dium for the seeds of most woody plants as all the factors for germination and growth can be definitely controlled. Seedlings may be held in "living storage" in sphagnum moss for long periods without harm. In addition the anti-biotic qualities of sphagnum moss will prevent infection by fungus diseases.

Sterile substances such as vermiculite, arcillite, or perlite have value as media for seeds which germinate rather quickly and are transplanted soon thereafter. The seed may be treated with a fungicide before sowing as a precaution against diseases which may be carried in or on the seed coat.

Soil should not be used indoors but is necessary for large lots of seeds out of doors. A good soil for sowing seed should be light in texture, well drained, well aerated, and contain a fair degree of organic matter to prevent rapid loss of moisture. Treatment with steam or chemicals to control weeds, nematodes, insects, and diseases is important before the seed is sown.

Since seeds vary so widely in their pregermination and germination requirements, the need for accurate observation and research with each particular species or seed strain is evident. Every plant propagator can assist in this endeavor. Accurate records of every operation and environmental factor should be kept and reported thereafter in the Proceedings or quarterly journal of the International Plant Propagators Society. Thus, bit by bit, the information will accrue so that the plant propagator of future years may be the recipient of more definite and detailed instructions for each type of seed than is available at present.

MODERATOR STEAVENSON: Before we have any discussion we will hear our next paper presented by another old friend of the Society, Mr. Al Fordham of the Arnold Arboretum.

HASTENING GERMINATION OF SOME WOODY PLANT SEEDS WITH IMPERMEABLE SEED COATS

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Germination of many seeds is hindered only by seed coats that retard the admission of water. If these impervious coats are not modified by pretreatment, germination can be erratic and sometimes extended over many years. Three hundred seeds of *Gymnocladus dioicus,* the Kentucky coffee tree, were placed in a tray of water in April 1963 and since that time have been kept at room temperature. Each week the seeds were examined, those which had germinated were removed, and the results recorded. In the first 10 days, 13 seeds imbibed water and the produced radicles. These, no doubt, had fissures in their seed coats at the outset. Twenty-one months later, in January 1965, three more imbibed water and germinated. The following table shows how many more have done so since that time:

Year	Number germinated
1963	13
1964	0
1965	4
1966	4
1967	5
Total	26 germinated since 1963

In four years and seven months about 8% of the seeds imbibed water and germinated. Large seeds such as those of Kentucky coffee tree can be perforated by holding them between the fingers and stroking them several times along the edge of a three-cornered file placed on a bench. Complete germination can then be expected in about a week.

In December 1963, 1000 seeds of *Gleditsia triacanthos*, the honey locust, were submerged in water under similar conditions to record germination. The following table shows how many have done so since that time:

Year	Number germinated
1963	20
1964	16
1965	8
1966	19
1967	22
Total	85 germinated since 1963

In four years about 8% of the seeds have germinated. A complete stand of seedlings appeared in about ten days after the seeds were steeped in concentrated sulfuric acid for 2½ hours. Comparative tests, shown in the following table, proved this to be an optimum treatment:

Treatment	% Germination
Control, sown without pretreatment	5
Steeped in hot water (190°F.)	29
Steeped in sulfuric acid for 1½ hours	62
Steeped in sulfuric acid for 2½ hours	98

As it now appears, the tests with Kentucky coffee tree and honey locust can go on indefinitely, possibly for decades.

Many legumes and some other seeds that are inhibited only by water-tight protective seed coats are relatively easy to prepare for germination. Abrasion, perforation, or modification of the seed coat with hot water or sulfuric acid is usually all that is necessary. When such seeds reach full development on the plant, the coats, which will provide protection for the contents, undergo changes in structure. They diminish in size and weight and develop hard, water-impermeable seed coats.

Seeds of *Laburnum watereri*, the Waterer laburnum, were collected on July 21, 1965. At this time the pods were soft and the seed coat only a thin green membrane. To test whether or not a barrier to germination existed at this stage, the seeds were divided into two lots and processed immediately. Seeds of Lot #1 were sown without pretreatment while the coats of those in Lot #2 were punctured with a needle. In five days, each lot germinated uniformly. There was no appreciable difference in percentage, for at this stage the seed coats were water-permeable. Dry seeds of *L. watereri*, however, are an entirely different matter. In a series of trials, dry seeds required a two hour steep in concentrated sulfuric acid to obtain the optimum germination.

Laburnum alpinum, Scotch Laburnum, seeds were collected in October 1963 and kept in dry storage until June 1965. The seeds were divided into four lots. An accounting 23 days later showed the following results:

Treatment	% Germination
Control sown without treatment	0
Hot water treatment	18
Sulfuric acid for one hour	29
Sulfuric acid for two hours	68

Although the highest percentage of germination was 68 only one sound seed remained ungerminated, thereby indicating that the balance was not viable.

Cytisus supinus seeds were provided treatment as follows:

Treatment	% Germination
Control sown without pretreatment	1
Hot water	4
One hour of acid	64

Germination of *Cercis siliquastrum* (Judas tree) seeds was hindered by impermeable seed coats plus internal conditions. Lot #1 was treated with hot water and sown, while Lot #2 was provided with hot water treatment followed with 3 months of cold stratification at 40 degrees. Lot #2 germinated uniformly in 22 days while Lot #1 produced only one seedling in four months. Seeds of *Cercis canadensis* (Eastern redbud), *C. chinensis* (Chinese redbud), *C. griffithii*, and *C. occidentalis* (Californian redbud) behave in a similar manner, requiring a cold treatment after the seed coat has been modified.

Germination of seeds of *Hovenia dulcis*, the Japanese Raisin tree, is inhibited only by extremely hard, water-impervious seed coats. Lot #1 was sown without pretreatment while Lot #2 was provided with a two hour sulfuric acid treatment. Lot

#2 germinated uniformly in 16 days, while the untreated lot produced only two seedlings in two months and six seedlings after a lapse of nine months.

Concentrated sulphuric acid treatment

Some seeds with coats not responsive to hot water treatment can quickly be germinated after a more drastic measure — immersion in concentrated sulphuric acid, (H_2SO_4). This highly corrosive substance, when employed for this purpose, accomplishes in hours, or portions thereof, a process that could require months or years if the seed coats were not treated.

Sulfuric acid treatment, when dealing with small amounts of seeds, consists of placing the dry seeds in a glass container and carefully pouring acid over them until they are covered. Sulfuric acid is a viscous substance of high surface tension which acts superficially on seed coats without penetration. In fact when trials were carried out on an unfamiliar subject suspected of having an impermeable seed-coat, periods of acid treatment as long as one and one-half hours have been given seeds which later proved to be water permeable. Despite such mistreatment, however, the seeds were not destroyed but germinated when sown. The acid did not have the ability to penetrate the seed coat, although water did.

As acid treatment progresses gummy by-products of corrosion will fuse the seeds into a cohered mass which must be separated from time to time to insure that all seeds are acted upon uniformly. Cautious prodding and careful stirring with a glass rod will accomplish this. The length of treatment varies greatly, depending upon the subject, the objective being to corrode away sufficient seed coat to permit the entry of water without exposing the interior to destruction by the acid. Observations can be made during treatment by removing a few seeds, rinsing them and examining the seed coat to see how much of it has been eaten away. When treating large batches it is advisable to run a few trial lots to determine proper timing before processing the main bulk. An important point which must be considered when using sulfuric acid is the effect of temperature. Higher temperatures accelerate the rate of action while lower ones retard it. Acid treatments at the Arnold Arboretum are usually performed in the winter when room temperature is maintained at approximately 70° F.

On completion of the treatment, seeds are placed in a sieve and washed thoroughly in running water for several minutes to remove all the acid. Now they are ready for the next step, which involves either immediate sowing or cold stratification. We do not employ a neutralizer after the use of acid and have never noticed detrimental effects for not having done so.

Precautions when handling sulfuric acid

Precautions to be taken when handling sulfuric acid cannot be over emphasized. It need not be feared, but should be handled with the greatest respect, for it becomes safe to use only when adequate precautions are observed. Each year millions of tons of this highly essential industrial chemical are transported about the country in tank-cars and tank-trucks. It is used extensively by chemists, industrial workers and students and with care others can do the same.

In our treatments, small though they are, the workman performing the task dons protective equipment consisting of glasses, neoprene gloves and an apron. The work is done adjacent to running water and nearby is a shower that could be reached in a few seconds if its use became necessary, for, despite precautions, accidents are always possible. To minimize the chance of breakage, our supply of acid, in a glass container, is imbedded in a five gallon can of perlite stored in an out-of-the-way location.

When treatments have been completed, the acid which has been used is poured into a glass bottle. In a few days extraneous substances caused by corrosion settle to the bottom and the clear acid is then poured off for re-use.

MODERATOR STEAVENSON: Thank you very much, Al, for a very fine presentation which was a fine complement to Steve O'Rourke's paper. Now we will open the floor for discussion.

VINCE BAILEY: I would like to ask Al if he recommends the use of sulfuric acid on *Tilia*.

AL FORDHAM: We have not had any experimental work with *Tilia*. However, I believe the Woody Plant Seed Manual does recommend the use of sulfuric acid for *Tilia*.

VINCE BAILEY: Is that after the removal of the fleshy seed coat or before removal?

AL FORDHAM: I beleive the procedure is to first remove the fleshy outer coat and then treat the inner seed coat.

HANS HESS: Has Al used sulfuric acid treatments on *Cercis canadenis* and on *Gymnocladus?*

AL FORDHAM: Yes, I have. With *Cercis canadenis* after treating the seed coat with the sulfuric acid it is necessary to give the seeds a period of cold stratification. The length of the cold treatment varies with the seed source. We also use a hot-water treatment to break the seed coat dormancy of *Cercis canadenis*. We pour hot water at about 190° over the seeds and they are left to cool overnight. The following day the seeds are placed in cold storage. The *Gymnocladus* seed needs a rather long period of sulfuric acid treatment. Actually we have not had personal experience with sulfuric acid on *Gymnocladus* seed. We have so few seed that we just scarify the coats with a file. If you use acid, it would probably take at least 2½ hours exposure.

RALPH SHUGERT: I would like to make a brief comment on the hot-water treatment. We have used the hot-water treatment for *Robinia* seed and at one of the meetings I gave our procedure to a member. He followed the procedure that I had given him and he lost the entire lot of seed. The thing that I am trying to bring out here is that it is very important, particularly in the case of *Robinia,* to know where the seed has come from. We expose our seed to three hot-water treatments — one at 140°, the second at 160° and the last at 170°F. This works very well on the seed brought in from Europe but, if you try this on domestic seed; you will lose all of it. The word of caution here is to try the treatment out on a small lot of seed before you treat the entire lot.

AL FORDHAM: Our treatment is a little bit different from yours. Rather than heating up the seeds to a temperature of 140, 160 or 170 degrees, we start out with water at about 190° and pour it over the seeds and then allow it to cool.

RALPH SHUGERT: That's right. I do the opposite as far as treatment in concerned. I put the seeds in water and then bring the temperature up to the 140, 160 or 170 degrees F level.

RALPH SYNNESTVEDT: Al, do you use the acid treatment for *Crataegus Crus-galli?*

AL FORDHAM: Yes, we generally do. The thickness of the seed coat varies enormously. There are many species of *Crataegus* and in some cases the seed coat may be as much as 3/16 of an inch thick. With this type of seed it may require as much as 7 or 8 hours of sulfuric acid treatment.

JIM WELLS: Why do you use a hot-water treatment? When I brought in a lot of *Acer palmatum* seed I found that just soaking them in cold water was sufficient. If the seeds were planted dry even though the soil was moist, germination was very poor. However, giving them a cold-water soak stimulated good germination.

AL FORDHAM: I think we are talking about two different things here. The hot-water treatment which I described is used to modify the seed coat which was impermeable to water.

JIM WELLS: Does the hot water cook the coat?

AL FORDHAM: No, the hot water modifies the seed coat so that moisture will be able to penetrate. Cold water is not effective in modifying the seed coat.

JOHN ZELENKA: Al, what are your recommendations for handling European Mountain Ash seed?

AL FORDHAM: European Mountain Ash just requires three months of cold stratification, if the seeds are fresh.

AL FERGUSON: Have you tried any detergents with your hot-water treatment,

AL FORDHAM: Yes, a few years ago we used wetting agents such as Tween 20 and they were of no help at all. With some other types of seeds which do not have impermeable seed coats such as grass seeds, it is sometimes possible to speed up the rate of germination a few days with wetting agents.

CASE HOOGENDOORN: Do you ever try to hold the seeds in hot water at a given temperature for a given period of time and then allow them to cool off?

AL FORDHAM: No, we do not do that. Just pour the hot water over the seed and allow it to cool. A prolonged period of high temperature could be harmful to the seeds.

MARTIN VAN HOF: Have you tried the scarification treatment with the sulfuric acid on *Myrica pennsylvanica,* the Bayberry.

AL FORDHAM: There are two problems with this seed. One is the waxy coat. The second is a cold stratification requirement. The wax is removed just by putting the seeds in lukewarm water and then the seed is given a three-month period of cold stratification. After that the germination should be very good.

JOERG LEISS: What is the concentration of the sulfuric acid which you use?

AL FORDHAM: I don't recall the specific gravity, but we use concentrated sulfuric acid. I believe it runs about 93%.

JIM WELLS: I would like to direct this question to Hugh Steavenson. I have read that if the seed bed is maintained at a moisture level 95% of field capacity that the seed germinaion will be very good. Have you had any experience along these lines?

MODERATOR STEAVENSON: It is essential during the germination process of most tree and shrub seeds to have an adequate to high level of moisture availability at the seed level. It is also essential to have a well aerated medium. The high moisture level can be obtained in a couple of ways. Some nurseries are well set up with irrigation systems and can give frequent light applications of water which keeps the soil moisture high. The alternative is to use a mulch. However, with the mulch system there are some seeds with which it does not work. For example we have not been successful with White Birch. Perhaps there is a light factor involved.

AL FORDHAM: I have heard about this light factor with Birch but in our experience it has not been a problem and we have tested seed from many, many sources. However, I should point out that this is done with small lots under greenhouse conditions.

JIM WELLS: My point about soil moisture goes back to some work done a number of years ago by Dr. Thornthwaithe who ran the Department of Climatology at Seabrook Farms. He developed a unit called an evapotransporometer. It is a device which enables you to determine exactly how much water has been lost both by evaporation and tranpiration. By using the evapotransporometer he was able to determine exactly when the soil moisture level had dropped to the 95% level of field capacity. I have a paper in my files done by a field testing station in Canada dealing with the raising of pine and spruce seedlings in which Dr. Thornthwaithe's evapotransporometer and formulas were used. They showed very clearly that if you precisely determine the moisure level and maintained it at hte 95% level, the size of the seedlings in one year was equal to the normal size at the end of two years. You were able to gain a full year's growth by controlling water.

PETE VERMEULEN: I would like to ask what effect does a mulch on a seed bed have upon the soil temperature?

MODERATOR STEAVENSON: Although the color of the mulch may effect its ability to absorb or reflect heat, in most cases the mulch is an insulating blanket so that the soil temperature may be held back in the springtime. With us, this is a real good thing because otherwise we have seeds which germinate too early and then are caught by a late frost.

CASE HOOGENDOORN: What do you use for a mulch?

MODERATOR STEAVENSON: We use sawdust.

ROBERT FARMER JR.: I would like to make a comment in regard to temperature. There is a growing body of knowledge that shows that southern seed sources require a much shorter period of cold stratification than do northern seed sources. This is true for most species although I believe the White Pine is an exception. The temperature required at germination is influenced by the amount of cold stratfication that the seeds have been exposed to. After a short period of stratification most tree species require a high temperature but the longer the cold stratification period they are exposed to, the lower the temperature they will be successfully germinated. The optimum temperature then for germination depends upon the geographical location of your seed source and the amount of cold stratification that has been used.

MODERATOR STEAVENSON: Our next paper for this morning's session will be given by Mr. Richard Bedger from Musser Forests, Inc. and he will speak on "Conifers and Hardwoods from Seed".

CONIFERS AND HARDWOODS FROM SEEDS

RICHARD C. BEDGER
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Mr. Steavenson, Society Members, and guests. It is a pleasure to discuss with you this morning the propagation of plants from seeds. I feel that the key to this whole phase of propagation is one word "seed". We can have the most beautifully prepared beds, the most fertile soil, and sufficient water, but if the germination capacity of the seed is low or if it is sterile, the beds will be poor or fail.

In our operations at Musser Forests, we store large amounts of seed in sealed jugs in refrigerated storage. In any year that nature produces a good crop, we purchase a two or three year supply of seed. Not only is the seed cheaper but the viability in a good crop year is normally greater.

As each shipment of seed is received from the supplier, it is put in the jugs for storage. A sample of approximately 1,000