried, and also moist seeds (soaked 3 hours) has some beneficial effects on germination. Etherizing seeds that have been stratified (frozen in stratification), hastens the sprouting and increases the per cent of germination. In both tests the good effects of the treatment were very marked.

## EXPERIMENT 5

In January and February, 1913, seeds of corn and eight common vegetables (all having been kept in house storage), were subjected to twenty different treatments before planting.

**Results from Experiment 5.** Corn frozen while dry made 100 per cent germination, while similar untreated seeds germinated only 68 per cent. Another lot of corn was frozen, soaked six hours and etherized, and the germination was 100 per cent, while others with the ether treatment omitted showed only 80 per cent.

Freezing wet corn twenty-four hours reduced the germination from 60 to 84 per cent.

Lima beans, untreated, showed 84 per cent germination; frozen while dry, 42 per cent; frozen while moist (soaked three hours), 40 per cent; while wet (soaked six hours), 26 per cent. Etherizing the seeds, either dry or wet, had little effect upon the germination in any way.

Freezing watermelon seeds, even when dry, injured them slightly while if wet they were killed. The effects of ether were variable, altno more favorable on dry than on wet seeds.

The following are a few of the more striking results secured with okra seeds: Untreated showed 18 per cent germination; soaked three hours, 4 per cent; soaked six hours, 6 per cent; soaked three hours and etherized 24 hours, 41 per cent; soaked six hours and etherized twenty-four hours, 20 per cent.

**Conclusions.** Etherizing old, dry seeds of herbaceous plants has but little effect upon their germination, and this mostly detrimental.

Corn seed etherized when dry seemed to be benefited, and after being soaked the ether treatments very materially increased the percentage of germination. Corn seed will stand being severely frozen when dry, but is severely injured if frozen when in a moist or wet condition.

Lima beans are bady injured if frozen even when dry; if moist or wet the injury is proportionately greater.

Freezing is injurious to watermelon seed and ether is also detrimental if the seeds are dry, but they are not hurt, and may even be benefited by freezing, if the seeds are quite moist.

Soaking okra seeds has a very bad effect on the germination. Ether treatments have little or no effect on dry seeds, but are very beneficial to moist or wet seeds.

## HISTORICAL

**Existence of a Rest Period in Seeds.** The fact of a rest period or resting phase in seeds has been recognized by practically every author of textbooks on plant physiology. Pfeffer[1] says: "Certain seeds are capable of immediate germination, whereas others must first rest for a few weeks, months or even years, even when they are not dry, but are kept under conditions that are favorable for germination."

Jost[2] says, in explanation of the foregoing paragraph: "It is now definitely known that these variations [in germination] depend on varying degrees of permeability of the testa for water, but we know nothing further as to why seeds which have imbibed water are prevented from germinating. At most we may draw analogous conclusions from the behavior of resting buds. . . . Undoubtedly internal factors play the chief part in determining the initiation and cessation of the resting period in seeds . . ."

Rest period experiments with seeds were carried on at the Missouri Agricultural Experiment Station in 1907-8.[3] In all, 93 species wer studied. These included annuals, biennials, and both herbaceous and woody perennials. It was found that 50 per cent or more of the species tested had a pronounced rest period.

**Mechanical Stimulation of Seeds.** In addition to the effects of the rest period which may prevent the germination of seeds, some have a very hard seed coat after becoming dry, and it is almost impossible for the embryo to force its way out. Also such seeds are almost impervious to water. Such seeds are sometimes treated by cracking them open or filing or boring openings thru the testa. Other methods, such as pricking with a needle, or burning with a hot wire, have been devised, and in many cases satisfactory results secured from their use. Leguminous plants are perhaps more conspicuous than any other group in possessing what are generally known as "hard" seeds. These are seeds which do not germinate readily and, because of this fact, breeding work with such plants, especially red clover, has often been seriously hindered. For rendering the seed coat permeable to water, Williams[4] devised the method of shaking the

1. Pfeffer, Plant Physiology, Vol. II, pp. 207 and 208.
2. Jost, Plant Physiology, pp. 341-42.
3. Howard, W. L., Rest Period Studies with Bulbs and Herbaecous Perennial Plants. Mo. Agr. Exp. Sta. Research Bul., No. 15.
4. Williams, N. Y. (Cornell) Agr. Exp. Sta. Bul. 312, p. 296.

seeds in a box lined with sand paper. This treatment caused the seeds to make a much better germination.

Crocker [1] (1907) made germination tests of seeds of aquatic plants. Seeds collected while still green germinated quite readily, but in many instances the dried seeds refused to germinate. This difficulty was overcome by cracking the seed coat. If allowed to become dry, the seeds of many water plants are unable to germinate because the seed coat becomes so hard that it cannot absorb moisture. While such seeds may have a rest period, the chief failure to germinate is due to the hardness of the seed coat. To secure germination this mechanical hindrance must be removed.

An injury to the seed embryo itself, such as mutilating a cotyledon, sometimes hastens germination.[2] While the effects of freezing and stratification may in some instances be mechanical in their nature, it is very probable that other changes are also induced by such treatments. Stratification is employed for softening the seed coat, and freezing generally assists in this process. Nurserymen find it necessary to treat many seeds, particularly of woody plants, by stratifying. Soaking under special conditions will sometimes produce the same results.

**Chemical Stimulation.** Various chemical or enzymic solutions have been used to hasten or retard germination. Rostrup [3] used sulphuric acid on seeds of *Lathyrus sylvestris* securing 100 per cent germination, as compared with 76 per cent in seeds not treated by the acid.

Todaro [4] also found that sulphuric acid (sp. gr. 1.84) acted upon the hard seeds of many leguminous plants, rendering them capable of prompt germination. He immersed the seeds in the acid for one hour at a temperature of 25° to 28° C. Not only was growth hastened, but also a higher percentage of germination was secured. Thornber [5] treated seeds of several species with sulphuric acid in which chomic acid had been dissolved and then neutralized with potassium hydrate. Seeds of acacia, mesquite, locust and others germinated readily. Quick germination was brought about in seeds that were almost impervious to moisture by soaking in water at a temperature of 85° to 88° C. for 2-6 minutes.

1. Crocker, Botanical Gazette, Vol. 44, pp. 375-380.
2. Experiment Station Record, Vol. 22, p. 326.
3. Rostrup, Exp. Station Record, Vol. 10, pp. 53-4.
4. Todaro, Experiment Station Record, Vol. 12, pp. 754-5.
5. Thornber, An. Report Arizona Agr. Exp. Sta. 1904, pp. 489-93.

Schneider-Orelli [1] treated refractory seeds with sulphuric acid, thereby increasing the germination from 15 to 75 per cent.

Love and Leighty [2] tested the effects of concentrated sulphuric acid upon the seeds of red clover, white clover, alfalfa and cotton. The acid treatment caused increased germination, and at the same time destroyed obnoxious weed seeds. Increased germination was brought about chiefly through the softening of the testa of the so-called "hard" seeds. The favorable effects of acid on the seeds continued even after they were allowed to become dry. The acid treatment caused old seeds to germinate quicker and better. However, it was found that thin coated seeds might be injured by the treatment.[3]

Organic acids have been found to increase and accelerate the germination process in seeds. It was believed that these treatments contributed to the nutrition of the growing embryo.[4]

Stone and Smith [5] (1895) attempted to stimulate the germination of seeds by subjecting them to various enzymic solutions. Asparagin and leucin increased the percentage of germination, and sometimes accelerated germination. Pepsin solutions gave fair results with some seeds, but negative results with others. Diastase, one of the most widely distributed enzymes, gave beneficial results with some seeds, but with others did not. The tests seemed to show that no one enzyme is beneficial to all seeds.

Waugh,[6] confirming the early works of Thomsen, reports that the percentage of germination of some seeds may be greatly increased by soaking for several hours in a solution containing some active enzyme. Tomato seeds seemed to respond exceptionally well to the action of diastase.

Pickering [7] found that heating a soil seems to have the effect of retarding the germination of seeds planted in it. This was supposed to be due to an inhibitory substance formed by the alteration of the bacterial content of the soil. The fact that heating a soil increases the soluble organic and nitrogenous matter present and also that these materials form a large proportion of the inhibitory substance, lends

1. Schneider-Orelli, Exp. Station Record, Vol. 24, p. 231.
2. Love and Leighty, N. Y. (Cornell) Agr. Exp. Sta. Bul. 312.
3. Experiment Station Record, Vol. 37, p. 132.
4. Experiment Station Record, Vol. 25, p. 222.
5. Stone and Smith, An. Rpt. Mass. (Hatch) Exp. Sta. 1901, pp. 74-79
6. Waugh, An. Rpt. Vermont Agr. Exp. Sta. 1898, pp. 290-5.
7. Pickering, 9th An. Rpt. Woburn Exp. Fruit Farm.

support to such a view. Fletcher[2] (1910) reported the same results.

**Electric Stimulation.** Many investigators have studied the effects of the electric current on different forms of plant life.[3] Nollet was probably the first person to study the effect of electricity on seeds. Later Specnew subjected different seeds to electric treatment and found that germination was very greatly hastened. Paulin found that the electric current would seemingly awaken life in seeds which appeared to have lost their vitality. Tschinkel showed that certain seeds germinated quicker in a soil thru which an electric current had been passed, but Woolny secured only negative results from the use of this treatment on the seed of summer rye, radish, and rape. Kinney[4] concludes that: "Electricity exerts an appreciable influence upon the germination of seeds and the application of certain strengths of current to seeds for short periods accelerates germination." It has also been reported that a galvanic current of high frequency gives beneficial results, while a continued current is detrimental to germination.[5]"

**Contact Stimulation.** Apparently seeds of certain plants, particularly seeds of vegetable parasites, will not germinate unless they come in contact with a particular host. Heinricher[6] (1909) studied the germination of seeds of parasites. He found that seeds of *Lathraea* would not germinate unless they were in contact with their host, and the same was true of the seeds of *Tozzia, while Bartschia,* a related genus, germinated without being in contact with its host.

**Stimulation of Seeds by Light and Heat.** Promsy and Drevon[7] found that X-rays increased or decreased the germination of seeds of lentils, wheat, beans, and lupines in varying degrees, depending upon the temperature and exposure. The greatest regularity in the effects was noticed during a rather high temperature when, with a certain exposure adopted as the best, the irradiation always favored germination and accelerated the development of the resultant plants.

**Immaturity as a Cause of Early Germination.** Altho green or immature seeds usually do not germinate as large a percentage as more mature seeds, yet they are sometimes used because of the earlier devlopment of the resultant plants.[8] This is especially true of tomatoes.

2. Fletcher, Experiment Station Record, Vol. 23, p. 722.
3. Mass. (Hatch) Agr. Exp. Sta. Bul. 43.
4. Kinney, Mass. (Hatch) Agr. Exp. Sta. Bul. 43.
5. Exp. Sta. Record, Vol. 25, p. 26.
6. Heinricher, Exp. Sta. Record, Vol. 23, p. 628.
7. Promsy and Drevon, Exp. Sta. Record, Vol. 28, p. 128.
8. Read, Thesis 1908, University of Missouri.

Maze[2] produced early maturity in seeds by drying grains of common field corn containing 50-60 per cent of moisture for five or six days. While the seeds before drying did not sprout; they did so after drying, producting normal plants. Maze concluded that the evaporation of the volatile matter tends to retard the growth of the embryo and hence aids in the normal development.

**Stimulation of Seeds with Anesthetics.** According to Hempel,[3] Clemens and Marcet (1848) were the first investigators to study the effects of anesthetics on plants. Afterward many workers experimented with plants by treating them with various anesthetics and narcotics, the earlier ones for the purpose of studying irritation and movement, but later ones for studying the rest period.

Giglioli[4] appears to have been the first to study the effects of ether and other gases and liquids on the vitality of seeds. Bernard, Sirgusa (1879), Detmer (1882) and Dubois (1891) made use of ether in studying seeds and seedlings.

Townsend[5] found that while a strong atmosphere of ether tends to retard germination, a weak dose appears to hasten growth. However, his results following ether treatments were not always uniform.

Johannsen (1893) (see reference to Hempel) diminished the rest period of seeds by etherization, but states that the rest period could be broken only at its beginning or toward its close. After the rest period had passed, no stimulation of germination was noticed. He gave it as his opinion that anesthetics act on the seeds in one of two ways; that is, on the "power of growth" (Wachstumstätigkeit) or on the "growth suspending power" (Hemmung), or possibly on both.

Coupin (1899), Schmid (1901), Behrens (1908) and Eberhard (1906) conducted experiments in etherizing dry and soaked seeds and all found that the rest period could be shortened by the treatment, but they held different opinions as to the specific results of the anesthetic.

As regards the relation of etherization to transpiration, Jumelle (1890), Lommen, Schneider (1893), and Woods and Dixon (1896), secured opposite results, the first two workers finding that transpiration was increased, while the others reported that it was reduced.

2. Maze, Exp. Sta. Record, Vol. 24, p. 720.

3. Hempel, Researches into the Effect of Etherization on Plant Metabolism. Det. Kongelige Danske Videnskabernes Selskab Skrifter, 7. Rahkke, Naturvidensk, Og Mathem. Afd. VI, 6. Copenhagen, 1911.

4. Giglioli, Nature, Vol. 35, p. 328.

5. Townsend, Botanical Gazette, Vol. 27, pp. 458-66.

Gayon (1877) found that an ether atmosphere suspended the evolution of $CO_2$ but Elfving reported an acceleration of respiration in *Pisum* seedings when exposed to the influence of ether. Lauren believed that seeds rich in carbohydrates could not have their respiration increased since respiration could be accelerated only in proportion to the amount of nitrogenous matter contained in the seed, and Abrahamson's [1] (1910) work showed that a high protein content in barley was correlated with a high respiration. Johannsen proved that in ripening lupines and sweet peas respiration was slightly retarded by etherization, but in young ripening barley seeds it was increased. Thus it seems that the specific effect of ether on respiration depends quite largely on the kind of seed being tested.

Hempel experimented extensively concerning the effect of etherization on plant metabolism, but the only part of that work of interest here deals with the effect of ether on ripening seeds of *Pisum* and *Lupinus*. It was found that etherizing germinating seeds retarded both the germination and also the subsequent growth. The effect of small doses for short periods was to accelerate the production of $CO_2$ but large doses retarded it. Respiration was never increased as an "after effect." The sugar forming process was not so vitally affected as the respiratory process, and because of the relation of the inversion of sugar to the other processes, it was thought that the retardation of the $CO_2$ production might be due to a lack of hexoses. Young *Pisum* seeds showed a hastening of the condensation of proteids normally taking place at maturity, when small doses of ether were used. Large doses retarded the synthesis of proteids or destroyed those already formed. Ether retarded the decrease of amides at ripening time in mono-amino seeds but small doses seemed to slightly increase it in di-amino seeds. Wounded seeds were not affected by small doses of ether, but large doses tended to produce an increase in the amides during the two days' exposure.

Summarizing, Hempel recognizes three phases of narcotization: (1) Exciting (small doses for short periods) during which time the normal plant activities are accelerated; (2) narcosis proper (small doses for long periods or large doses for short periods) characterized by a retardation of the normal processes; and (3) toxic (large doses for long periods) causing all the phenomena characteristic of the death of the plant.

Lewis [2] (1906) reported quicker germination and more uniform growth from seeds which have been etherized than from untreated

1. Abrahamson, Exp. Sta. Record, Vol. 24, p. 629.
2. Lewis, Cornell Countryman, 3 (1906), No. 8, pp. 190-91.

seeds. Taubenhaus[2] reported very similar results and he also stated that ether seemingly put new life into old seeds thereby causing a higher germination. In both of these tests the seeds used were those of common vegetables and grains.

Kiessling[3] (1911) found that an 80 minute exposure to ether would hasten the germination of seeds but longer doses reduced both the rapidity and total per cent of germination. Alcohol, chloroform, etc., acted as stimulants to barley, wheat and oats. Injury to the seed, especially to the hulls, tended to promote increased and hastened germination.

Aspit and Gain[4] (1911) showed that the effect of ether was considerably increased at high temperatures.

**Miscellaneous Work.** Waldron[5] (1904), in making a study of the vitality of buried seed, found that green and yellow foxtail would not germinate before May 1 of the year following the production of the seed. Kinghead (*Ambrosia trifida,* L.) grew more abundantly the second season following planting than the one immediately following planting. The ability of some seeds to germinate seemed to depend quite largely upon the depth to which they were planted, the deeper buried ones (up to ten inches) being the better preserved. It was also shown that some seeds maintained their vitality much longer than others kept under the same conditions.

Fawcett[6] (1904) made a study of the viability of seeds under different conditions of treatment and also of their dormant period. Seeds stored indoors showed almost uniformly a longer dormant period than those stored outside, and the longest dormant period occurred in those seeds with the hardest and thickest seed coat. Some seeds showed a gradual decrease in the percentage of germination from month to month but others showed an increase. There seemed to be two natural periods for seed germination, one in the fall and the other in the spring. Exposing seed to the action of the weather tended to increase the percentage of germination and also to shorten the dormant period.

Pammel and King[7] (1906), in a study of delayed germination, confirmed some of the earlier work of Fawcett. It was reported that

2. Taubenhaus, Cornell Countryman 5 (1908), No. 6, p. 201.
3. Kiessling, Exp. Sta. Record, Vol. 26, pp. 130-31.
4. Aspit and Gain, Exp. Sta. Record, Vol. 27, p. 220.
5. Waldron, North Dakota Exp. Sta. Bul. 62.
6. Fawcett, Proc. Iowa Acad. of Science, Vol. 15, No. 38.
7. Pammel and King, Proc. Iowa Acad. of Science, Vol. 15, No. 45.

the seeds of many plants such as the willows, soft maple, etc., germinated immediately, but others, such as the ash and hornbeam, did not germinate until the following year. In the case of many trees and shrubs maturing their seed early in the season, it was thought that germination must proceed immediately or the seeds would be destroyed.

It has long been known that in the case of some paired seeds, such as the cocklebur, both seeds do not usually germinate the same season. Arthur,[2] who made the first careful study of *Xanthium,* reported that generally the germination of one kernel in the bur was delayed, but that in some cases both may germinate the same season. Shull[3] (1911) in further investigations with *Xanthium* found that the minimum oxygen requirement for the germination of the seed from this plant was abnormally high, and also that the minimum for the two seeds differed. This explained the delay in germination and also the irregularities in the delayed growth.

Beal[4] (1910) gives some interesting data concerning the vitality of buried seeds and incidentally raises some questions concerning their germinating capacities. Eight or nine species out of twenty-two germinated even after they had been buried thirty years. In speaking of his results, Beal says: "I have never felt certain that I had induced all the sound seed to germinate. I moisten the sand containing the seeds and forthwith a goodly number germinate, and then they come straggling along. I dry the soil and wait a few weeks, and after moistening, in a few days, or few months, more seed germinate. Why was I unable to induce them to start, when treated to various degrees of temperature and moisture, for several months?"

2. Arthur, Proc. Soc. Prom. Agr. Sc., 16, p. 70.
3. Shull, Bot. Gazette, 52, pp. 453-77.
4. Beal, Proc. Soc. Prom. Agr. Sc. 31, pp. 21-23.

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