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AN INVESTIGATION
OF THE
REST PERIOD OF SEEDS

by

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AN INVESTIGATION OF THE REST PERIOD OF SEEDS.

INTRODUCTION.

"All life is rhythmic in character, each life cycle being a repetition of a preceding one, and during the progress of the "grand period" of each individual various periodic¹ movements occur in growing and adult organs."

In all plants, including fungi and algae, as well as higher forms, this periodicity of growth, due to season, nutrition, environment, etc., is seen. Practically all temperate zone plants exhibit a yearly periodicity. The change in season causes a period of activity in summer and a corresponding one of rest in winter. Seeds also show this same phenomenon of periodicity of growth.

The fact that nearly all plants exhibit a periodical rest period, during which - under normal conditions - there is no growth, has long been known, and the general problem of discovering the causes and factors influencing this dormant

¹
Pfeffer, Plant Physiology Vol. II p. 197.

period has interested investigators for many years. However, it is only within the last few years that any definite knowledge has been secured in answer to some of the many interesting questions arising from a consideration of this fundamental plant-growth problem. Much work must still be done before the final explanation of some of the phenomena accompanying the dormant period can be satisfactorily made.

The following report, dealing with an investigation of the rest period of seeds, is only one specific part of a problem dealing with the rest period of plants in general. Work upon this broader problem was begun several years ago by Dr. W. L. Howard of the Missouri Experiment Station, and the present work has been carried out largely under his direction. Much help and many useful suggestions have come from him in connection with the present investigation.

OBJECTS OF THIS INVESTIGATION.

The objects of this investigation were two in number. The first one was to answer the question: 'Do seeds have a natural rest period and, if so, in which species is it the most pronounced?' The answer to this question might also answer the question: 'Why are certain plants found growing only in certain seasons of the year?' To accomplish this object seeds were gathered and planted as soon as mature. Others were allowed to become thoroughly dry before planting so that all ripening processes were completed before the seeds were placed under normal growing conditions. Also a few were gathered before

quite mature and planted immediately.

A second object was to determine the effect of various treatments such as etherization, freezing, and soaking, or a combination of these, on hastening the process and increasing the percentage of germination. This really resolves itself into the question: 'Can the rest period of seeds be broken, and if so, what agencies stimulate them into growth?'

GENERAL STATEMENT.

The present work, however, does not attempt to cover all phases of seed germination but rather restricts itself to that portion of the problem, the results of which can be made to compare directly with the previously mentioned work on the "Rest Period of Plants".² For that reason the work was confined to only certain phases of the general problem. No consideration was given to the subsequent growth of the seedlings, the only concern being the ability of the seed to germinate and the length of time between planting and the beginning of growth.

While any form of treatment to hasten the germination of seeds probably has more scientific than practical value, yet there are some seeds which lose their germinating capacity very quickly and, if the percentage of germination could be materially increased at a small expense, such treatment would be worthy of practical application.

²Howard, Mo. Exp. Sta. Research Bul. I.

It has often been noticed that some seeds germinate much more quickly than others under the same conditions. Pfeffer³ in speaking of the periodicity of growth in seeds, sums up as follows: "Certain seeds are capable of immediate germination, whereas others must first rest for a few weeks, months, or years, even when they are not dry but are kept under conditions favorable for germination.

"Thus the seeds of Trapa natans and probably of most other aquatic plants whose seeds sink to the bottom when ripe, germinate the following spring. Wiesner found that seeds of the mistletoe, and Kientz that those of the white fir, pine, beech, hornbeam and ash, germinate the following year, and only very exceptionally the same year. Of sowings of ripe seeds of Cuscuta, Euphorbia cyparissias, etc., a number germinate very soon, but others not until the following year, and in the case of Euphorbia exigena, some not until after nine years."

Pfeffer⁴ further states that this delay of germination is due only in part to the relative impermeability of the seed coat for evidently some internal change is occurring in those seeds which swell up but still do not germinate. Growth may be entirely or only partially suspended during the dormant phase. An example of this appears in the seeds of Eranthis hiemalis, Ranunculus Ficaria and other plants. These seeds have only small embryos when shed, but the embryos gradually

³Pfeffer, Plant Physiology Vol. II p. 207

⁴Pfeffer, Plant Physiology Vol. II p. 208

enlarge at the expense of the endosperm. The length of the dormant period may be affected by previous cultural conditions but the conditions which lead to certain seed resting under the soil for as long as fifty years and germinating when dug up have not yet been determined.

In a discussion of this subject Jost⁵ raises several questions, some of which are: "Is this state of 'rest' real and absolute or only apparent? Is the quiescence of the dry seed really due not to the abolition of vital processes but only to the diminution of these to such an extent that they cannot be realized? Does respiration, a vital process, cease or only greatly diminish?" etc.

Kolkwitz (1901) showed that the amount of CO_2 given off by seeds decreases very rapidly as the percentage of water decreases, and in air dry seeds it reaches a value which is practically zero since only 1% of the dry weight of the seeds would be respired in one hundred years. From this work the conclusion may be drawn that respiration is not essential to the continuance of a vital capacity since many seeds are not injured, so far as their germinating capacity is concerned, by enduring a desiccation so thorough that respiration would have no physiological significance. Schroeder (1886) germinated barley containing only 2% moisture but an interval of eleven to twelve weeks elapsed before germination. Although a change in the proteids of the seed, tending to make them insoluble, probably occurs, yet it is out of the question to suppose that

⁵Jost, Plant Physiology pp. 34~~4~~⁵-345.

the death of the resting seed is due to the using up of all⁶ the reserve substances in the respiratory process.

Many seeds are unable to germinate immediately after reaching maturity and they show the power of development only after a certain period of hibernation. It is definitely known that the variations in the germination of certain seeds depend upon the varying degrees of the permeability of the seed coat to water but we know nothing farther as to why those which have imbibed water are kept from germinating.⁷ Undoubtedly internal factors play a most important part in determining the initiation and cessation of the resting period in seeds.

HISTORICAL.

Previous work along the line of hastening or increasing the germination of seeds has been quite extensive and many methods of stimulation, mechanical as well as chemical, etc., have been tried with varying success. A brief review of some of this work is given.

Mechanical Stimulation---It is a well known fact that many seeds have such a hard seed coat when they become dry that it is almost impossible for the young plant to force its way out through this hard covering. To overcome this difficulty seeds with a hard stony covering are sometimes cracked open before planting. In other cases a hole may be bored through the testa so that the entrance of moisture may be greatly hastened. Other

⁶Jost, Plant Physiology p. 342

⁷Jost, Plant Physiology p. 342

methods such as pricking with a needle, burning with a hot wire, etc., have been devised and in many cases satisfactory results were secured.

Perhaps the leguminous plants are more conspicuous than any other group in possessing what are termed "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. ⁸Williams in speaking of this breeding work at the Ohio Agricultural College is credited with the following statement: "Some samples show 80-90% germination and others only 5-10%. I feel reasonably safe in saying that fully three-fourths of our plants show 20% germination or below."

Obviously any method that will increase the germination of clover seed or any other seed exhibiting the same peculiarities would have a distinct economic as well as scientific value. Williams solved this problem in a way by shaking the seed in a box lined with sand paper. After such treatment better germination was secured but such a method would necessarily have only a limited value.

⁹Crocker (1907) did some work with the germination of seeds of aquatic plants. Seeds collected while still green germinated quite readily but in many instances the dried seed refused to germinate. However, this difficulty was overcome by

⁸Cornell, Experiment Station Bulletin 312 p. 296

⁹Crocker, Botanical Gazette 44:375-380

cracking the seed coat. Such treatment gave prompt growth and a high percentage of germination. The results are accounted for on the theory that the delay and even failure in the germinating process was due to the inability of water to penetrate the seed coat rather than to any specific embryo characters.

A direct wounding of the seed itself may sometimes¹⁰ stimulate accelerated germination.

While freezing and stratification may in some instances be mechanical in nature yet other effects also are very probably secured from such treatment. Nevertheless, it is generally known that some seeds seemingly must undergo freezing before they will germinate.

Chemical Stimulation---Various chemical or enzymic solutions have been used by different scientists to hasten or retard germination but the use of sulphuric acid is probably¹¹ the most common treatment. Rostrup¹¹ (1898) used sulphuric acid on a sample of Lathyrus sylvestris and secured 100% germination as compared with 76% in the untreated lot. Treated "flat pea" seed also gave a much greater percentage of germination than the untreated ones.

¹² Todaro (1901), working independently, had also found that sulfuric acid (sp. gr. 1.84) acted upon the hard seeds of

¹⁰Experiment Station Record Vol. 22 p. 326

¹¹

Experiment Station Record 10:53-4

¹²Experiment Station Record 13:754-5

many leguminous plants rendering them capable of prompt germination. The treatment consisted of immersion in the acid for one hour at a temperature of 25-28° C. In addition to hastening the growth a greater total germination was also secured in some cases.

¹³Thornber treated seeds of several species with sulfuric acid in which chromic acid had been dissolved and then neutralized with potassium hydrate. Seeds of acacia, mesquite, locust and others germinated quite readily. In the case of extremely moisture resistant seeds it was found that treating with hot water (85°-88° C.) for 2-6 minutes accelerated germination.

¹⁴Schneider-Orelli used the sulfuric acid treatment for refractory seeds and increased the percentage of germination from 15% to over 75%.

¹⁵Love and Leighty carried on experiments regarding the effects of concentrated sulfuric acid upon seeds of red clover, white clover, alfalfa and cotton. Their data show that increased germination was secured and also that some of the obnoxious weed seeds were destroyed. Contrary to an opinion previously expressed by Todaro they found that the effects of the acid treatment were apparent even after the seeds were allowed to dry before germination.

¹³Thornber, Ariz. Station Report 1904 p. 489-93

¹⁴Experiment Station Record 24:231

¹⁵Love & Leighty, Cornell Exp. Station Bulletin 312

Old seed often germinated more quickly and a higher percentage was also secured after the acid treatment. However, seeds with thin seed coats may be injured by such treatment.¹⁶

Organic acids have also been found to increase and accelerate the growth process in seeds. Such treatment has been held to contribute to the nutrition of the growing embryo.¹⁷

¹⁸Stone and Smith (1895) made a series of tests to determine to what degrees seeds could be stimulated into germinating by subjecting them to various enzymic solutions. The solutions used were those commonly found in seeds and seedlings. It was thought that possibly these might supply a needed essential constituent and thus enable the poorer and exhausted seeds to germinate by converting certain seed products into a form available for germination. The seeds used were Medicago sativa, Brassica napus, Vicia sativa, Fagopyrum esculentum, Ornithopus sativus and Canadian Field Pea. Asparagin and leucin increased the percentage of germination and in some cases gave an accelerated germination. However, a pepsin solution gave fair results with some seeds and negative results with others. Diastase, one of the most widely distributed enzymes, gave beneficial results with some seeds but with others results of no consequence were secured. Thus it seems that the enzyme

¹⁶Experiment Station Record Vol. 27 p. 132

¹⁷Experiment Station Record Vol. 25 p. 222

¹⁸Stone & Smith, Mass. Hatch Exp. Sta. Report 1901 pp. 74-79

must be fitted to the particular seed.

¹⁹Waugh found, thus confirming the earlier work of Thomsen, 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. The action of the various solutions apparently is to convert a large amount of the starch content and it can hardly be questioned but that this is to the advantage of the germinating seed.

²⁰Pickering reports 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 support to such a view.

²¹Fletcher (1910) also reported that a heated soil seemed to retard germination.

²²Electric Stimulation---Many investigators have been interested in the effect of an electric current on plant life in general, but Nollet was the first to apply it as a stimulus

¹⁹Waugh, Vermont Station Report 1898 pp. 290-295

²⁰Pickering, 9th Report Woburn Experiment Fruit Farm

²¹Experiment Station Record Vol. 23 p. 722

²²Except where otherwise noted, this account is taken from Mass. Hatch Experiment Station Bulletin 43.

to seeds. Later Specnew subjected different seeds to electric treatment and found that germination was very greatly hastened. Paulin found that electricity would awaken life in seeds which had apparently lost all vitality. He used soaked seeds and declared that the seeds must be planted while still moist or the electrical effect would all be lost.

Tschinkel showed that certain seeds germinated quicker in a soil through which an electric current had been passed, but Woolny secured only negative results from the use of this treatment on seeds of summer rye, radish and rape.

After considerable work along various lines with the effect of electricity on the seeds of Trifolium pratense,
²³
Brassica napus and Brassica alba, Kinney comes to the following conclusions: "Electricity exerts an appreciable influence upon the germination of seeds and the application of certain strengths of current to seeds for short periods accelerates the process of germination." Treated seeds gave a higher germination earlier and a greater total germination than the untreated lot. The experiments showed that there is an optimum as well as a maximum and minimum current and also that the range of current stimulating rapid germination is exceedingly limited. The effect of a single application of the current lasted only a short time but hourly applications acted as a constant stimulus.

It has also been reported that a galvanic current of high frequency would give beneficial results but a continued

²³Kinney, Mass. Hatch Experiment Station Bulletin 43.

current proved to be detrimental to seed germination.²⁴

Contact Stimulation---Heinricher²⁵ (1909) made a study of the seed germination of parasites. He found that the seeds of Lathraea would not germinate unless they were in contact with the host. Bartschia seeds germinated without the stimulus of the host plant but Tozzia, a related ~~species~~ ^{genus}, failed to germinate unless in close proximity to the host.

Light and Heat Stimulation---It is quite generally known that light and heat have great influence on germination and much literature is available.

Promsy and Drevon²⁶ found that the X-ray had a variable effect on the seeds of lentils, wheat, beans, and lupines at ordinary temperatures, but with moderately high temperatures the phenomena became regular. With the exposure adapted, however, the irradiation always favored germination and accelerated the development of the plants.

Immaturity as a Cause of Early Germination---Although green or immature seeds do not germinate usually as large a percentage as more mature ones²⁷ yet they are sometimes used in order to secure earlier developing plants. This is especially true of tomatoes. Maze²⁸ induced early maturity in the seeds by drying corn kernels containing 50-60% moisture for five or

²⁴Experiment Station Record Vol. 25 p. 26

²⁵Experiment Station Record Vol. 23 p. 628

²⁶Experiment Station Record Vol. 28 p. 128

²⁷Read, Thesis 1908, University of Missouri

²⁸Experiment Station Record Vol. 24 p. 720

six days. The dried seed would then yield normal plants. He advances three theories to explain the results but he seems to favor the following as the most probable: Evaporation of the volatile matter tends to retard the growth of the embryo and hence aids in the normal development.

Stimulation from Anesthetics²⁹---The whole question of how vapors and gases cause growth to begin in dormant plants is little understood. According to Hempel, Clemens and Marcet (1848) were the first to study the effects of anesthetics on plants. They used chloroform to suspend the irritability of Mimosa. Leclerc (1853) investigated the effects of ether on plants. His work was followed by that of Blondeau (1867) and Bert (1867). Heckel (1873-4) noted the behavior of Berberis stamens under the influence of chloroform. Later he studied the sensitiveness and movements of other plants as affected by various anesthetics and narcotics. About the same date Pfeffer decided that the sleep movements of Mimosa were eliminated in an atmosphere of ether but he was of the opinion that such treatment would injure the plant.

The first record of a study of the effect of ether on seeds appears in the work of Giglioli (1868) who studied extensively the effect of gases and liquids on the vitality of seeds.³⁰ Ether was used in both the gaseous and liquid forms on both wet and dry seeds. The conclusion reached was that wet seeds were

²⁹Unless otherwise noted, this account is taken from Hempel's work - "Researches into the Effect of Etherization on Plant Metabolism."

³⁰Giglioli, Nature Vol. 35 p. 328

more easily killed than the dry ones but he does not state whether germination was hastened or not. Bernard, Sirgusa (1879), Detmer (1882), and Dubois (1891) agreed that ether retarded the growth of seedlings and prevented the germination of seeds but that when the etherizing influence was withdrawn, growth and germination went forward. Dubois also reports a strong dehydrating effect of ether, thus suggesting the possibility that it is very similar in its action to drying and freezing.

Townsend³¹ (1897) tested the effects of ether on seeds of Zea Mais, Avena sativa, Phaseolus vulgaris and Cucurbita Pepo. The seeds were placed in an ether atmosphere and allowed to remain there continuously. He found that while a strong atmosphere tends to retard or prevent germination, a weak one has the effect of hastening this process. Different seeds seemed to be affected differently by the same treatment. Seeds which had been kept from germinating several days by a strong ether atmosphere, germinated quite readily when removed to an ether-free atmosphere. Although the treated seeds germinated more readily yet it was noticed that the untreated seeds later overtook them in point of growth.

Johannsen (1893) diminished the rest period of seeds by etherization but he 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 supposed that anesthetics acted in either one or both of two

³¹Townsend, Botanical Gazette 27:458-66

ways, on the "power of growth" (Wachstumstatigkeit) or on the "growth suspending power" (Hemmung).

Although the results usually secured from freezing and desiccation are the same as those from the use of anesthetics, yet Johannsen states that these results do not come from the same cause. In support of this theory, he cites the case of Hordeum zeocrithon which has a pronounced rest period. While slight ether fumes stimulated immediate germination, drying had no apparent effect. He differs with Dubois on the question of etherization increasing the transpiration but it has since been demonstrated - at least in the case of twigs³² - that such treatment does tend to increase transpiration.

Coupin (1899) experimented with both air dry and soaked seeds and he concluded that anesthetics could affect only active protoplasm since they did not influence the active seeds and retarded the soaked ones. Schmid (1901) gave as his opinion that anesthetics acted as a poison to active protoplasm.

Behrens (1908) shortened the resting phase of seeds by exposure to ether thus causing them to germinate almost immediately. He supposed this acceleration was due to a direct stimulation rather than to an indirect effect on the seed coat enabling it in some way to absorb moisture more readily. Eberhard (1906) had held the same views.

While all vital processes are retarded or quickly arrested by the influence of anesthetics or narcotics, the chemical processes are never retarded, and in some cases are accelerated,

³²Howard, Missouri Exp. Station Research Bul. 1.

by such an influence. Such was the opinion of Bernard and for this reason he held that respiration, a chemical process as he thought, would be unaffected by etherization. It has been proven that anesthetics do affect ferments but the opinions as to their action on enzymes are somewhat divided.

In regard to the relation of etherization and transpiration, Jumelle (1890) and Lommen believed that transpiration was accelerated and assimilation suspended by anesthetics but Schneider (1893) thought that an ether atmosphere always reduced transpiration. Woods and Dixon (1896) also held the same opinion as Schneider but they concluded that it was from a physical cause and that transpiration and evaporation were identical.

Gayon (1877) had found that an ether atmosphere suspended the evolution of CO_2 but Elfving reported an acceleration of respiration in Pisum seedlings when exposed to the influence of ether. Lauren states 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's³³ (1910) work showed~~ed~~ 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

³³Experiment Station Record Vol. 24 p. 629

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.

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

Lewis³⁴ (1906) reported quicker germination and more uniform growth from seeds which have been etherized than from untreated seeds. Taubenhause³⁵ (1908) 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.

Kiessling³⁶ (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 Gain³⁷ (1911) showed that the effect of ether was considerably increased at high temperatures.

Miscellaneous Work---Waldron³⁸ (1904) in making a study of the vitality of buried seed found that green and yellow fox-tail would not germinate before about May 1 of the year following the production of the seed. Kinghead 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,

³⁴ Lewis, Cornell Countryman 3 (1906) No. 8 pp. 190-191

³⁵ Taubenhause, Cornell Countryman 5 (1908) No. 6 p. 201

³⁶ Experiment Station Record Vol. 26 pp. 130-131

³⁷ Experiment Station Record Vol. 27 p. 220

³⁸ Waldron, N. D. Experiment Station Bulletin 62

the deeper buried ones (up to ten inches) being the better preserved ones. It was also shown that some seed maintained their vitality much longer than others kept under the same conditions.

Fawcett³⁹ (1904) made a study of the viability of seeds under different conditions of treatment and also of their dormant periods. Seeds stored indoors showed almost uniformly a longer dormant period than those stored outside, and the longest dormant periods occurred in those seed 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 shorten the dormant period.

Pammel and King⁴⁰ (1906) in a study of delayed germination confirmed some of the earlier work of Fawcett. It was reported that 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

³⁹Fawcett, Proc. Iowa Acad. of Science Vol. 15, No. 38.

⁴⁰Pammel & King, Proc. Iowa Acad. Science Vol. 15, No. 45.

the same season. Arthur,⁴¹ 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. Shull⁴² (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. Thus the delay in germination and also the difference in the delay is secured.

Beal⁴³ (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?"

EXPERIMENTAL DATA.

Work on this investigation was begun early in the summer of 1911 and continued until October 1 of that year. As soon

⁴¹Arthur, Proc. Soc. Prom. Agrl. Sc. 16, p. 70.

⁴²Shull, Bot. Gazette 52, pp. 453-477

⁴³Beal, Proc. Soc. Prom. Agrl. Sc. 31, pp. 21-23

as seed began to ripen in 1912, it was again taken up and continued until the latter part of July when, on account of serious illness, it was interrupted and had to be dropped until October. At that time it was further extended and considerable work was carried on throughout the 1912-13 school year. Some of the later plantings were still under observation on May 1, 1913.

In the course of this study, seed from almost two hundred species representing fifty-one orders were collected and over nine hundred samples of seed were planted. The usual number of seed in each sample was one-hundred and hence this investigation represents a planting of nearly one hundred thousand seed.

The most extensive previous work of which any record was found is that of Fawcett⁴⁴ who collected and planted ninety-two samples of seeds representing fifty-two different species. This collection extended over a period of only three months.

The seeds collected, in practically all cases, were from species native to Columbia and vicinity, or from those growing on the University grounds. The system of nomenclature used follows quite largely that used in Gray's "New Manual of Botany" but a few species were classified from Bailey's "Cyclopedia of American Horticulture."

First Season's Work---During the first summer an attempt was made to secure seed from as large a number of species as possible. The seed were taken just as they were considered fully matured. In some cases it was difficult to decide just when this

⁴⁴Fawcett, Proc. Iowa Acad. of Science No. 38, Vol. 15.

stage was reached but it was assumed that they were mature when they had begun to fall naturally or when the fruit had ripened.

A sample of each species was planted immediately after it was collected while another sample was placed in the laboratory and allowed to become thoroughly air dry, when it was planted also. The second planting followed the first one at any interval of approximately one month.

The object of these plantings was to determine which species were capable of germinating immediately upon ripening and to discover those which require further development before germination will take place. At maturity seeds usually contain a much higher percentage of moisture than later, and the seed coats are not nearly so hard as they are when the seeds become air dry. A plentiful supply of moisture and a softened seed coat are conditions conducive to rapid germination and it might naturally be supposed that mature seeds possessing these requirements would germinate more readily than seeds which have become air dry. The fact that the germination of many seeds is apparently dependent upon the moisture supply would seem to bear out this assumption. However, the statement has often been made and, in some instances experimental evidence produced to prove it, that at least some seeds will not germinate as soon as they ripen.

All plantings, both of the mature and air dry seeds, were made in sand in the greenhouse bench. The sand bed was four or five inches deep and was kept moist by frequent sprinkling. All outside conditions such as light, heat, moisture, etc., were made as uniform as possible.

The data taken covered the number of days the seed remained dormant, that is, the time elapsing between planting and the first germination, and the total percentage of germination.

It was found that over one-half of the one hundred and twenty-five species planted refused to germinate before October 15 when the greenhouse space was required for other purposes.

The results secured from the first summer's plantings are given in Table No. I.

Table No. I

Seeds Planted Both as Soon as Ripe and After Being Air Dried.

*No Germination Before October 15, 1911.

Name of Species	Date Collected	Days Dormant		Total % Germination	
		Mature	Dry	Mature	Dry
<u>Gramineae</u>					
Alopecurus pratensis L.	5/20	*	50	0	5
Hordeum nodosum L.	6/9	61	38	90	96
Bromus mollus L.	6/15	22	7	57	84
Lolium perenne L.	6/21	14	6	52	53
Panicum crus-galli L.	6/24	*	44	0	2
Setaria glauca (L.) Beauv.	6/30	48	*	14	0
Triticum vulgare Vill.	6/13	7	4	66	96
Dactylis glomerata L.	6/15	22	8	32	59
Avena sativa L.	7/3	16	4	23	71
Phleum pratense L.	7/22	7	8	71	90
<u>Cyperaceae</u>					
Cyperus sp.	6/24	*	11	0	48
<u>Liliaceae</u>					
Asparagus officinalis L.	8/3	8	11	93	57
Yucca filamentosa L.	8/8	19	28	61	27
Canna sp.	8/26	16	35	22	7
<u>Urticaceae</u>					
Morus alba L.	6/5	13	8	42	57
<u>Polygonaceae</u>					
Rumex crispus L.	6/5	18	22	73	71
<u>Phytolaccaceae</u>					
Phytolacca decandra L.	8/25	26	*	42	0
<u>Caryophyllaceae</u>					
Lychnis calcedonica L.	6/22	45	10	1	20
Saponaria officinalis L.	7/13	16	40	3	5
Lychnis alba Mill.	8/26	7	6	34	35

<u>Ranunculaceae</u>					
Aquilegia sp.	6/12	21	20	40	48
<u>Berberidaceae</u>					
Berberis vulgaris L.	9/8	56	38	2	19
<u>Cruciferae</u>					
Sisymbrium officinale (L.) Scop.	6/23	*	21	0	40
<u>Leguminosae</u>					
Baptisia australis (L.) R. Br.	6/26	14	27	34	28
Trifolium pratense L.	6/12	33	*	2	0
Caragana aborescens Lam.	6/12	10	7	96	78
Pisum sativum L.	6/22	3	2	61	52
Medicago sativa L.	7/13	8	8	69	71
Lathyrus latifolius L.	7/14	6	14	60	79
Melilotus alba Desr.	7/19	8	*	4	0
Gymnocladus dioica (L.) Koch	8/3	10	20	85	85
Robinia Pseudo-Acacia L.	8/25	9	*	1	0
Gleditsia triacanthos L.	8/3	6	11	25	22
<u>Oxalidaceae</u>					
Oxalis Acetosella L.	6/22	*	47	0	4
<u>Geraniaceae</u>					
Geranium carolinianum L.	6/9	88	37	13	35
<u>Celastraceae</u>					
Celastrus scandens L.	8/30	6	*	3	0
<u>Malvaceae</u>					
Malva rotundifolia L.	6/22	*	45	0	1
Althaea rosea Cav.	6/29	6	6	73	72
Abutilon Theophrasti Medic	8/3	16	24	7	15
Hibiscus Moscheutos L.	8/3	6	*	69	0
<u>Umbelliferae</u>					
Pastinaca sativa L.	6/30	66	18	3	4
<u>Solanaceae</u>					
Solanum Dulcamara L.	9/14	9	19	70	46
Datura Stramonium L.	9/14	30	17	22	90

<u>Bignoniaceae</u>					
Tecoma radicans (L.) Juss.	9/12	20	4	33	8
<u>Plantaginaceae</u>					
Plantago virginica L.	6/19	30	*	3	0
Plantago lanceolata L.	6/30	8	6	20	33
<u>Caprifoliaceae</u>					
Lonicera ta ta tarica L.	6/20	66	18	2	30
<u>Cucurbitaceae</u>					
Citrullus vulgaris Schrad.	8/26	7	6	18	35
<u>Compositae</u>					
Taraxacum officinale Weber.	5/20	70	*	7	0
Lactuca Scariola L.	6/8	21	9	14	21
Chrysanthemum Leucanthemum L.	6/21	*	42	0	1
Gaillardia sp.	6/22	75	27	2	5
Cent urea grandiflora Hort.	6/28	17	10	28	27
Rudbeckia hirta L.	7/20	*	10	0	22
Zinnia elegans Jacq.	7/24	8	4	23	52
Echinops sphaerocephalus L.	8/8	17	10	8	2
Ar ti um minus Bernh.	8/29	14	9	4	68
Helianthus annuus L.	9/6	*	9	0	40
Average for all species in Table I		22.2	17.8	33.3	40.9

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

Gramineae

Poa pratensis L.

Eragrostis major L.

Cyperaceae

Carex sp.

Carex Frankii Kunth.

Carex sp.

Cyperus strigosus L.

Betulaceae

Ostrya virginiana (Mill.) K.Koch

Polygonaceae

Rumex Acetosella L.

Amaranthaceae

Amaranthus spinosus L.

Amaranthus sp.

Caryophyllaceae

Silene antirrhina L.

Portulacaceae

Portulaca oleracea L.

Cruciferae

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

Saxifragaceae

Ribes nigrum L.

Ribes gracile Michx.

Rosaceae

Agrimonia microcarpa Wallr.

Prunus Cerasus L.

Fragaria virginiana Duchesne.

Prunus hortulana Bailey

Rubus occidentalis L.

Amelanchier canadensis (L.)

Rubus villosus Ait.

Pyrus Malus L. (Medic.)

Prunus Persica (L.) Stokes

Rosa rugosa L.

Physocarpus Opulifolius (L.)

Crataegus sp. (Maxim.)

Leguminosae

Trifolium repens L.

Cercis canadensis L.

Rutaceae

Ptelea trifoliata L.

Zanthoxylum 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.

A review of the foregoing table and list brings out some interesting facts. Probably the most prominent one presented is that some species seem to possess the capacity for prompt germination immediately after ripening while others apparently must have a period of rest before growth will begin. Among the orders ^{the species of} which germinate readily as soon as mature, are found Gramineae, Liliaceae, Caryophyllaceae, Malvaceae and Compositae, while those which tend to have delayed germination include Cyperaceae, Rosaceae, Anacardaceae and Vitaceae. The first plantings (In this discussion, "first planting" always has reference to seeds which were planted immediately after ripening, and "second planting" to seeds which had been air dried for one month before being placed under growing conditions, of Liliaceae and Leguminosae, as a general rule, germinated quicker and gave a higher percentage of germination than the second plantings, but the results from plantings of Compositae and Gramineae were exactly the reverse. These two observations would seem to indicate that the seeds of the various species in an order are similar in some respects.

Of the fifty-eight species which showed ability to germinate, nine gave no results from the planting of mature seeds and nine others none from the planting of the air dry seeds. Twenty-six of the remaining species, however, gave a quicker germination from the second planting than from the first, thus indicating the presence of a rest period. This brings out the fact that the seeds from a majority of the species studied re-

quire an interval of rest after maturity before they will germinate, and also indicates that this interval is shorter one month after maturity than it is at maturity.

The average length of the dormant period following the first planting was 22.2 days while after the second planting it was 17.8 days, thus showing a decrease of 4.4 days.

The fact that seeds germinate more readily after becoming air dry is also brought out by the percentage of germination obtained. Twenty-six species gave a higher total germination from the second planting than from the first, while the reverse was true in only thirteen cases. The average increase in germination due to the later planting was 6.6%.

In nearly every case the higher percentage of germination was correlated with the shorter dormant period. This might indicate that there is some relationship between the length of the dormant period and the percentage of germination.

Second Season's Work. Although the first summer's work had brought out some interesting points, it was desired to further corroborate them by more extended study and with this idea in view the work of the second season was planned. As in the previous work, as large a collection as possible was made of seeds from species in and about Columbia, but the collecting began earlier and was much more extensive.

The seeds were collected as before just as they were mature but all plantings were made in an out-door bed of well drained soil instead of in sand in a greenhouse bench. It had

been impossible to allow the seed of the previous planting to remain undisturbed until the following spring or until all hopes of further germination were gone and hence it was felt that this test had been incomplete. It was planned to allow the new test to proceed until the seeds had either all germinated or decayed. Then, too, it was thought that more natural conditions would be secured and all artificial stimulation avoided by the out-door plantings. The soil used was a mixture of loam and sand and was kept moist by sprinkling when necessary. During the summer months a partial shade was provided by using muslin covers. At the approach of winter a thick mulch was spread over the bed. This mulch was removed before the growing season began in the spring.

The work was also somewhat broadened by the collection and planting of immature seeds. These seeds were taken when they were in the condition spoken of as the "dough stage." For the most part all species used in this way were woody plants and two plantings were usually made, one immediately after collecting and the second one after some of these immature seeds had become air dry.

The work of this season was necessarily abruptly dropped in the latter part of July, on account of illness, and hence the data are not as complete as were hoped for. However, in spite of this, some rather striking points were brought out by the data secured.

Although a planting of the air-dry mature seeds of several species was made, yet the results from these plantings

are not given because they are so few in number and also because, in the main, they bring out the same points as Table No. I.

The germination of the seeds planted when mature naturally classifies them into three groups and for this reason the results of this work are given in three tables. A fourth is used for the seeds planted while still immature. These four tables follow.

Table No. II

Seeds Planted at Maturity, Showing Immediate Germination.

Name of Species	Date Collected	Days Dormant	Total Germination
<u>Gramineae</u>			
Secale cereale L.	7/1	7	29
Triticum vulgare Vill.	7/2	7	30
Avena sativa L.	7/12	24	34
Bromus ciliatus L.	7/13	11	24
Hordeum sativum Jess	7/13	6	36
Lolium perenne L.	7/13	11	37
<u>Liliaceae</u>			
Asparagus officinale L.	7/3	26	46
<u>Urticaceae</u>			
Ulmus scabra Mill	5/9	14	18
" fulva Michx	5/15	17	2
" americana L.	5/9	13	15
Morus alba L.	6/15	17	2
<u>Leguminosae</u>			
Caragana aborescens Lam.	7/2	8	81
<u>Aceraceae</u>			
Acer saccharinum L.	5/15	9	55
<u>Malvaceae</u>			
Althaea rosea Cav.	7/20	4	53
<u>Umbelliferae</u>			
Pastinaca sativa L.	7/6	18	3
<u>Solanaceae</u>			
Solanum Dulcamara L.	7/15	9	51.5
<u>Cucurbitaceae</u>			
Cucumis Melo L.	7/18	6	97
<u>Compositae</u>			
Cent ^a urea grandiflora Hort.	7/5-	19	5.5

Table No. III

Seeds, Planted Immediately After Maturity, Showing
Germination in the Fall, Oct. 30, 1912.

Name of Species	Date Collected	Total Germination
<u>Geraniaceae</u>		
Geranium carolinianum L.	6/8	22.
<u>Rubiaceae</u>		
Galium Aparine L.	6/20	81.
<u>Compositae</u>		
Lactuca Scariola L.	6/21	5.

Table No. IV

Seeds, Planted at Maturity, Showing Germination
in the Following Spring, April 16, 1913.

Name of Species	Date Collected	Total Germination
<u>Gramineae</u>		
Melica mutica Walt.	6/25	25.0
Dactylis glomerata L.	6/27	47.5
Phleum pratense L.	7/13	9.0
Hordeum nodosum L.	6/8	8.5
<u>Commelinaceae</u>		
Tradescantia reflexa Raf.	6/24	7.5
<u>Liliaceae</u>		
Trillium sessile L.	7/1	50.0

<u>Polygonaceae</u>		
Rumex obtusifolius L.	7/2	48.0
" crispus L.	6/19	12.5
<u>Saxifragaceae</u>		
Ribes gracile Michx.	7/5	13.5
<u>Rosaceae</u>		
Prunus hortulana Bailey	7/19	5.0
<u>Leguminosae</u>		
Trifolium pratense L.	6/25	40.0
" repens L.	7/2	57.0
<u>Anacardaceae</u>		
Rhus canadensis Marsh	6/20	5.0
<u>Balsaminaceae</u>		
Impatiens pallida Nutt.	6/22	78.0
" biflora Walt.	7/9	28.0
<u>Violaceae</u>		
Viola pubescens Ait.	6/21	20.8
" papilionacea Pursh.	6/21	65.0
Hybanthus concolor (Forster) Spreng	6/26	27.0
<u>Umbelliferae</u>		
Osmorhiza longistylis (Torr) DC	7/5	40.0
Pimpinella Saxifraga L.	7/12	11.0
<u>Oleaceae</u>		
Fraxinus quadrangulata Michx.	6/25	4.0
<u>Hydrophyllaceae</u>		
Ellisia Nyctella L.	6/8	31.5
<u>Boraginaceae</u>		
Cynoglossum officinale L.	6/28	36.0
<u>Plantaginaceae</u>		
Plantago lanceolata L.	7/14	40.0

<u>Compositae</u>				
Cent ^a urea	grandiflora	Hort.	7/5	23.5
Coreopsis	lanceolata	L.	7/5	10.0
Gaillardia	pulchella	Fouq.	7/5	17.0

Seed from the following species refused to germinate inside of ten months when planted immediately after maturity:

Gramineae

Bromus hordeacus L.

Cyperaceae

Carex Shortiana Dewey
" graviora 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 monspeliensis L.
 Prunus Cerasus L.
 " virginiana L.

Rubus strigosus Michx.
 " occidentalis L.
 " 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.

Table No. V

Seeds Planted While Immature

*No Germination

Name of Species	Days Dormant		Total Germination	
	Green	Mature	Green	Mature
<u>Rosaceae</u>				
<i>Pyrus malus</i> L.	*	57	0	1
<u>Saxifragaceae</u>				
<i>Ribes gracile</i> Michx.	*	200	0	13.5
<u>Leguminosae</u>				
<i>Gymnocladus dioica</i> (L.) Koch.	*	12	0	46
<i>Robinia Pseudo-Acacia</i> L.	6	6	32	25
<i>Caragana aborescens</i> Lam.	14	10	9.5	81
<u>Rhamnaceae</u>				
<i>Rhamnus cathartica</i> L.	*	21	0	56

The following list of species comprises those from which no germination was secured from plantings of either green or mature seeds.

Liliaceae

Polygonatum biflorum (Walt) Ell.

Betulaceae

Ostrya virginiana (Mill) K. Koch

Urticaceae

Celtis occidentalis

Rosaceae

Rosa rugosa Thunb.

Physocarpus opulifolius (L.)
Maxim

Rutaceae

Zanthoxylum americanum Mill.

Ptelea trifoliata L.

Aceraceae

Acer saccharum Marsh.

Oleaceae

Fraxinus americana L.

Tables Nos. II-IV bring out some of the same points shown by Table No. I; that is, that a large number of species will not germinate immediately after maturity and also that the species in a single order show more or less the same characteristics in regard to the time and percentage of germination.

These tables probably also furnish an explanation why no germination was recorded for so many species used during the first season's work. It will be noted that only eighteen species out of forty-eight showing germination were able to germinate immediately after maturity, while twenty-seven were able to grow only after an interval of eight or ten months. During this resting interval they were subjected to the influence of freezing and undoubtedly ^{this} had its effect, but evidently these species must have an extended rest period or some signs of growth would have been noticeable before spring.

Four species showed a capacity for germination in the fall. It is entirely possible that these species may require some definite temperature; that is, a temperature lower than summer heat before they can germinate. Since such a temperature is obtained only during the spring and autumn, may furnish an explanation why no growth was noticed during the summer season.

It is quite clearly shown that green or immature seeds, at least from woody plants, do not germinate nearly so freely or so readily as mature seeds of the same species. In Table No. V the germination of the immature seeds is compared directly with the germination of mature seeds. Although plantings of

air dry immature seeds were made no results were secured from them. Not enough species were used to obtain conclusive results, but green seeds seem to show a longer dormant period and a ^{lower} percentage of germination than mature seeds of the same species.

Work During the Winter of 1912-13

(A.) Seeds of Woody Plants. The principal part of the studies carried on during the winter of 1912-13 was confined to a smaller number of species but the seeds of each were treated in several different ways to test their powers of germination. A review of the tables previously given shows, in a general way, that seeds of woody plants possess the longer dormant period and germinate a lower percentage than herbaceous species. With the belief that woody seeds would present some interesting problems, practically all the seeds used during the remainder of the work were from woody species.

In addition to merely planting the seeds of woody plants in the usual way, some of them were treated by etherizing to find if the rest period could be broken and germination hastened.

The seeds were gathered late in the fall of 1912 and thoroughly dried. They were then stored in card-board boxes on shelves in a basement room where the atmosphere would become neither too hot nor too dry. One planting of each species was made immediately upon collecting, and another about one month

later. At the time of the second planting, another sample was soaked in tap water for three hours and then etherized for twelve hours before planting. Still another sample of dry seeds was etherized for the twenty-four hours just preceding planting.

During the exposure to the influence of ether, the seeds were placed under a bell jar, a sufficient quantity of liquid ether inserted under the jar to allow 1 c.c. of ether for every 25 liters of air space, and the jar sealed to a glass plate by means of vaseline. The temperature usually ranged between 22° C and 25° C.

All plantings were made in a sand bed in the greenhouse, the treated seeds being planted immediately upon removal from the ether fumes. The sand bed was kept thoroughly moist by frequent sprinkling and the greenhouse held at as uniform a temperature and humidity as possible.

Another series of experiments was begun December 17, 191~~2~~³, by stratifying and freezing some seed from each species. These were placed between folds of cheese-cloth and buried in a box of sand. They were left exposed to the varying conditions of out-door temperature until February 7, 191~~3~~³, when they were brought inside. One sample of each species was planted immediately while another sample was etherized for twelve hours, and another for twenty-four hours immediately previous to planting. These plantings were all made in the sand bed under conditions very similar to the previous plantings of the same species.

The results secured from the work with woody seeds are given in Tables Nos. VI-VIII.

Table No. VI

Effects of Various Treatments Designed to Break the
Dormant or Rest Period of Woody Plants.

*No germination up to May 1, 1913.

Name of Species	Treatment of Seed						
	Mature no-treat- ment	Dry no-treat- ment	Soak 3 hrs Ether 12"	Dry Ether 24hrs	Stratified no-treat- ment	Stratified Ether 12 hrs	Stratified Ether 24hrs
<u>Liliaceae</u>							
Canna sp.	34	*	124	105	*	*	*
Smilax rotundifolia L.	34	110	75	109	38	52	37
<u>Rosaceae</u>							
Pyrus Malus L.	57	*	*	*	13	15	10
Crataegus Marshallii Eggleston	*	*	59	*	*	*	*
Rosa carolina L.	150	*	*	*	21	*	*
<u>Leguminosae</u>							
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	*
<u>Anacardaceae</u>							
Rhus glabra L.	*	52	102	113	*	*	30
<u>Celastraceae</u>							
Celastrus scandens L.	*	*	107	*	*	*	*
<u>Aceraceae</u>							
Acer Negundo L.	*	*	70	*	7	7	6
" saccharum Marsh	*	*	*	*	13	*	18
" platanoides L.	*	*	*	*	16	*	*
<u>Rhamnaceae</u>							
Rhamnus cathartica L.	21	62	79	63	*	14	*
<u>Vitaceae</u>							
Ampelopsis quinquefolia Michx.	89	*	117	54	21	18	18
" tricuspidata Sieb. & 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

	47	1	2	3	4	5	6	7
<u>Ebenaceae</u>								
Diospyros virginiana L.		31	45	71	63	37	45	*
<u>Oleaceae</u>								
Ligustrum vulgare L.		*	33	29	31	*	26	*
<u>Solanaceae</u>								
Datura Stramonium <i>L.</i>		10	10	7	10	8	8	8
<u>Bignonaceae</u>								
Tecoma radicans (L.) Juss		23	37	23	21	12	12	10

Table No. VII

Effects of Various Treatments on Percent of Germination
of Woody Seeds.

Name of Species	Treatment of Seed						
	Mature No Treat- ment.	Dry No Treat- ment.	Soak 3 hrs Ether 12 "	Dry Ether 24 "	Stratified No Treat- ment.	Stratified Ether 12 hrs	Stratified Ether 24 "
<u>Liliaceae</u>							
Canna sp.	20	0	6	6	0	0	0
Smilax rotundifolia L.	7	9	7	12	51.4	45.7	48.5
<u>Rosaceae</u>							
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
<u>Leguminosae</u>							
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
<u>Anacardaceae</u>							
Rhus glabra L.	0	2	1	1	0	0	1
<u>Celastraceae</u>							
Celastrus scandens	0	0	1	0	0	0	0
<u>Aceraceae</u>							
Acer Negundo L.	0	0	1	0	76.6	80.0	83.3
" saccharum Marsh	0	0	0	0	15.7	0	21.0
" platanooides L.	0	0	0	0	2.2	0	0
<u>Rhamnaceae</u>							
Rhamnus cathartica L.	56	17	12	11	0	9	0
<u>Vitaceae</u>							
Ampelopsis quinquefolia Michx	1.5	4	5	3	49	68	52
" tricuspidata Sieb. & Zucc.	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

	1	2	3	4	5	6	7
<u>Ebenaceae</u>							
Diospyros virginiana L.	1	52	37	51	11.7	17.6	0
<u>Oleaceae</u>							
Ligustrum vulgare L.	0	13	27	16	0	2	0
<u>Solanaceae</u>							
Datura Stramonium L.	53	53	46	42	65	100	90
<u>Bignonaceae</u>							
Tecoma radicans (L.) Juss	11	47	65	54	69	86	77

Table No. VIII

Summary of Tables Nos. VI - VII.

Effects of Treatments on Seed Germination	Treatments			
	Soak 3 hrs Ether 12 hrs	Dry Ether 24 hrs	Stratified Ether 12 hrs	Stratified Ether 24 hrs
No. of species showing shortened dormant period	8	7	5	8
" " " " prolonged " "	3	4	4	2
" " " " uninfluenced " "	0	0	2	1
" " " " increased germination	5	4	9	8
" " " " decreased "	6	8	1	2
" " " " no influence on "	1	0	1	1
" " " in which germination was induced	6	3	3	1
" " " " " " prevented	0	0	4	4

Table No. VIII (cont.)

	Treatment					
	Dry No Treat- ment	Soak 3 hrs Ether 12 "	Dry Ether 24 hrs	Stratified No Treat- ment	Stratified Ether 12 hrs	Stratified Ether 24 hrs
Average length of dormant period	52.6	45.3	54.8	22.0	22.7	20.7
" percentage of germination	20.2	23.1	20.7	51.6	61.9	55.0

The following list of species used during the winter of 1912-13 gave no germination under any of the treatments:

Betulaceae

Ostrya virginiana L.

Carpinus caroliniana L.

Rosaceae

Prunus Persica (L.) Stokes
Crataegus coccinea L.

Pyrus Scheideckeri Hort.
" *fastigiata bifers* Hort.

Leguminosae

Robinia Pseudo-Acacia L.

Rutaceae

Ptelea trifoliata L.

Celastraceae

Evonymus atropurpureus Jacq.

Cornaceae

Cornus asperifolia Michx.

Caprifoliaceae

Symphoricarpos vulgaris Michx

The results of the various treatments on the dormant period and the germination of seeds of woody species may be briefly summarized as follows:

With the unstratified seeds, the twelve hour exposure of soaked seeds to the influence of ether shortened the dormant period in nine species out of twelve. The average decrease was 7.3 days. Etherization induced germination in six species where the check planting refused to germinate but in no case was germination prevented. In six species out of twelve, however, the percentage of germination was decreased by this treatment but the average of all percentages shows an increase of 3.4% in favor of etherization.

The twenty-four hour exposure of dry unstratified seeds to ether fumes showed a shortening of the rest period in seven out of twelve species and a slight average decrease in the percentage of germination. Germination was induced in ^{two} ~~three~~ species and prevented in none.

Stratified seeds etherized twelve hours gave a decrease in the length of the dormant period in some cases and an increase in others. However, the percentage of germination was very markedly increased, the average increase being 10.3%. Germination was induced in three species and prevented in four.

The twenty-four hour exposure of stratified seeds to ether gave a decrease in the dormant period in eight cases out of eleven, and gave an average increased germination of 3.4%. Germination was prevented in four species and induced in only one.

The general conclusions to be drawn from this winter's work are: Stratified seeds germinate much more readily and also a higher percentage than the unstratified ones. The effect of the ether is much more marked on stratified than on unstratified seeds. The general tendency of the etherization seems to be toward reducing the dormant period and increasing the germination but different species respond to this treatment differently. The twelve hour treatment seems to be more effective than the twenty-four hour dose, both in reducing the dormant period and increasing the germination, although here again different species vary considerably. In several cases the twenty-four hour exposure was apparently too long, for, although the percentage of germination was still increased above the check, yet it was lower than from the twelve hour treatment

(B) Seeds of Vegetables---It was seen early in the winter that only a comparatively low percentage of the woody seeds would germinate, and hence work was taken up with vegetable seeds. The seeds used were those of common vegetables which had been purchased previously from a commercial seed house and kept in ordinary storage.

The treatments used were (1) Etherization for twelve or twenty-four hour periods; (2) Freezing for twenty-four hours; (3) Soaking for three or six hours; and (4) A combination of two or more of these treatments. Whenever the etherization was used it was the last treatment preceding planting. The amount of ether and the method of etherizing employed were the same as

those used in the earlier work. The freezing was done with a salt and ice mixture, the temperature being kept at from -5 to -10° C. 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 between sheets of filter paper in wooden plates. These plates were kept in an enclosed space in the greenhouse at a temperature of approximately 22° C. although at times the temperature varied considerably from this.

The data taken show the total germination of each sample at the end of each day for one week after the seeds were placed under conditions favorable for growth, and also the final grand total germination. These data are given in the following tables.

Table No. IX

Effects of Various Treatments on the Germination of

Zea Mays L.

Condition and Treatment	Percent of Germination by Days							Total Germination
	1	2	3	4	5	6	7	
Dry-Check				18	60	68	68	68 -
Ether 12 hrs.				41	78	91	91	92
" 24 "				58	94	97	97	97
Frozen 24 "			40	74	100	100	100	100 -
" Ether 12			14	48	92	92	92	92
" " 24			12	78	96	98	98	98
" Soak 3 hrs.				50	60	60	60	64 -
" " Ether 12		8	67	95	98	98	98	99
" " " 24			16	80	96	97	97	97
" Soak 6 hrs.				48	74	74	78	80 -
" " Ether 12		10	50	92	98	98	98	98
" " " 24			18	78	98	98	100	100
Soak 3 hrs. Check				50	60	60	60	64 -
Ether 12 hrs.		12	80	90	98	100	100	100
" 24 "					46	70	90	94
Frozen 24		4	16	18	22	24	30	30
" Ether 12				22	30	38	40	40
" " 24			12	22	28	30	30	30
Soak 6 hrs. Check				48	74	74	78	80 -
Ether 12 hrs.		2	36	74	88	88	88	88
" 24 "				32	84	98	100	100
Frozen 24 hrs.		4	8	12	12	14	16	16
" Ether 12			4	12	20	22	22	22
" " 24			4	4	6	6	10	10

Table No. X

Effects of Various Treatments on the Germination of

Phaseolus lunatus L. var. Macrocarpus, Benth.

Condition & Treatment	Percent of Germination by Days							Total Germina- tion
	1	2	3	4	5	6	7	
Dry - Check			4	18	38	42	54	84
Ether 12 hrs.			19	39	53	54	55	71
" 24 "			25	52	58	62	66	75
Frozen 24 "		2	10	14	22	22	22	42 ⁴
" Ether 12			12	28	32	34	40	60
" " 24			12	22	42	56	58	84
" Soak 3 hrs.		10	24	40	48	48	50	88 ⁷
" " Ether 12	2	6	14	36	58	62	70	82
" " " 24			18	36	50	62	72	90 ⁹
Soak 6 hrs.		20	28	54	58	62	62	70
" " Ether 12	12	24	38	52	56	56	58	74
" " " 24	2	4	20	36	56	66	78	96
Soak 3 hrs Check				44	52	56	62	78
Ether 12	5	8	25	45	64	69	71	95
" 24		3	25	49	55	59	63	82
Frozen 24		2	4	22	24	30	38	50
" Ether 12				12	24	34	38	40 ¹⁷
" " 24			2	14	24	36	46	54
Soak 6 hrs. Check			12	40	54	56	66	82
Ether 12	4	8	20	32	44	56	66	86
" 24			12	44	54	58	60	86
Frozen 24		2	8	14	20	22	24	26 ²²
" Ether 12			2	4	20	28	40	46 ²
" " 24				12	16	20	24	30

Table No. XI

Effects of Various Treatments on the Germination of
Phaseolus vulgaris L.

Condition and Treatment	Percent of Germination by Days							Total Germina- tion
	1	2	3	4	5	6	7	
Dry - Check				2	2	2	6	10
Ether 12 hrs				1	2	4	4	4
" 24 "				2	3	8	8	11
Frozen 24				2	4	8	8	8
" Ether 12					2	2	6	6
" " 24					2	2	2	6
" Soak 3			2	4	4	6	6	6
" " Ether 12				4	8	12	24	26
" " " 24			2	4	8	10	10	12
" Soak 6		2	2	8	12	14	16	18
" " Ether 12					4	6	8	12
" " " 24					2	10	10	12
Soak 3 hrs. Check			2	6	10	10	10	12
Ether 12				4	7	12	13	15
" 24					2	9	10	11
Frozen 24				8	8	8	8	8
" Ether 12				4	6	16	18	18
" " 24			6	12	14	16	22	22
Soak 6 hrs. Check				2	8	12	12	16
Ether 12				2	2	6	12	12
" 24			2	6	6	6	8	12
Frozen 24			6	6	10	14	14	16
" Ether 12				4	10	14	14	14
" " 24			2	2	4	6	10	10

Table No. XII

Effects of Various Treatments on the Germination of

Citrullus vulgaris Schrad.

Condition & Treatment	Percent of Germination by Days							Total Germina- tion
	1	2	3	4	5	6	7	
Dry - Check								82
Ether 12 hrs.								77
" 24 "							1	66
Frozen 24 hrs.							2	62
" Ether 12					2	28	60	84
" " 24					4	12	24	72
" Soak 3							2	82
" " Ether 12					2	8	50	74
" " " 24					8	20	52	86
" Soak 6					2	16	38	78
" " Ether 12					2	28	52	78
" " " 24				2	2	18	60	82
Soak 3, Check								76
Ether 12 hrs.							4	52
" 24 "						2	6	25
Frozen 24 hrs.								0
" Ether 12								2
" " 24								0
Soak 6 hrs. Check								48
Ether 12						6	48	82
" 24								82
Frozen 24								0
" Ether 12								0
" " 24								0

Table No. XIII

Effects of Various Treatments on the Germination of
Cucurbita maxima Duchesne.

Condition & Treatment	Percent of Germination by Days							Total Germina- tion
	1	2	3	4	5	6	7	
Dry - Check					12	16	28	40
Ether 12				4	20	29	29	62
" 24				4	11	19	28	53
Frozen 24				6	20	26	46	68
" Ether 12					30	50	64	66
" " 24				10	30	50	70	74
" Soak 3				4	14	28	54	72
" " Ether 12				20	38	52	52	54
" " " 24			6	20	48	66	70	76
" Soak 6			10	22	38	56	62	74
" " Ether 12				6	32	54	68	74
" " " 24				18	38	50	52	58
Soak 3 hrs. Check					4	8	22	88
Ether 12			5	20	47	64	66	96
" 24		2	10	27	44	49	54	77
Frozen 24 hrs.			4	16	28	36	38	40
" Ether 12				14	36	36	38	54
" " 24			10	24	30	36	40	42
Soak 6 hrs. Check						12	22	60
Ether 12			2	6	28	54	64	66
" 24					12	22	34	66
Frozen 24				4	10	14	14	14
" Ether 12				8	16	20	20	24
" " 24			10	10	18	18	20	22

Table No. XIV

Effects of Various Treatments on the Germination of
Spinacia oleracea L.

Condition & Treatment	Percent of Germination by Days							Total Germina- tion
	1	2	3	4	5	6	7	
Dry - Check			6	6	22	46	58	88
Ether 12		4	17	29	39	54	54	74
" 24			23	43	51	51	56	69
Frozen 24 hrs.			2	20	48	66	66	76
" Ether 12		2	12	44	66	70	72	90
" " 24			18	44	66	66	70	82
" Soak 3		2	6	22	54	62	64	66
" " Ether 12			10	50	60	64	72	78
" " " 24			24	50	58	62	62	74
" Soak 6			10	20	42	44	50	60
" " Ether 12		8	20	56	66	74	74	80
" " " 24			24	42	48	54	58	66
Soak 3 Check		2	24	26	54	66	74	84
Ether 12	11	24	50	60	68	74	74	95
" 24	13	33	49	68	71	77	79	89
Frozen 24 hrs.			4	10	12	12	14	18
" Ether 12	2	10	14	36	46	48	48	54
" " 24			8	24	40	40	50	66
Soak 6 Check		4	4	14	36	46	60	72
Ether 12	6	22	38	58	66	70	74	86
" 24			18	36	54	70	80	86
Frozen 24		2	6	10	16	16	18	22
" Ether 12		8	16	34	34	34	46	56
" " 24			4	12	28	34	34	52

Table No. XV

Effect of Various Treatments on the Germination of

Raphanus sativus L.

Condition & Treatment	Percent of Germination by Days							Total Germina- tion
	1	2	3	4	5	6	7	
Dry - Check	14	62	70	80	80	80	80	80
Ether 12		40	58	74	76	78	82	82
" 24		4	36	44	48	50	50	56
Frozen 24		64	68	76	76	76	76	76
" Ether 12	16	58	68	74	82	82	82	86
" " 24	12	66	76	80	84	84	86	86
" Soak 3 hrs.		20	48	76	76	84	86	88
" " Ether 12	20	68	68	74	74	76	76	80
" " " 24	16	66	74	76	76	82	82-	82
" Soak 6 hrs.		28	60	76	76	82	84	86
" " Ether 12	50	72	78	78	78	80	80	80
" " " 24	42	72	78	84	84	84	84	88
Soak 3 hrs. Check		42	78	84	84	84	88	88
Ether 12		60	86	90	90	92	92	92
" 24		24	74	80	82	82	84	86
Frozen 24 hrs.	10	28	38	38	42	42	42	44
" Ether 12	8	48	78	80	86	88	88	90
" " 24			14	20	30	30	30	44
Soak 6 hrs. Check		42	76	82	88	90	92	96
Ether 12	54	84	84	84	84	84	88	88
" 24		36	58	70	72	72	78	78
Frozen 24 hrs.	2	30	38	40	46	46	46	50
" Ether 12	6	38	70	78	80	82	82	88
" " 24			18	28	34	38	38	44

Table No. XVI

Effects of Various Treatments on the Germination of

Hibiscus esculentus L.

Condition & Treatment	Percent of Germination by Days							Total Germina- tion.
	1	2	3	4	5	6	7	
Dry - Check				4	4	10	10	18
Ether 12			4	14	20	21	21	25
" 24			7	15	17	17	17	20
Frozen 24				6	12	12	12	18
" Ether 12	2	4	6	6	10	10	10	18
" " 24				8	10	10	10	12
" Soak 3 hrs.					2	2	2	2
" " Ether 12				6	6	6	6	6
" " " 24					4	6	8	10
" Soak 6 hrs.								2
" " Ether 12				2	4	6	10	12
" " " 24				6	10	10	10	16
Soak 3 hrs. Check								4
Ether 12		3	9	27	27	27	27	29
" 24		3	27	37	38	38	38	41
Frozen 24		4	6	10	12	12	12	14
" Ether 12	2	10	14	22	22	22	22	24
" " 24			4	12	12	14	14	14
Soak 6 hrs. Check						4	6	6
Ether 12	4	4	10	18	20	22	26	26
" 24				6	8	12	16	20
Frozen 24		8	8	8	8	8	8	10
" Ether 12		4	8	16	26	26	26	26
" " 24			4	8	8	8	8	10

Table No. XVII

Effects of Various Treatments on the Germination of

Allium Cepa L.

Condition & Treatment	Percent of Germination by Days							Total Germina- tion
	1	2	3	4	5	6	7	
Dry - Check		2	2	2	2	14	28	62 -
Ether 12		2	5	8	15	19	20	40
" 24			4	23	37	40	43	62 - 3
Frozen 24				4	14	24	34	66 - 6
" Ether 12			2	10	16	24	28	40
" " 24	4	4	10	18	22	28	32	38
" Soak 3			8	8	14	16	20	30 -
" " Ether 12		8	16	16	28	34	46	52
" " " 24				10	18	30	32	40
" Soak 6			4	4	16	18	20	40 -
" " Ether 12		2	2	10	20	32	42	52
" " " 24			2	10	18	22	22	26
Soak 3 hrs. Check		2	2	2	2	10	24	50 -
Ether 12		3	7	28	40	49	53	63 14
" 24		4	14	30	38	41	44	63 15
Frozen 24	6	10	12	12	12	12	12	18 - 18
" Ether 12			4	8	8	8	16	26 +7
" " 24				2	12	16	18	22
Soak 6 hrs. Check		2	2	2	6	8	26	46 -
Ether 12		2	6	6	18	32	40	56 20
" 24			2	2	2	8	18	46 21
Frozen 24	2	6	14	16	18	26	32	38 - 22
" Ether 12	4	6	10	12	12	14	22	32
" " 24				2	6	14	20	24

Table No. XVIII

Summary of Tables Nos. IX to XVII

Condition and Treatment	Table No.									Average %
	IX	X	XI	XII	XIII	XIV	XV	XVI	XVII	
Dry Check	68	84	10	82	40	88	80	18	62	59.1
Ether 12	92	71	4	77	62	74	82	25	40	58.5
" 24	97	75	11	66	53	69	56	20	62	56.5
Frozen 24	100	42	8	62	68	76	76	18	66	57.3
" Ether 12	92	60	6	84	66	90	86	18	40	60.2
" " 24	98	84	6	72	74	82	86	12	38	61.3
" Soak 3	64	88	6	82	72	66	88	2	30	55.3
" " Ether 12	99	82	26	74	54	78	80	6	52	61.2
" " " 24	97	90	12	86	76	74	82	10	40	63.0
" Soak 6	80	70	18	78	74	60	86	2	40	56.4
" " " Ether 12	98	74	12	78	74	80	80	12	52	62.2
" " " " 24	100	96	12	82	58	66	88	16	26	60.4
Soak 3 hrs. Check	64	78	12	76	88	84	88	4	50	60.4
Ether 12	100	95	15	52	96	95	92	29	63	70.7
" 24	94	82	11	25	77	89	86	41	63	63.1
Frozen 24	30	50	8	0	40	18	44	14	18	24.6
" Ether 12	40	40	18	2	54	54	90	24	26	38.6
" " 24	30	54	22	0	42	66	44	14	22	32.6
Soak 6 hrs. Check	80	82	16	48	60	72	96	6	46	56.2
Ether 12	88	86	12	82	66	86	88	26	56	65.5
" 24	100	86	12	82	66	86	78	20	46	64.0
Frozen 24	16	26	16	0	14	22	50	10	36	21.3
" Ether 12	22	46	14	0	24	56	88	26	32	34.2
" " 24	10	30	10	0	22	52	44	10	24	22.4
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 hr. 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 hr. Treatments	78.2	74.6	12.0	51.6	58.5	73.0	70.2	17.8	37.6	52.6

An analysis of the ten preceding tables shows that etherization of old dry seeds has but little effect on their germination and, in some cases, a detrimental effect on the total germination is observed.

Freezing dry seeds apparently has but little effect on either the time or the percentage of germination. A twelve hour exposure to ether after the freezing process, however, will quite materially hasten the germination of some species but in others no difference occurs. The twenty-four hour exposure is not so effective in stimulating germination as the shorter treatment.

Seeds which have been frozen and then soaked for three hours will generally have a hastened growth, but if the soaked seeds are etherized for twelve hours before planting a marked difference is observed. Quick germination has been materially stimulated and a higher germination occurs. The twenty-four hour treatment gives practically the same results as the shorter exposure.

Soaking the frozen dry seeds for six hours has nearly the same effect as soaking for three hours. However, the twelve hour exposure of such seeds to ether gave a higher average total germination than did the ones which were treated for twenty-four hours. This may perhaps be explained on the theory that growth had already begun in seeds which had been soaked six hours and that a twenty-four hour ether exposure was harmful to active protoplasm.

Soaking dry seeds for three hours has a tendency to produce quickened germination but a twelve-hour exposure to ether

in addition to the soaking, will hasten it still more in many cases. Hastened germination was secured in seven cases out of nine in which the last treatment was used. A twenty-four hour period of etherization also seems to hasten germination but the percentage of germination is not so materially increased as with the preceding treatment.

Seeds which had been 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 treatments apparently stimulated a higher percentage of germination and in a majority of cases the twelve hour exposure induced quicker growth.

Seeds soaked six hours do not show much advantage in either the time or amount of germination over those soaked only three hours. However, etherization of such seeds tends to hasten the germination and also raise the percentage of germination. The twelve hour treatment is more effective than the longer exposure.

Seeds soaked six hours and then frozen are badly damaged by such treatment but etherization, especially for the twelve-hour period, seems to have the power of causing a greatly increased percentage of germination. The twenty-four hour treatment seems to be of very little advantage in this case.

A summary of all the treatments in every table shows that the average percentage of germinations for ALL check plantings was 47.8%; for ALL plantings after a twelve-hour ether treatment 56.3%, and for ALL ~~after~~ the twenty-four hour etherization

52.6%. The check planting germinated in twenty-nine cases on the first day on which germination was recorded for that series (that is, the check, 12 hour and 24 hour ether treatments), the twelve-hour exposure in forty-seven cases and the twenty-four hour treatment in only thirty cases. The twelve-hour treatment, when compared with the check, gave a hastened germination in thirty-six cases and retarded it in only eighteen while the twenty-four hour exposure hastened it in twenty-five cases and retarded it in twenty-four.

SUMMARY

First year's work.

First:--Seeds have a rest period or period when they will not germinate even when placed under ideal growing conditions.

Second:--The rest period of seeds seems to begin as soon as they are ripe or mature.

Third:--Seeds that were air-dried for one month and then planted, germinated 4.4 days quicker than those which were planted immediately after ripening.

Fourth:--Air-dried seeds also gave a higher percentage (6.6%) of germination than the ones planted just after maturity.

Fifth:--Just how long the rest period of seeds lasts was not determined but it probably varies greatly with the different species.

Sixth:--The various species of a single order seem to behave more or less alike in regard to the time and percentage of germination.

Second Season's work.

First:--The rest period of the seeds of some species is very much more extended than that of others.

Second:--Many species, which do not show germination immediately after maturity, will germinate if given sufficient time. (That is, they probably pass through their rest period before sprouting).

Third:--Those species which did not germinate until spring may have been affected by freezing.

Fourth:--A few species which did not grow in summer, did germinate in the autumn.

Fifth:--Green or immature seeds, at least of woody plants, usually do not germinate as readily as mature seeds of the same species.

Work during Winter of 1912-13.

(a) Seeds of Woody Plants.

First:--A twelve hour ether treatment of dry seeds hastened germination on the average 7.3 days and increased the germination 3.4%.

Second:--A similar twenty-four hour exposure to ether fumes hastened germination in a majority of cases but exerted only a small influence on the per cent.

Third:--Ether treatment seems to induce germination in some species.

Fourth:--Stratified seeds of practically all the species used germinated more quickly and gave a higher percentage.

Fifth:--The effect of ether on stratified seeds is much greater than it is on dry seeds.

Sixth:--Ether/seemingly prevented germination in some species.

Seventh:--A twenty-four hour exposure to ether does not seem to be as effective as a twelve-hour expos-

ure for stimulating germination.

Eighth:--Different species react differently to the various treatments used.

(b) Seeds of Vegetables.

First:--Etherization stimulates early germination of seeds but its effect varies with the different species.

Second:--Soaked or moist seed are more readily affected by ether than dry ones.

Third:--A twelve hour exposure to an ether atmosphere seems to be more effective in promoting hastened and increased germination than the longer treatment.

Fourth:--Rapid freezing does not greatly affect dry seeds but it seriously damages the germinating power of many species if the seeds have been previously soaked.

Fifth:--Etherization of frozen seeds seems to increase the total percentage of germination and in some cases hastens germination.

General Conclusions.

1. Seeds do have a rest period, evidenced by the fact that many species which will not grow immediately after maturity, will germinate after they have been dried, subjected to various treatments, or allowed to lie in the ground all winter.

2. The length and intensity of the rest period varies with different species but all the species of a single order seem to be more or less similar in these respects.

3. Seeds which have been air-dried for one month will germinate on the average more quickly and with a higher percentage than the freshly gathered mature seeds, but it was not determined whether this was due to the desiccation or to some other factor or factors.

4. Stratified seeds as a general rule germinate more readily and with a higher percentage than seeds not so treated.

5. Etherization tends to stimulate seeds into an early growth and it also tends to increase the percentage of total germination. Soaked or stratified seeds are more strongly affected by ether treatments than dry seeds. A twelve hour exposure to ether is more favorable for germination than the twenty-four hour exposure.

6. Not all species respond in the same way nor to the same extent to treatments with ether.

7. Rapid freezing more seriously affects moist or soaked seeds than dry ones.

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