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STUDIES OF FRUIT SEED STORAGE AND GERMINATION

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SUMMARY

It is a common opinion that seeds of the hardy fruits must be frozen before they will germinate, and practices of storage and stratification are frequently based thereon. The results here reported show this idea to be erroneous.

Seeds that do not germinate immediately after they reach maturity, that is, seeds which have a rest period, or period of dormancy, are said to be controlled by one or both of two factors, viz., (1) external, in which the seed coat plays the important part, and (2) internal, in which the condition of the embryo is of chief importance.

These studies indicate that in the case of the peach the factors involved are primarily internal, and that peach seeds fail to germinate unless they have completed their after-ripening processes. These processes were hastened by a temperature slightly above freezing and in the presence of moisture, after which the germinating and expanding embryo generally overcame the breaking strength of the confining stone and split it open. Freezing did not necessarily crack the stone, but temperatures much below freezing were actually harmful to the vitality of the seed. Stones which had been dried, cracked more readily than those which had not.

Cherry seed responded to treatment similar to which the peach reacted, the chief difficulty being, however, in securing viable seed. Sour cherry seed was more viable than that of either the sweet or Duke cherry, tho in some cases sour cherry seed ran as high as 100 per cent abortive.

Prunus munsoniana, the Wild Goose plum, also responded to the treatment which gave good results with the peach, but ***Prunus domestica***, the European plum, failed to respond to any conditions provided.

Apple seed gave a 100 per cent germination test after subjection to eight weeks of cool, moist conditions, and pear seed gave a similar test after two to four weeks.

In the case of seed of *Rubus* (brambles) and *Ribes* (currants and gooseberries), a combination of internal and external factors was encountered. Gooseberry seed alone germinated readily after subjection to cool, moist conditions. Treatment with sulfuric acid increased the percentage of germination in all cases excepting in that of the gooseberry, the latter being killed by a 15-minute immersion. Blackberry seed, on the other hand, increased in percentage of germination after a four-hour treatment. Seed that was permitted to dry out after removal from storage failed to respond to acid treatment. The wide variation exhibited between varieties and species in their reaction to the acid treatment makes a recommendation regarding the use of acid inadvisable.

INTRODUCTION

A knowledge of the best conditions for the storage and germination of seed of the hardy fruits is of importance (1) to the nurseryman or professional plant propagator, (2) to the plant breeder, and (3) to the amateur gardener. It is of financial interest to the nurseryman to know how to handle the seed at harvest, how to store it, and what conditions to provide in order to produce the best stand of seedling trees. In the case of the plant breeder, the value of such knowledge cannot be easily stated in dollars and cents, for one ungerminated seed may contain a potential tree of inestimable value. The amateur needs to be included among those to whom information of this kind is important not alone because of the satisfaction that he may derive from increased knowledge, but because amateurs have played no small part in increasing the world's store of valuable plant materials.

SEEDAGE IN GENERAL

Frequent statements may be found that seeds of the hardy fruits must be frozen before they will germinate. In the case of peach seed,[1] it is the general impression that freezing cracks the pit. The common practice in the storage of these seeds is to stratify them, that is, to mix with sand or soil and place them where they may be acted upon by frost, as in boxes buried out of doors. It is an interesting fact, however, that in the South where frost is of but rare occurrence special effort is made to keep the peach pits wet, when they crack and germinate successfully.

[1]Gould, H. P. Peach-Growing. *New York: Macmillan Co. XXI+426 pp. 1918.*

The object in stratification has been to subject the seeds to conditions which would result in the cracking of the stone or hard seed coat or the breaking-up of the so-called rest-period. The theory has been that, in the case of the stone fruits, a freezing temperature would do this. Now seed of corn and wheat germinates readily immediately, or almost as soon as, it is mature. In fact, tomato[2] seed will germinate tho gathered in an immature condition. Frequently with hard or "stoney" seed the germination is delayed.[3] The nature of the rest period or period of dormancy is: (1) External, in which the seed coat plays the important part, and (2) internal, in which the condition of the embryo is the leading factor.

EXTERNAL FACTORS

The external factors are many. In some cases it is a seed coat that prevents the entry of water[4] necessary for germination; in others, perhaps a seed coat that excludes oxygen;[5] while in still others, a seed coat whose breaking strength is greater than the outward pressure of the confined embryo.[6] In most cases of this nature the methods of destroying dormancy are mechanical, such as abrasion of the seed coat with sandpaper or carbonization with sulfuric acid. In fact, treatments with acid, alkali, and hot water may also be classed as mechanical insofar as they alter the colloidal nature of the seed coat, just as the strength of leather, paper, and similar organic materials of a collodial nature is decreased by absorption of water so seed coats may lose their confining power thru treatments aimed at changes in their colloidal nature which will increase water absorption.[7]

INTERNAL FACTORS

The internal factors, which hold a seed in a state of dormancy even tho optimum conditions of light, heat, moisture, and oxygen have been provided, are less easily understood and may often be masked by external factors. Even tho the seed coats of *Crataegus*

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[2]Goff, E. S. The effects of continued use of immature seed. *Wisconsin Agr. Exp. Sta. Ann. Rpt.* **17**, *295. 1900.*

[3]Howard, W. L. An experimental study of the rest period in plants: Seeds. Fourth Report. *Missouri Agr. Exp. Sta. Res. Bul. No. 17. 1915.*

[4]Love, H. H. and Leighty, C. E. Germination of seed as affected by sulphuric acid treatment. *Cornell Univ. Agr. Exp. Sta. Bul. No. 312. 1912.*

[5]Crocker, William. Rôle of seed coats in delayed germination. *Bot. Gaz.* **42**, *265. 1906.*

[6]Crocker, William and Davis, W. E. Delayed germination in seed of *Alisima Plantago. Bot. Gaz.* **58**, *285. 1914.*

[7]Crocker, William. Mechanics of dormancy. *Amer. Jour. Bot.* **3**, *99. 1916.*

mollis[8] are removed and the naked seed placed in optimum conditions for germination, the seed will not germinate unless certain changes[9] have occurred within the embryo. The process by which dormancy due to such a cause is destroyed is termed the *after-ripening process*, and it is retarded or hastened by such conditions as temperature and moisture.

Among the seed of most hardy fruits the factors involved in delayed germination are internal and therefore conditions of storage which hasten after-ripening become of primary importance. Factors of strong seed coats[10] or seed coats impervious to water may be of secondary importance in germination of seed of some species of hardy fruit, but in the main, after-ripening is the first consideration.

PROCEDURE

In the summer of 1921, seed from the following representative fruits was collected: Ancient Briton blackberry; Lucretia dewberry; Wineberry; Newman No. 23 and Buckeye red raspberry; a seedling purple-cane raspberry; Houghton, Poorman, and a European type of gooseberry; Boskoop Giant black currant; North Star red currant; White Dutch white currant; Riga cherry, representing *Prunus cerasus*, Morello type; Montmorency cherry, representing *Prunus cerasus*, Amarelle type; Olivet cherry, representing *P. cerasus* x *P. avium*, Duke type; Schmidt Bigarreau cherry, representing *P. avium;* Wild Goose plum, representing *P. munsoniana*; Shropshire plum, representing *P. insititia*; Palatine plum, representing *P. domestica*; Rhode Island Greening and Hubbardston apple; and Gold Nugget pear.

The seeds of the small fruits were separated from the pulp by maceration, drying the seeds on blotting paper. Seeds of the orchard fruits were removed by cutting away flesh. Excepting where otherwise noted, all seeds were placed indoors at room temperature before being subjected to the different treatments.

STUDIES IN STRATIFICATION AND STORAGE

STUDIES WITH PEACH SEED

Common methods of handling peach seed.—Nurserymen secure peach

[8]Davis, W. E. and Rose, R. E. The effect of external conditions upon the after-ripening of the seeds of *Crataegus mollis*. *Bot. Gaz.* **54**, *49*. *1912*.

[9]Eckerson, Sophia. A physiological and chemical study of after-ripening. *Bot. Gaz.* **55**, *286*. *1913*.

[10]Rose, R. C. After-ripening and germination of seeds of *Tilia*, *Sambucus*, and *Rubus*. *Bot. Gaz.* **67**, *281*. *1919*.

pits for the propagation of seedling stocks from canning factories and from wild seedlings in the southern Appalachian Mountains. Pits from the latter source are especially esteemed because of their small and uniform size and because of the vigor and uniformity of the seedlings that they produce. They are gathered from here and there in the fall and collected at central points from which seedsmen or nurserymen secure them. Two-year-old pits, that is, pits produced two seasons previous, are preferred.

Until recently it has been the practice to stratify the pits during the autumn or summer season. They are mixed with sand in a bed about 2 to 2½ feet deep, 6 feet wide, and as long as necessary, and are covered with 3 or 4 inches of sand. The next spring the pits are dug and sifted to separate the cracked from the uncracked, when those still intact are cracked by hand. It was no uncommon sight in a nursery region to see a dozen youngsters busily engaged in cracking by hand the pits that had not opened during the winter.

In recent years, however, the practice in general use in the North is to plant the pits in rows in the fall about 1½ or 2 inches deep, ridging them so that they would be covered with about 3 inches of soil, the ridges being leveled again in the spring. It is interesting to note that in the South, where the winters are mild, the pits are still frequently bedded, pains being taken to have them kept moist. They then crack in January or February, often without any freezing. If the pits are planted out in rows in the fall, they are said to germinate in part the first year and in part the second, so that two successive lots of seedlings are secured from the one planting.

Attempts to germinate new seed.—The fact that the cracking of the pit appears necessary to the germination of the seed, suggested the removal of the seed from the pit and placement under conditions favorable for germination. Accordingly kernels of Chili which had been stored dry at room temperature since removal from the flesh were placed in a Hottes Germinator[11] consisting of a flat rectangular pan with sliding cover containing six square plaster of paris blocks in contact with water. Immediately, the seeds apparently took up

[11]The Hottes Germinator is of the type devised by Dr. C. F. Hottes, Professor of Plant Physiology at the University of Illinois. It is ideal for seed studies in several respects. It is rodent poof, easy to handle, and affords excellent opportunity to watch development of the seeds without disturbing them. Moreover, high relative humidity is maintained, and the blocks may be kept relatively free from molds and fungi by washing. A novice should not attempt to make his own plaster blocks because they are almost certain to be of varying composition and hence result in ununiform water absorption.

water, but no germination resulted. In fact, the seeds were kept under conditions favorable to germination for 11 months, yet failed to germinate. That they were in a healthy and viable condition during this period is evident, since by subsequent treatment they were made to germinate.

Absorption of water by unstratified kernels.—The seeds were supplied with abundance of moisture as shown by the fact that garden seed placed beside them germinated in high percentage. Moreover, peach kernels from a similar lot were weighed before and after being on moist plaster blocks and also after being immersed in water for a period of five days, with the results shown in Table 1.

TABLE 1.—ABSORPTION OF WATER BY PEACH KERNELS.

NUMBER OF SEEDS	TREATMENT	DURATION	ORIGINAL WT.	FINAL WT.	GAIN OR LOSS	GAIN OR LOSS
		Days	*Grams*	*Grams*	*Grams*	*Per cent*
10	On plaster blocks......	5	2.882	3.832	+0.950	+32.9
10	Immersed in water at 60° F..............	5	2.789	4.407	+1.618	+58.0
10	In drying oven at 250° F.................	5	2.763	2.620	—0.143	—5.1

Thus it is seen that water was absorbed to the extent of approximately one-third or one-half of the weight of the kernels and yet they, too, failed to germinate.

Permeability of pits to water.—There was still the possibility that irregular germination might be due to the exclusion of moisture from the enclosed embryo by the stone itself, the latter being impervious to water and the embryo being therefore unable to secure moisture until the stone was cracked. To determine this point both vertical and horizontal cross sections of Chili stones were placed in contact with water, some of the sections being paraffined inside, some outside, and some having the cut edges alone paraffined. The results are shown in Table 2.

TABLE 2.—PERMEABILITY OF PEACH PITS TO WATER.

TREATMENT	CROSS SECTIONS	LONGITUDINAL SECTIONS
None....................	Moisture	Moisture
Paraffined inside..........	No moisture	No moisture
Paraffined outside........	No moisture	No moisture
Edges parafined..........	Moisture	Moisture

Again, to make sure that the moisture present in the cross sections was neither from condensation nor from the collection of hygroscopic moisture, some sections were placed on a metal block and others on a plaster block in a dish of water and with the surfaces of the blocks above the water. In two hours the sections on the plaster block showed the presence of moisture, while the sections on the metal block were dry. Now when the sections from one block were placed on the other, the wet sections became dry within 24 hours, while the sections formerly dry evidenced the presence of moisture. Thus, it appears that the stone of the peach is pervious to water both at the sutures and thru the sides, and that delayed germination of peach kernels cannot be accounted for by a lack of water.

Trials of different methods of stratification and storage.—Ten lots of 20 Chili pits each which had been removed from the flesh and stored for one month at room temperature were stratified in the fall in various ways and taken up in the spring and planted in soil. The treatments and results are given in Table 3.

TABLE 3.—TRIALS OF DIFFERENT METHODS OF STRATIFICATION AND STORAGE.

NUMBER OF SEEDS	TREATMENT	CRACKED NATURALLY		GERMINATED AND GREW	
		Number	*Per cent*	*Number*	*Per cent*
20	Stratified out of doors in sand after soaking well with water	18	90	18	90
20	Stratified out of doors in moist moss	20	100	20	100
20	Stratified out of doors in sand without soaking	19	95	19	95
20	Stratified out of doors in sand after soaking in water for 72 hours	19	95	19	95
20	Stored dry below freezing	0	0	0	0
20	Stored dry above freezing	0	0	0	0
20	Stored dry alternately above freezing for 28 days, then below freezing for 28 days	0	0	0	0
20	Stored alternately above freezing for 28 days, then below freezing for 28 days and alternately moistened and dried	0	0	0	0
20	Stored above freezing, but soaked for 24 hours every 14 days and then dried	6	30	0	0

It is apparent at once from a study of this table that continued storage either above or below a freezing temperature without adequate moisture did not supply the conditions required for successful after-ripening; but where both low temperature and moisture were present, the percentage of seed completing after-ripening processes successfully was high. At the same time freezing, alone, apparently had no effect upon the cracking of the pits.

Does soaking weaken the stone?—It may further be noted in the treatment in which the seeds were stored above a freezing temperature but soaked for 24 hours every 14 days and then dried, that six of the pits cracked unaided tho none of the kernels grew. The kernels of this lot were all shrivelled and the pits were very weak so that they could be broken along the sutures with very little pressure and were so brittle as to shatter with a slight blow with a hammer. Further, when 20 Chili peach pits were alternately soaked for 48 hours and dried for 48 hours at room temperature for 70 days, one stone fell apart in handling 30 days after the treatment had begun, while the others could be cracked artificially very easily. Not only were the stones weakened along the sutures, but they broke readily where deeply pitted or furrowed. All of these kernels remained sound yet dormant in the Hottes Germinator for six months.

On the other hand, when pits of Salwey were stratified in the flesh the stones remained exceptionally strong so that it was almost impossible to crack them. In other words, the drying and soaking of the pits weakened them, facts which indicate why nurserymen prefer the old peach pits which have become quite dry, to the new pits, and why it is the practice in some sections to keep the pits moistened during bedding or stratification. Chili pits were used largely thruout the studies and cracked without great difficulty as did also Crosby pits. Pits of Belle of Georgia and Waddell cracked less easily and Salwey the most difficultly of all.

Effect of freezing upon the rest period and upon the breaking of the stones.—Twenty Chili pits which had been soaked in water at room temperature for 50 hours were placed outside at low temperatures, together with 20 unsoaked seed, half of the pits of each lot having been previously cracked by hand and the other half left undisturbed. The minimum temperatures the following days were as follows: −6°, −6°, and −8° F. Upon examination of the stones, there was no cracking noticed; while when the kernels and pits were placed in the Hottes Germinator, all save one of the soaked lot rotted, while 40 per cent of the others rotted and 60 per cent remained dormant. The indications were that freezing did not crack the pits, but was actually harmful to the seed, especially when the kernels were high in moisture content. This, of course, has been noted[12] with many seeds.

[12]Kisselbach, T. A. and Ratcliffe, J. A. Freezing injury of seed corn. *Nebraska Agr. Exp. Sta. Res. Bul. 16. 1920.*

Effect of storage above a freezing temperature.—Since the indications were that freezing did not crack the pit but was actually harmful to the kernels, that the best natural cracking and germination were secured where seeds were stratified wet, that water permeated the stone readily, and that soaking and drying weakened the suture, and since the higher temperatures retarded or prevented the after-ripening necessary to germination, it was felt that stratification at low temperatures under moist conditions would be desirable.

Accordingly 40 Chili peach stones that had been kept dry at room temperature were stratified in wet sand, placed on blocks of ice, and covered with straw. The temperature of the sand varied between 34° and 40° F. and the seeds were kept wet by the melting ice. Ninety days later the pits were examined and 75 per cent were found cracked and 25 per cent uncracked. Upon being placed in the Hottes Germinator all save one, or 97.5 per cent, cracked naturally and germinated.

Now the 10 kernels which had lain dormant in the Hottes Germinator for 11 months[13] were placed under similar conditions for 30 days, and at the end of that time every one germinated and grew when returned to the Hottes Germinator.

Length of time to complete after-ripening.—Subsequently several hundred Chili pits were stratified in wet sand and placed on ice as noted above, and 20 pits were removed at intervals of two weeks, half cracked artificially and half untouched, and placed in the germinator.

Of the 10 pits removed at the end of the first two-week period none had cracked, but 60 per cent were cracked at the end of 4 weeks; 70 per cent at 8 weeks; 80 per cent at 10 weeks; and 100 per cent at 12 weeks. Of 50 pits stratified with the others but kept dry as a check only 10 per cent cracked at the end of 12 weeks.

Attention must be called to the fact that in this series of experiments which was carried on in mid-summer with pits gathered the preceding season, there was frequently lack of uniformity in the cracking of the pits and in uniformity of germination unless the pits were cracked artificially. This fact is both interesting and illuminating, for it indicates that the enclosed seed cannot germinate even after it has completed its after-ripening process until the breaking strength of the pit is less than the pressure of the kernel within. In normal methods of stratification, where the pits are allowed to dry out and

[13]See page 8.

are then kept wet during the period of stratification, the percentage of crack is high—90 to 100 per cent.

Summary and conclusions.—These studies indicate that even tho all requirements for germination are provided peach seed they will fail to germinate unless they have completed their after-ripening process; that the pit is pervious to water and cannot be held to delay germination on that score; that freezing does not necessarily crack the stone but may actually be harmful to the vitality of the seed; that the after-ripening processes of the seed are hastened at a temperature above freezing and in the presence of moisture; that the seed completes after-ripening in a relatively short time under favorable conditions but that it cannot germinate until the force of the expanding embryo overcomes the breaking strength of the confining stone; that drying and wetting the stone has a weakening effect upon it; that stratification of the pits without affording them an opportunity to dry out results in less natural cracking of the pits than otherwise; and that pits of some varieties of peaches crack more readily than others. This would seem to uphold the practice in the nurseries of cracking by hand those pits which had not cracked naturally, of preferring two-year seed to one-year seed, and of keeping stratified pits at cool temperatures and under moist surroundings.

STUDIES WITH CHERRY SEED

Common methods of handling.—Since stocks for cherries are largely imported, the proper handling of seed does not become such an important problem as it does in the case of peaches. Mahaleb stocks, grown from seed of *Prunus mahaleb*, a European species of cherry, are imported almost entirely, tho Mazzard stocks, grown from seed of the wild sweet cherry, are sometimes grown from seed in this country. The stones split readily, and the percentage of germination is high. In fact in the South it is not uncommon to crack the stones artificially and plant the seed as soon as it is harvested. Enough growth is secured the same year so that budding may be done the next. Seed is usually planted in the fall in rows, no bedding or stratification being practiced.

Treatment of cherry seed.—In the first place, thru a series of experiments identical to those carried on with peach stones, it was found that cherry stones were also readily pervious to water. Moreover, the kernels when removed from the pit likewise failed to germinate unless the after-ripening process had been completed. Stratification under cool, moist surroundings provided the conditions favorable to after-ripening, and drying and wetting appeared to weaken the stone so that it might be more readily broken by the expanding embryo. It has been said that cherry pits should not be allowed to become dry, a statement not borne out by this work.

Pits of Schmidt Bigarreau, representing the sweet cherry, *P. avium*; Olivet, representing the Duke cherries, hybrids between the sweet and the sour cherries; and Riga and English Morello, representing the sour cherry, *P. cerasus*, were stratified in wet sand in contact with ice as was done with peach stones and 10 seeds of each lot removed and placed in the Hottes Germinator at intervals of two weeks. The seeds of Riga, Olivet, and Schmidt were from the preceding season, while those of Morello were from the current season. From the Morello seed two lots were made, the one consisting of seed allowed to dry for three weeks, and the other consisting of seed not removed from the flesh and consequently not permitted to dry. Table 4 records the results of the tests.

Discussion.—The most important consideration, especially in the case of the sweet cherry, is the acquisition of viable seed, for there is considerable self-sterility and incompatibility among cherries which results in immature, abortive, or otherwise undesirable seed. Seed from four Mazzard trees was gathered at this Station, the seed from three trees failing to germinate and rotting within the stone.

To the plant breeder the germination of cherry seed becomes an important topic. Out of 273 cherry seeds secured from hybridizing work during the season of 1921, one lone seedling sprang, while from the several hundred crosses made in 1922, only one seedling developed. But here again the problem does not appear to be so much a question of proper storage conditions for seed as a matter of securing viable seed, for certain crosses failed to germinate while others germinated in high percentage. Upon examination of the ungerminated seed it was found that it was rotted, abortive, or otherwise lacking in viability. As an illustration of this, 14 out of 21 crosses failed to germinate any seed whatsoever, and the seed upon examination was found to be in poor condition; while out of the total of 452 seed secured from hybridizing, only 43 appeared sound, and only 2 of these produced seedlings. On the other hand, a lot of *Prunus tomentosa* seed, closely allied to the cherry, germinated almost 100 per cent with no special attention.

TABLE 4.—RESULTS OF STRATIFYING CHERRY PITS IN WET SAND ON ICE.

VARIETY	PREVIOUS TREATMENT	2 WEEKS		4 WEEKS		6 WEEKS		8 WEEKS		10 WEEKS		12 WEEKS		12 WEEKS DRY AS CHECK	
		No.	*Per cent*	*No.*	*Per cent*	*No.*	*Per cent*	*No.*	*Per cent*	*No.*	*Per cent*	*No.*	*Per cent*	*No.*	*Per cent*
Schmidt	Dried 52 weeks	10	0	10	0	10	0	10	0	10	0	10	0	50	0
Olivet	Dried 52 weeks	10	0	10	0	10	0	10	0	10	0	10	0	50	0
Riga	Dried 52 weeks	10	0	10	40	10	20	10	40	10	60	—	—	50	0
Morello	Dried 3 weeks	10	0	10	20	10	40	10	40	10	60	10	80	50	0
Morello	Stratified without drying	10	0	10	0	10	0	10	0	10	30	10	0	50	0

TABLE 5.—RESULTS OF STRATIFYING PLUM PITS IN WET SAND ON ICE.

VARIETY	2 WEEKS		4 WEEKS		6 WEEKS		8 WEEKS		10 WEEKS		12 WEEKS		12 WEEKS DRY AS CHECK	
	Number	*Per cent*	*Number*	*Per cent*	*Number*	*Per cent*	*Number*	*Per cent*	*Number*	*Per cent*	*Number*	*Per cent*	*Number*	*Per cent*
Palatine	10	0	10	0	10	0	10	0	10	0	10	0	50	0
Wild Goose	10	0	10	0	10	20	10	40	10	40	10	100	50	0

TABLE 6.—RESULTS OF STRATIFYING APPLE AND PEAR SEED IN WET SAND ON ICE.

VARIETY	2 WEEKS		4 WEEKS		6 WEEKS		8 WEEKS		10 WEEKS		EEKS DRY AS CHECK	
	Number	*Per cent*	*Number*	*Per cent*	*Number*	*Per cent*	*Number*	*Per cent*	*Number*	*Per cent*	*Number*	*Per cent*
Hubbardston apple	10	0	10	20	10	80	10	100	10	100	100	16
Rhode Island Greening apple	10	10	10	40	10	80	10	100	10	100	100	14
Gold Nugget pear	10	100	10	90	100	98	—	—	—	—	100	11

In this connection it is interesting to note that in the cracking of a large number of stones, representing 32 varieties of cherries, to determine whether there was any correlation between hybridity and soundness of seed as represented by the Duke cherries (hybrids between the sweet and sour cherry), a wide range of viability was noted. Even among sour cherries the number of abortive kernels ran as high as 100 per cent and only a few varieties were 80 per cent sound, while among the other species there was the same variability.

No difficulty was experienced in the natural cracking of the pits. The important factor appeared to be the securing of viable seed. It was unnecessary to crack the pits artificially to secure germination; rather, if the pits contained viable seed which had completed after-ripening processes, they were easily forced open by the expanding embryo. Why the Morello pits which were not allowed to dry did not germinate well is not understood. That it was not a question of a strong stone which the expanding force of the confined embryo was unable to overcome was shown by the fact that when the stones were cracked artificially the kernels still remained dormant.

Conclusion.—It is not difficult to germinate cherry seed, provided the seed is viable. The pits crack readily after they are kept moist at cool temperatures for a relatively short time.

STUDIES WITH PLUM SEED

Customary methods of handling.—Plum stocks are also largely imported so that the growing of plum seedlings from seed has not reached commercial importance in this country. Plums are propagated largely on Myrobalan, St. Julien, and peach stock, all but the latter being imported from Europe. However, Marianna, a native plum is used as a stock, in a small way, and some other American types, to a limited extent. The seed is usually planted in rows in the fall.

Pits of Wild Goose, representing *P. munsoniana*, and Palatine, representing *P. domestica*, were used in these studies and the same treatments performed as with the cherry and peach and in like manner. It was found that the stones were pervious to water and that the embryo failed to germinate unless after-ripened, tho satisfactory conditions for after-ripening were evidently not provided for the pits of Palatine as the results in Table 5 show. The stones were stratified in wet sand on ice as in the case of the peaches and cherries. Even when the stones were cracked artificially, the seed of Palatine failed to germinate, tho occasionally one germinated after weeks of dormancy. Either the after-ripening process goes on slowly or else the seed requires different conditions for after-ripening or germination than those provided. The Wild Goose stones, on the other hand, cracked naturally and easily and the seed germinated readily by this treatment.

STUDIES WITH APPLE AND PEAR SEED

Customary method of handling.—Until recently apple and pear stocks have been imported almost entirely from Europe. More recently, especially in the far West and the Middle West, attention has been given to the growing of seedlings from seed. With the heightened interest in the propagation of resistant stocks for pears, the subject of seed storage and germination becomes of increased importance.

Correspondence with several nurseries in various parts of the country indicates the discontinuance of the old method of stratification and the prevalence of the practice of soaking apple seed in water and then cooling with ice before planting in the spring. To quote from a Kansas firm: "In treating small lots of apple seeds the best method would be to soak the seed a little for three or four days in cool water. Let air for an hour or two each day, and then pack in damp sand and keep moist and cool. If you want to hold them for some time before planting, freeze them in the sand and place in ice, or pack ice around them. In treating large lots, we soak the seed several days, then place in icehouse between layers of ice and with ice around the outside. Do not place seed in cold storage where it freezes up solid, as this will stop the treatment of the seed." This is especially interesting in the light of recent work[14] showing that apple seeds after-ripen best at cool temperatures and under moist conditions.

Treatments.—Seeds from recently harvested apples and pears failed to germinate when placed in the Hottes Germinator. On the other hand, seed from apples which had been kept in cold storage gave germination tests varying between 90 and 100 per cent.

Seed of Hubbardston and Rhode Island Greening apples were stratified in wet sand on ice as with the seed of peaches, cherries, and plums, and removed at 10-day intervals. The check consisted

[14]Harrington, G. T. and Hite, B. C. After-ripening and germination of apple seeds. *Jour. Agr. Res.* **23**, *153. 1923.*

of seed stratified with the others but in a bottle free from moisture. The germination noted in Table 6 was uniform and rapid and after-ripening was accomplished in a relatively short period.

Conclusion.—There is little difficulty in germinating apple and pear seed. For the plant breeder, however, who has been in the habit of stratifying his seed outside, the methods here employed in hastening after-ripening will be helpful, especially if he desires to start his seedlings indoors early enough to obtain sufficient growth by transplanting time. Frequently the ground is frozen so late that the seed stratified out of doors cannot be taken up in time to plant in the greenhouse.

STUDIES WITH RUBUS AND RIBES SEED

Treatment.—Currant, gooseberry, raspberry, and blackberry seed gathered the same season did not germinate readily. Occasionally one or two would germinate, but the bulk lay on the plaster blocks of the Hottes Germinator from the middle of January until the middle of October without germinating and yet in a healthy condition. It was thought that perhaps the hard testa or seed-coat prevented the entry of water necessary to germination as previously noted for clover seed. Consequently the seeds of the various species and varieties were treated with concentrated sulfuric acid for different durations of time.

The method employed was to place the small quantities of seed in Gooch crucibles (porcelain crucibles with perforated bottoms) and to put them, dishes and all, into an acid bath. After the treatment the crucibles and seed were washed in running water for two or three minutes and then placed in a solution of calcium carbonate for about 10 minutes with frequent agitation, subsequently washing with water for 15 minutes. With the small amounts of seed employed, this method was found very satisfactory and several lots of seed could be treated at one time. It must be noted that the seed had been kept indoors at room temperature. The results of the treatment were entirely negative and once more pointed to the necessity of examining internal factors. The following year the seed was stratified in moist moss. A compact, rodent-proof container employed at this Station for small lots of small-fruit seeds is afforded by wrapping the seed in small pieces of heavy muslin or canvas within individual squares of non-rusting wire screening.

Seed of the small fruits, handled in this way and stratified at 34° to 38° F. from November until March, were placed on the germinating blocks. No germination occurred with the exception of the gooseberry seed, varieties of which germinated variously between 20 and 80 per cent. Other lots of seed were now treated with acid for different durations of time with the results shown in Table 7.

TABLE 7.—RESULTS OF TREATING SEED WITH SULFURIC ACID.

VARIETY	NUMBER OF SEEDS USED	CHECK	15 MINUTES	1 HOUR	2 HOURS	4 HOURS	5½ HOURS
		Per cent		*Per cent*	*Per cent*	*Per cent*	
Ancient Briton blackberry	50	0	—	0	0	32	Dead
Lucretia dewberry	50	0	—	0	12	12	Dead
Wineberry	50	0	—	0	12	Dead	Dead
Newman No. 23 red raspberry	50	0	—	0	0	34	Dead
Buckeye red raspberry	50	0	—	4	4	10	Dead
Purple raspberry	50	0	—	78	52	Rotted	—
Van Fleet gooseberry	50	10	—	36	Rotted	Rotted	—
Poorman gooseberry	50	82	Rotted	Rotted	Rotted	—	—
Houghton gooseberry	50	48	Rotted	Rotted	Rotted	—	—
Boskoop Giant black currant	50	6	—	Rotted	Rotted	—	—
North Star red currant	50	0	—	Rotted	Rotted	—	—
White Dutch white currant	50	0	—	Rotted	Rotted	—	—

One of the interesting observations to be made is that the seed which is ordinarily most easily germinated was the most quickly influenced by acid, while that which is notoriously difficult to germinate in high percentages withstood long immersion in the acid. This may indicate further the importance of the seed coat in the germination of small-fruit seed.

At one time during the series of experiments a sample of seed was allowed to dry out after being removed from storage and was then treated with acid. From a comparison of these results with those recorded in Table 8 of samples treated immediately upon withdrawal from storage, it is seen that germination is impaired by drying.

Such a phenomenon is not uncommon among peas and beans and is ascribed to a re-hardening of the seed coat upon drying, tho the seed coat may have been permeable to moisture previous to the drying out. This "hardshell" or secondary dormancy may account for much of the difficulty experienced in raising berries from seed, for frequently the seed is permitted to dry out after having been stratified and before it is planted.

In cases where no germination is secured the first year, it appears advisable to hold the seed a second year. Frequently it has been observed that seed which failed to germinate the first year germinated in high percentage the following year if held in cool moist surroundings.

TABLE 8.—COMPARISON OF SEED PERMITTED TO DRY OUT AFTER REMOVAL FROM STORAGE WITH THOSE TREATED WITH ACID IMMEDIATELY.

VARIETY	NUMBER OF SEED USED	PERMITTED TO DRY	TREATED IMMEDIATELY
		Per cent	*Per cent*
Ancient Briton blackberry	50	0	24
Lucretia dewberry	50	2	10
Wineberry	50	2	78
Buckeye red raspberry	50	4	26

Conclusion.—The experience with the small-fruit seeds indicates why so much difficulty attends upon attempts to raise plants from seed, for here is a combination of both external and internal factors controlling after-ripening and germination. Proper conditions of moisture and temperature must be provided before the internal processes which constitute after-ripening can be completed, and then the factor of a strong or impermeable seed coat must be reckoned with before germination can be effected.

Storage at low temperature and under moist conditions was found to give a fair germination, tho far from what was desired, while the absence of either low temperature or adequate moisture held the seed in a dormant state. Treatment with sulfuric acid afforded some advantage in increased germination, yet such measures cannot be recommended as yet, for there is such a wide variation between the reaction of different species, or even varieties of the same species, that a recommendation that might apply for one variety or one species would not suit another. Again, methods of storage and treatment subsequent to removal from storage may so affect the seed that it may react in one way to acid at one time and in an entirely different way at another time.