We have found that mechanical, chemical and stratification methods hastening germination can become quite complicated, time consuming and not conducive to mass production methods. It creates problems in calibrating our seeder and thus we are unable to accurately sow the seed. We practice a very simple method — plant the seeds and allow Mother Nature to do her work in the normal way. Since we have to assemble a tremendous amount of equipment each time we want to make seed beds, this allows us to plant all of our seed at one time and to make the best use of mass production methods. Also, we have attempted to do some stratification in storage and have found that so often these seeds are ready to be planted exactly when we are busiest in the spring of the year.

In conclusion I realize that my viewpoint is strictly from the commercial angle and I certainly feel that continued research must be done in hastening the germination of seed since sometimes nurserymen are caught short and would like to produce seedlings in shorter periods of time. We should have this information available to us for use for such an emergency basis. Also, the universities and other research institutes are helped a great deal by these various methods of hastening germination. For those that are interested there are two very excellent references in the field of seed dormancy. (1) Woody Plant Seed Manual, 1948, Prepared by the Forest Service, USDA Miscellaneous Publication No. 654. (2) A reference sheet prepared by Dr. L. C. Chadwick, Ohio State University.

I feel that most nurserymen still rely upon Mother Nature to take care of the dormancy problems in seed propagation. No doubt as the nursery industry becomes more and more specialized and more and more advanced, these techniques of hastening seed germination may become part of our commercial practices.

MODERATOR LEACH: The other half of the subject Stimulation of Germination by Chemical and Mechanical Means as applied to Exotic Plant Materials is to be discussed by Alfred J. Fordham, Arnold Arboretum.

METHODS OF TREATING SEEDS AT THE ARNOLD ARBORETUM

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The USDA Woody-Plant Seed Manual and Contributions from the Boyce Thompson Institute are invaluable sources of information for those concerned with germinating seeds of trees and shrubs. However, when it comes to many woody ornamental plants and the more remote botanical garden subjects, information as to germination becomes hard or impossible to find. No doubt, at times in the past, people have known how some kinds of seeds perform but much was unknown and little recorded for the information of others. Among that which is written it is not uncommon to find erroneous informa-

tion e.g. A comparatively recent, widely circulated publication, says regarding *Liquidambar styraciflua,* "Propagated by seeds which, if stratified, do not usually germinate for two years." Such false information is misleading to those wishing to propagate *L. styraciflua* for 2 months of cold stratification will produce a general germination.

Those involved with seed germination realize the importance of seed age and methods of storage. Many kinds of seeds will perform predictably after periods of storage, others go through changes which alter their characteristics, and those which are microbiotic (with viability of short duration) become worthless.

Many of the seeds used to obtain the information that follows were collected in the Arnold Arboretum. For these the method of handling was known, but others were received as exchange material from domestic and foreign botanical institutions where it is customary to collect the fruits as they ripen, separate the seeds and place them in dry storage. Seed lists are then circulated, usually in the late fall or early winter, and correspondents desiring seeds can check their wants. Where this is the common practice, it seems reasonable to assume that the seeds from such sources were collected from the past season crop and kept in dry storage.

Seed Coat Dormancy

Germination of many woody legumes is hindered by hard seed coats which prevent the imbibition of water. If such seeds are not pretreated before being sown germination can be intermittant and prolonged, sometimes extending over a period of many years. To obtain a prompt and uniform germination a rapid means of effecting the entry of water becomes necessary. Several procedures will accomplish this. Large type legume seeds, in small quantities, are perforated with a file, knife or some such means while smaller type seeds, or seeds handled in volume can be treated with hot water or sulphuric acid. An organization such as ours does not handle seeds in sufficient quantity to warrant the employment of mechanical scarifiers. Treatment with hot water consists of putting the seeds in a container and pouring water heated to a temperaure of abou 200° over them. The seeds are then left in the water over night. The amount of water used should be five or six times the volume of seed and this is important as too small a quantity can cool before it has the desired effect on the seed coats. On being removed from the water the seed is sown at once without being allowed to dry out. A second method is to sow the seed and then pour boiling water over the seed pan or seed flat.

Two years ago we conducted trials with seeds of *Albizia julibrissin rosea.* Concentrated sulphuric acid treatments at room temperature of ½ hour, 1 hour, and 2 hours were tested. A hot water treatment was also tried. Each treatment produced a general germination in ten days, but with hot water time was saved and the precautions involved when working with acid were avoided.

The sulphuric acid treatments consist of placing the dry seeds in glass containers and carefully pouring acid over them until they are

covered. When treatments are terminated the acid is poured into a glass container so that it can be reused. The seeds are then thoroughly rinsed in running water to remove any remaining acid. We do not use a neutralizer after acid treatments and have never noticed detrimental effects for not having done so.

Acid Treatment of Cotoneasters

Many species of cotoneasters are characterized by double-dormancy which first requires modification of the hard, impermeable seed coats, followed by a period of cold stratification to induce germination. Using the polyethylene bag system (see below) this will be accomplished by 5 or 6 months of warm stratification followed by 3 months of cold. The USDA Woody-Plant Seed Manual recommends soaking *Cotoneaster horizontalis* seeds in concentrated sulphuric acid for 1½ hours followed by 90 to 120 days at 41° to 50° F as a method of germinating this particular species. It also suggests that such a procedure might be effective with others. Some cotoneasters were tried using acid for various periods of time followed by 3 months of cold stratification at 40°. Two hour acid treatments followed by 3 months stratification at 40° worked well with *Cotoneaster adpressa, C. adpressa praecox, C. apiculata, C. franchetii* and *C. frigida.*

One cannot generalize when considering seed dormancies. This is brought out by the fact that in the last few years we had experience with three cotoneasters which acted as though their seeds were without inhibitors. *Cotoneaster wardii, C. microphylla* and its variety *C. microphylla thymifolia* each behaved like a handful of grass seed and germinated without pretreatment. Although each was from a foreign source and treatment before we received them was unknown, it seems safe to assume that dormancies did not exist for it is unlikely that storage methods would alter impervious seed coats.

Stratification

At the Arnold Arboretum our pretreatment of seeds requiring periods of stratification is done by using polyethylene plastic bags. This method has been employed for some years and the procedure is reasonably well known, however a few remarks might be in order.

Polyethylene film has the property of being air permeable yet vapor proof, with the result that oxygen is available to the contents by diffusion. The stratifying medium to be used is dampened, the emphasis here is on the word dampened for too wet a medium could exclude sufficient oxygen. In proportion, the medium should not exceed two or three times the volume of seed. (This too is stressed as at planting time the seeds are not separated from the medium but the entire contents of the bag are sown.) The seeds are distributed throughout the medium and placed in the bag which is then twisted at the mouth and made vapor tight with a rubber budding band using much the same technique employed to bind a graft union. A properly sealed bag providing it has no flaws, will not require attention during pretreatment no matter how long this period might be.

Bags of seeds needing pretreatment by cold are placed in a refrigerator, set at about 40°F for the required time. Those needing

two stages of pretreatment to overcome double-dormancy are placed on a greenhouse bench to undergo warm stratification; after this is done they are transferred to the refrigerator to fulfill the cold requirement.

This method of handling seeds has a number of distinct advantages. No attention is needed during treatment periods, making it care free; and the possibility of human misjudgment or neglect are eliminated, making it dependable. Seeds treated in the conventional manner, if kept under wet soggy conditions or if permitted to dry out through human error, can through such mistreatment, pass into new dormancies or perish. The transparent wall of the bag has the advantage that visual inspections can be made to reveal any activity that occurs within. For example, when dealing with materials such as *Davidia, Chionanthus* and many of the *Viburnums* which have epicotyl, or shoot bud dormancy, the extent of radicle development can be easily observed in this way.

Stratifying Media

The stock medium used for this purpose is composed of half sand and half peat moss. A few tests of stratifying media have been made using a variety of materials such as Perlite, sand, peat moss, sphagum moss, unsterilized potting soil and vermiculite. It was found that three peonies performed best in a medium of plain sand but with other subjects there was no improvement over the sand and peat moss combination. Some people use sphagnum moss as a medium and for seeds needing only periods of cold, this would be satisfactory. However, for seeds dependent upon the break-down of impervious coats by micro-organisms, its use becomes questionable as sphagnum moss has anti-biotic properties which could retard this action.

Whenever it is practicable, counted numbers of seeds are used when making tests to acquire germination data. If they are small, and counting would be too time-consuming or difficult, measured amounts are used so that reasonable comparisons of germination can be made. The percentage of sound seeds is usually determined by a cutting test but no tests of germinative capacity have been performed.

When working with seeds at a botanical institution one is called upon to handle material from a wide variety of species from many parts of the world, some of which have never been in cultivation. Furthermore seed gathered at such an institution often provides sufficient quantities even of rare subjects to allow a dozen or more treatments, while work involving seeds from other sources may be limited by the supply.

Experiences with Some Selected Materials

This final section will describe a selection of experiences with such materials. The importance of variability in seed dormancies should be stressed. Many will perform consistantly in a manner similar to these examples, yet when collected from other sources, or when stored by different methods, behavior of some might be unpredictable.

Ilex serrata when subjected to eight experimental pretreatments, responded best to 3 months at 40° F producing a good germination in 7 days. One lot sown without pretreatment produced a single seedling in 7 months.

Ilex latifolia, I. integra, and *I. yunnanensis* when provided with 5 months of warm followed by 3 months of cold produced a general germination for each.

Ilex crenata convexa produced a germination without pretreatment of 76% and a 90% stand after 3 months at 40°. Two months of warm stratification followed by 2 months of cold also produced a germination of 90%, whereas longer treatments of 3 months warm followed by 3 months of cold reduced the stand to 72%.

Actinidia polygama germinated generally in 20 days after three months of cold while *A. kolomikta* provided its best germination in 23 days after 3 months of warm followed by 3 months of cold stratification.

In Styracaceae—*Pterostyrax corymbosa* and *P. hispida* performed best after 3 months of cold. *P. corymbosa* when sown without pretreatment started an erratic germination in 8 days which was still continuing 5 months later. One lot provided with 3 months of cold produced a uniform stand in 12 days.

Styrax obassia and *S. japonica* are each doubly-dormant and germinated best after 5 months of warm followed by 3 months at 40°. However, in each case some sound seeds remained which would perhaps have germinated if longer warm periods were given or sulphuric acid scarification was tried.

When tried with 5 pretreatments *Cornus controversa* and *C. racemosa* each did best with a 5 month warm and 3 month cold combination. *C. hessei* needed only a single treatment; 3 months of cold for germination.

Four months of warm followed by 3 months of cold satisfied the requirements needed to germinate both *Staphylea trifolia* and *S. colchica.*

Ptelea nitens performed as does our native *P. trifoliata* and germinated after receiving 3 months of cold.

When sown without pretreatment *Poncirus trifoliata* produced an 85% germination in 9 months but with 3 months of cold stratification a 140% germination took place in 24 days. This figure sounds ridiculous but as these seeds were polyembrionic more than one seedling developed from some of the seeds.

Prinsepia sinensis has no dormancy. After 14½ months of dry storage it still produced a general germination, the longest period for which we have a storage record.

Pseudolarix amabilis germinated erratically without pretreatment but after two months of cold stratification a uniform stand of seedlings appeared in 10 days.

Of six *Kalopanax pictus* pretreatments 4 months of warm followed by 3 months of cold produced a 15% germination, 5 months warm and 3 months cold a 37% germination and 6 months warm 3 months cold a germination of 47%.

Seeds of *Acanthopanax henryi* were received from Czechoslovakia in the month of May. Their period of stratification was planned so that if germination occurred it would take place under conditions favorable to seedling growth. That is during the lengthening days of late winter rather than the short days of late autumn or early winter when growth is less vigorous and disease possibility more prevalent. When seeds are thought to be doubly-dormant the warm treatment is lengthened to arrive at such timing. Stratification periods of 6 months and 3 months resulted in a late February sowing date and a germination which was completed in 7 days.

Celastrus stephanotifolius behaved as our native *C. scandens* does with general germination occurring after 3 months of cold stratification.

Eucommia ulmoides, which has a reputation for germinating poorly, produced a germination of 40% in ten days when given a 2 month cold period. These were the best results in two instances.

In cooperation with a graduate student, working on the quinces, seeds of the three species of *Chaenomeles* and a large number of cultivars were germinated. In all cases a 2 month period of cold proved to be the best method of treating both *Chaenomeles* and*Cydonia.*

The period of longevity of *Albizia julibrissin* seeds in dry storage is extremely long. Seeds collected in China in 1793 were stored in a box at the British Museum of Natural History. In September of 1940, during the course of an air raid fire, the box became wet and the seeds germinated after 147 years of dry storage. Should a person worry about the hazards of working with acid, or not have facilities to provide hot water, he still has another method of germinating *Albizia julibrissin* seeds — just store them in a box for 147 years and then soak them down with a fire hose.

MODERATOR LEACH: Thank you, Mr. Fordham.

We have five minutes for questions which is on a subject of great interest as I can see, looking at the audience.

MR. JAMES WELLS: I would like to ask Al Fordham what treatment he gives Amabilis.

MR. FORDHAM: A cold period of about five months followed by three months — we have had good success with three months of each, but I think a longer period of warm stratification would be better.

MR. SHUGERT: I would like to address this to Tom. Tom, have you had any experience in the germination of virginianas?

MR. PINNEY: The *Juniperus virginiana* — we have had considerable trouble with variation in the storage and germination characteristics of this seed.

MR. HILL: Tom, will you give us a brief description of this Dybvig machine for cleaning and flushing the seeds?

MR. PINNEY: Yes, Jack, it is a little cylinder. The whole machine isn't over two and a half feet high and I imagine 18 inches around. There is a series of discs. The tighter you put the discs down or screw them down, and the amount of water you use, and speed you rotate the discs determines the efficiency of the cleaning

operation. You can clean some very delicate seeds with it very nicely by changing speed and by changing the pressure. Sometimes we use this in *Juniperus virginiana,* trying with water to get the waxy coat off.

MR. LOWENFELS: Wasn't some work done on viburnum at these proceedings where the seed was germinated better if it was picked before it was ripe? Have you done anything on that?

MR. FORDHAM: We have tried this with a few things but we haven't had very much success by picking seed prior to ripening.

DR. REISCH: Chad, would you comment on this work done at Ohio State by B. P. Smith years ago on the time the seed was collected? I wasn't around at that time.

DR. CHADWICK: Back some 20 years ago there was a report that came out of Iowa by the city forester who had been collecting and germinating seed of viburnum for several years. He stumbled onto the fact that if the seed was collected just previous to the time it was ripe, I would say probably two to three weeks before you normally would collect it, and if it was taken at that time and sown directly, that germination was considerably better than going through the regular stratification period.

Now we attempted to repeat that work at Ohio Stae and I must say that we were not successful in getting the same results that he reported.

MODERATOR LEACH: I might be able to add just a word. Japonica if collected in the middle of November will scarely germinate at all. If you take the seed about the middle of August and dry in an oven at 102 degrees and sow immediately, it will germinate very well.

I believe we have time for one more question.

MR. WAYNE LOVELACE: For the past four years we have picked *Viburnum trilobe* and *Viburnum dentatum* just prior to ripening and all four years seeded directly to the field in August and got germination the following spring. We did that again this year and upon inspecting our seedling areas, the Japonica apparently were well germinated. We have also done this with *Cornus mas.* So apparently there is something to consider here.

DR. REISCH: How many warm days do you have following sowing?

MR. LOVELACE: Again we normally sow that immediately upon collection, which is in August. Of course, we have a good warm August and September.

MODERATOR LEACH: Gentlemen, I am sorry to have to cut off this discussion. It is a subject of great interest to all of you, I know, and I hope you can corner Dr. Reisch, Tom Pinney and Mr. Fordham after this session. To all three we are greatly indebted.

I will turn this meeting back to President Bill Snyder.

PRESIDENT SNYDER: Thank you very much, Dave.

The meeting this afternoon will commence at 1:15.

(The session recessed at 12:10 o'clock.)

RECESSED