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Establishing a Propagation Database

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Title: Establishing a Propagation Database

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Abstract:

The Morris Arboretum has been propagating woody plant material since its inception in 1932. The current system of record keeping has been in place since the late 1970's, coinciding with the approximate date of the first international plant exploration trip undertaken by the Arboretum. The records of each plant propagated are maintained on index cards and include source information, germination protocol and results. The system is straightforward, easy to use, compatible with input from several individuals and easy to access. The purpose of this project is not to replace the current system, but rather to review the records accumulated in the past twenty-five years and consolidate them in such a way that the records from individual genera may be viewed as a whole and conclusions may be drawn more easily from past efforts. It is intended that the information can be easily updated as propagation efforts continue. The project is limited to those genera identified by the propagator as being of particular interest or uniquely challenging from a propagation perspective. The project includes spreadsheets detailing past propagation attempts, research from accepted authorities, synopses of propagation research and Arboretum experience, and collected research relative to the same. It is intended as a resource for future propagators, interns and other interested persons relative to the propagation of woody plant material from seed.

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INTRODUCTION

Propagation has been ongoing since the inception of the Morris Arboretum in 1932. The records that have been reviewed, compiled and summarized in this project are those that are maintained in the head house dating to the late 1970's. Older records exist, but are maintained in the offices of the Plant Recorder, Elinor Goff, and have not been included in this project. The purpose of this project is to review the research records of selected genera and compile them in such a way as to make them readily accessible to the Arboretum propagators in a format that is easy to read and subject to future updating.

METHODS

Upon collection and/or receipt of seeds by the propagator, the seeds of each species, or seeds collected from individual trees within the same species, are given a greenhouse accession number, and a green accession card is completed for each accession. The greenhouse inventory is updated to include the newly-acquired seeds. Accession cards for seeds in active propagation are kept in a separate file and updated as seeds move through the process of cleaning, stratification, germination and potting. Once seeds have germinated and the seedlings have been potted up, the cards are filed in the inactive file and the inventory is modified to indicate the number of seedlings. When seeds fail to germinate after a reasonable period of time, they are discarded and the cards are filed in the inactive file.

The records included in this project are maintained on 5" x 8" index cards and kept in file drawers in alphabetical order by genus, then chronological order by the greenhouse accession number. The earliest cards are all white index cards containing relatively few categories for completion and even less completed information. When the information on such cards was so sketchy as to be useless, it was omitted from this project.

The index cards were updated in the early 1980's and contain lines for identifiers as well as propagation methods, media and results. These cards are also color-coded, with green cards used for seed propagation and pink and yellow cards for cutting propagation. A shortcoming of the seed propagation cards is that they do not provide adequate space and delineation for separate treatments within an accession. The seed propagation cards have been updated in the course of this project to provide for separate treatments. A copy of the proposed card is included in the Appendix.

In the course of this project, sixteen genera have been reviewed and compiled on individual spreadsheets. The information on the spreadsheets replicates that contained on the index cards. A sample spreadsheet is included in the Appendix. Each genus is reviewed and synopsized separately. This synopsis includes research from authoritative sources, a review of successful and unsuccessful stratagems and conclusions. The synopses of the genera reviewed to date is included in the Appendix. The spreadsheets, synopses and compiled research are included in a reference notebook to be kept in the head house. All of the information included in the project notebook is maintained on the internal and external hard drives in the head house so that it can be updated as propagation continues in the future.

DISCUSSION

I. Sexual vs. Asexual Reproduction

Plants in the wild reproduce either sexually, through seed production, or asexually through vegetative organs such as roots and shoots. Asexual reproduction produces a clone, or exact duplicate, of the parent plant. Sexual reproduction through seed production produces offspring with a unique genotype separate from the parent plant. It is through this process of natural selection that plants are able to adapt to their environments.

Commercial propagation of trees and shrubs is most often accomplished through asexual, vegetative propagation by means of cuttings and grafting. Cultivars are naturally occurring selections chosen for particular attributes such as fall color, form or flowering potential. Once identified, a cultivar is cloned through cuttings and marketed under the cultivar name, such as *Acer saccharum* 'Red Sunset'. While this form of reproduction results in uniformity and a proliferation of trees with a particular attribute, it also produces a monoculture. A residential street lined with Red Sunset sugar maples is unquestionably attractive due to the uniformity of the trees and the outstanding color in the fall. The risk to this practice is that, since the trees are genetically identical, a fungi, bacteria or insect that has the ability to destroy one tree will have the ability to destroy all the trees.

The Morris Arboretum is committed to genetic diversity through plant exploration. This is accomplished through the propagation of seeds collected throughout the world. If superior varieties are found amongst these collected seeds, the goal of genetic diversity is furthered. However, the goal is only partially achieved if the newfound varieties are then reproduced clonally as opposed to sexually through breeding and seed production.

II. The Problem With Seeds

Most seeds have dormancy mechanisms that inhibit germination. This is nature's way of ensuring the survival of the species by delaying germination until the conditions are favorable for growth of the plant and also to draw out the germination period for a batch of seeds produced in any given year so that all seeds don't germinate at the same time. While dormancy mechanisms ensure the survival of the species, they play havoc on a commercial nurseryman's production schedule. This is likely one reason why so much production is accomplished through cutting and grafting rather than seed propagation.

Absent dormancy mechanisms, a seed would be sown, it would germinate, and a plant would result. Every seed would result in a plant, and no research or records would be necessary. A number of species have no dormancy mechanisms and can be sown directly. Those species are not included in this project. Most seeds of woody plants require some period of warm or cold stratification, or both; and many require pretreatments such as scarification. Before propagating a seed accession at the Arboretum, research is conducted to determine the best method of germinating the seed batch.

Whether little is known about seed propagation because it's not practiced a great deal, or whether it's not practiced because so little is known and understood about seed propagation, the result is that there are few reliable sources of information relative to seed propagation. Three sources are relied upon for detailed information on seed propagation of individual species. The oldest and best, Seeds of Woody Plants in the United States, Agriculture Handbook No. 450, was published in 1974 by the U.S. Department of Agriculture. The drawback to this book is that it restricts itself to woody plants native to the United States and has not been updated since 1974 to include current research.

Seeds of Woody Plants in North America by James Young and Cheryl Young was published in 1992 and represents itself as a "revised and enlarged handbook" based on the above-referenced Handbook 450.

The most comprehensive resource is The Reference Manual of Woody Plant Propagation by Michael Dirr and Charles Heuser, published in 1987. This reference, together with Dirr's Manual of Woody Landscape Plants (1998), is most cited in the research included in the propagation records of the Arboretum. The weakness of this reference is that it often gives propagation information without citation to a source and less often gives the author's actual experience.

The synopsis page preceding each genus in the database cites all three reference manuals for the purpose of comparison and to save future researchers (propagators and interns) the time involved in reviewing all three.

In addition to information contained in reference manuals, research cited on propagation cards and relied upon in determining propagation protocol includes past propagation efforts by the Arboretum that is contained in the inactive propagation file. In many ways, this information is more reliable than the authorities cited above. The records include first-hand and anecdotal information relative to past propagation efforts. Often a record will exist in the Arboretum files for an unusual species of plant that is not found in the propagation manuals. The difficulty in utilizing the Arboretum records is that they can be numerous; and by reviewing individual records, the over-all picture or solution may be difficult to discern. The compilation of individual records into spreadsheets by genus allows the researcher to review and compare records more easily and comprehensively.

III. Overcoming Dormancy Mechanisms and Other Issues

A. Seed Viability

Seeds accessioned at the Arboretum are generally collected in the wild. Often they are collected half a world away, sometimes by unknown collectors, and travel to the Arboretum through circuitous means involving time delays, quarantines and questionable handling practices. The quality of the seed arriving at the Arboretum must be assessed if germination percentages are to have any meaning. For example, a protocol which results in a ten percent germination rate may be deemed unsuccessful and not retried. However, if that same seed lot was assessed for viability and determined to be only forty percent viable, the true germination percentage would be twenty-five percent—worth repeating. Several methods of testing seed viability are commonly used.

The easiest method of determining viability, and one that can be used in the field at the time of collection, is the cut test. This involves cutting the seed open to determine if there is a seed within the seed coat or shell and visually assessing the seed for moisture content (wet vs. dry) and health (rotten or not). A refinement of this method can be used at various stages of handling. For example, a seed can be cut open after stratification and before sowing to determine if the seed is healthy or rotten and, more importantly, to determine if any structures—radicles or cotyledons—are visible. In examining a seed under a microscope, a seed ready to germinate will have a clearly defined radicle in position to emerge from the seed coat.

A second method of assessing seed viability is the float test. Seeds are placed in a container of water; seeds that float are considered non-viable, while seeds that sink are considered viable.

The most precise test of seed viability is the tetrazolium test. In this method, seeds are soaked in a solution of tetrazolium. The exact protocol for each genus is set forth in the Tetrazolium Testing Handbook, which is not currently available at the Arboretum. The need for different protocols is due to the different characteristics of the seed coats. Some seeds may need to be punctured before soaking or may need to be pre-soaked in water before soaking in tetrazolium. The tetrazolium test distinguishes between viable and dead tissues of the embryo on the basis of their relative respiration rate in the hydrated state.[1] Since viable, respiring tissue will stain red, cutting open the seed after soaking in the solution will allow for evaluation of all the seed structures for viability.

B. Dormancy

A seed is defined as dormant when all conditions favorable to germination are met but it fails to germinate. Dormancy can be divided into two categories—physical and physiological.

Physical dormancy is most often characterized by a hard seed coat. A hard seed coat is one that restricts the flow of water and gases in and out of the seed or physically prevents the emergence of the radicle. The inability of water to pass through the seed coat not only inhibits the intake of water but prohibits the leaching of substances within the seed that inhibit germination. The hardness of a seed coat cannot always be determined by a physical examination. Some seeds that appear to have hard seed coats, such as Quercus, in fact do not. Seeds with hard seed coats include Tilia and Koelreuteria. Dormancy caused by a hard seed coat can be overcome by removal of the seed coat, scarification of the seed coat, either mechanically or with acid, or warm stratification. Removal of the seed coat cannot always be accomplished without damaging the seed. At the Arboretum, acid scarification is often used to overcome a hard seed coat. Experience has shown that a combination of acid scarification and stratification can reduce the thickness or soften the seed coat, thus enabling or enhancing germination. Removal of the seed coat is often possible after stratification, further enhancing germination. (See *Koelreuteria panicula*, Greenhouse Accession No. 2005x123).

Physiological dormancy is that which is caused by factors within the seed itself. Seeds that are surrounded by fleshy fruits, such as Magnolia and Cornus, should be cleaned immediately, as

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[1] Copeland, Lawrence O. and McDonald, M.B., 2001, Seed Science and Technology, Kluwer Academic Publishers: Boston, Mass.

the fleshy covering may contain germination inhibitors or may prevent the intake of water to the seed through osmotic inhibition.[2] Substances within the seed that effect germination include gibberellins, cytokinins and abscissic acid (ABA). A very simple explanation of the role and interaction of these hormones would be to define ABA as an inhibitor and gibberellins and cytokinins as promoters of germination. The balance between these hormones determines whether the seed germinates or remains dormant.

Physiological dormancy is overcome by imposing periods of cold or warm stratification under moist conditions or alternating periods of both. Finding the right balance of these conditions is the challenge of the propagator. External application of gibberellins or cytokinins can promote germination, and gibberellic acid (GA_3) has been used at the Arboretum. Gibberellic acid promotes growth of the hypocotyl while cytokinin promotes root growth. One concern of using externally applied gibberellic acid without also using cytokinin is that the shoot may be etiolated and the root will be insufficient to support the plant.[3]

Some species, including white oaks, *Chionanthus* and *Viburnum*, exhibit hypocotyl dormancy. In these species, the root emerges and a period of cold stratification is required to overcome the shoot dormancy. In practice, these seeds should be sown in flats to allow radicle emergence prior to cold stratification, as sowing after radicle emergence can damage the radicle.

Finally, species such as Magnolia, Lindera and Ilex produce seeds with immature embryos. While not a dormancy mechanism under the strict definition, the seeds will fail to germinate until the embryo has achieved the requisite growth. This is generally accomplished through a period of warm, moist stratification prior to any required period of cold stratification, often referred to as after-ripening.

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[2] Copeland, Lawrence O. and McDonald, M.B., 2001, Seed Science and Technology, Kluwer Academic Publishers: Boston, Mass.

[3] Rascio, Nicoletta, Mariani, Vecchia, Rocca, Profumo & Gastaldo, "Effects of seed chilling or GA_3 supply on dormancy breaking and plantlet growth in *Cercis siliquastrum* L., Plant Growth Regulation 25:53-61, 1998.

CONCLUSION

The spreadsheets that have been compiled in the course of this project, along with the synopses of each profiled genus, are a starting point for assessment of a given seed batch for germination protocol. It is important that the propagation cards be completed as thoroughly as possible, as these provide a reference for future propagations and are a valuable resource for propagators at the Arboretum and elsewhere. Because seed counts were often missing, it was not possible to calculate germination percentages for many seed lots. In these instances, the germination percentage was listed as 1% or >1%; and these are listed in the synopses as successful propagations. Because the relative success cannot be measured, the protocol may bear repeating to determine its validity.

Seed propagation is a trial-and-error process. Each successful propagation solves one piece of the puzzle and serves as a building block for the next attempt.

The Morris Arboretum is in a unique position to further research into the propagation of trees and shrubs from seed. Its non-profit status allows it to pursue endeavors for the sake of the pursuit rather than the profitability of the pursuit. The grounds of the Arboretum provide a ready source of seed for research, and the international plant collection efforts provide additional material for research. One of the missions of the Arboretum is to educate--conducting and publishing research would further this mission. More importantly, there is a need for further research in seed propagation of woody species because it isn't being done on a comprehensive basis anywhere else. The Arboretum is committed to the promotion of genetic diversity. While the current climate may favor asexual reproduction, sexual reproduction remains the only way to breed new species, to take advantage of the mechanisms and protection of natural selection and to further the goal of genetic diversity.

REFERENCES

Copeland, Lawrence O. and McDonald, M.B., Seed Science and Technology, Kluwer Academic Publishers, Boston: 2001.

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Dirr, Michael A. and Heuser, Charles W., Jr., The Reference Manual of Woody Plant Propagation, Varsity Press, Inc., Athens: 1987.

Hartmann, Hudson T., Kester, Davies & Geneve, Hartmann and Kester's Plant Propagation Principles and Practices, Seventh Edition, Prentice Hall, Upper Saddle River, New Jersey: 2002.

U.S. Dept. of Agriculture, Seeds of Woody Plants in the United States, Agriculture Handbook No. 450, Washington, D.C.: 1974.

Young, James A. and Young, Cheryl G., Seeds of Woody Plants in North America, Timber Press, Portland: 1992.

APPENDIX A: SEED PROPAGATION CARD TEMPLATE:

Scientific Name:____ Date: ___ ___/___ ___/___ ___

Greenhouse Acc. # ________ x _________ Permanent. Acc.#_________ - ________
Collection Date: _____________________
Collection Information:______________________________ Wild Collected: ____________________
Viability: Cut Test: ________ Other: ________________ Direct Sown:(Date) _________________

	TRT 1	TRT 2	TRT 3
Quantity of Seed:			
Scarification:			
Stratification:			
Media:			
Baggie:			
Sown in pot:			
- warm: (Dates)			
- cold: (Dates)			
- warm: (Dates)			
Germination Date:			
Germination Percentage:			

Additional Treatments: Bottom Heat: ________ Fungicide: (rate/freq) ______________________________
Extended Photoperiod: ________ Other: _____________________ Disasters: ________________________

APPENDIX B:MORRIS ARBORETUM PLANT COLLECTING TRIPS SINCE 1979

MA Rep.	No.	Destination/Year	Psource.num	Keyword
PWM	1	Korea-Taiwan 1979	1	KT
PWM	2	China & Korea 1981	2 & 3	CK
PWM	3	Korea 1984	4	KNW
PWM	4	Korea 1989	5	NEKG
PWM	5	China 1991	477	NACPEC
RJL	6	Korea 1991	508	RJL
PWM	7	China 1993	541	HLJ
PWM	8	China 1994	557	WD
RJL	9	China 1994	558	BJG
RJL	10	China 1995	570	SHX
RJL	11	China 1996	604	QLG
PWM	12	China 1997	625	NACPEC97
RJL	13	China 1998	642	TS
ASA	14	S.E. U.S. 2000	682	MWPCC
PWM	15	Armenia 2002	724	ARM
ASA	16	China 2002	725	NACPEC02
ASA	17	England-Belgium 2004	767	WHIP
PWM	18	Republic of Georgia 2004	812	GE-2004
ASA	19	China 2005	840	NACPEC05

APPENDIX C: GENERAL REVIEW PAGES

GENUS: **Abelia**

TOTAL SPECIES: **5**

PROPAGATION ATTEMPTS: **15**

% SPECIES PROPAGATED SUCCESSFULLY: **80%**

RESEARCH:

Dirr & Heuser:

Abelia x grandiflora – collect and sow seed when ripe.

H.B. 450:

Not listed.

Young, etc.:

Not listed.

ARBORETUM RECORDS:

Species	Times Propagated	Highest Germ. Rate
biflora	9	>1%
coreana	2	>1%
dielsii	1	0%
schumannii	1	>1%
taihyoni	2	>1%

SUCCESSFUL STRATAGEMS:

With one exception, Abelia has been direct sown at the Arboretum. A. biflora germinates within 30-45 days. Other species require 2-6 months. A. schumannii was the only species given 3 months cold stratification and successfully germinated after six months. Banrot was frequently used, which might indicate problems with damping off of seedlings.

UNSUCCESSFUL STRATAGEMS:

A. coreana was propagated two times, with only one attempt resulting in germination, which yielded 3 seedlings, although germination was within two months. A. dielsii was propagated one time and failed to germinate with direct sowing.

GENUS: **Abies**

TOTAL SPECIES: **33**

PROPAGATION ATTEMPTS: **84**

% SPECIES PROPAGATED SUCCESSFULLY: **94%**

RESEARCH:

Dirr & Heuser:

Cold stratification of 0-3 months. "Best results are obtained with fresh seed that is fall planted or stratified 1-3 months." Collect cones in fall and allow to dry inside until seed is released.

H.B. 450:

Collection practice – After-ripening of the seed involves metabolic changes in the seed. "…[S]eed should not be extracted from cones immediately after collection, particularly not from early-collected cones. Immediate extraction can result in seed of low viability."

Cold stratification speeds germination for many Abies species and in some cases increases total germination. Generally, stratify at 34 – 41 deg. F. for 14-28 days. "A soaking period prior to stratification has been suggested." See Table 7 on p. 178.

Young, etc.:

"Laboratory studies…illustrate 4 factors about the basic physiology of [Abies] seed: (1) the embryo can be dissected from the seed coat and made to germinate without dormancy problems, suggesting that dormancy is associated with the covering of the embryo; (2) light is necessary for germination in most species; (3) pre-chilling seed for 2 to 4 weeks enhances germination; and (4) reduces or in some species replaces the light requirement for germination." See tables on p. 7 for stratification requirements of individual species.

Seeds tend to become infected with fungi, especially Rhizoctonia. Dusting with fungicide recommended.

ARBORETUM RECORDS:

Species	Times Propagated	Highest Germ. Rate
sp.	4	0%
alba	2	31%
amabilis	2	18%
balsamea	1	40%
barisii-regis	1	5%
cephalonica	2	>1%
cilicia	2	>1%
concolor	4	25%
delavayi	3	<1%
densa	2	0
equi-trojani	1	>1%
ernestii	2	>1%
fargesii	2	>1%
firma	2	<1%
forrestii	3	>1%
georgei	1	>1%
gracilis	1	25%
grandis	3	27%
holophylla	7	100%
kawakamii	2	>1%
koreana	6	9%
lasiocarpa	3	63%
magnifica	3	>1%
mariesii	1	>1%
mexicana	1	<1%
nephrolepis	6	57%
nordmanniana	5	40%
pindrow	2	58%
procera	4	15%
recurvata	1	0*
sachalinensis	1	>1%
squamata	1	>1%
veitchii	4	>1%

* Current accession in propagation successfully germinated.

GENUS: **Acer**

TOTAL SPECIES: **104**

PROPAGATION ATTEMPTS: **332**

% SPECIES PROPAGATED SUCCESSFULLY: **63%**

RESEARCH:

Dirr: See listings for individual species.

H.B. 450: See table on p. 191 for stratification requirements of individual species; probably need a minimum of 15% moisture content; for best results, sow in fall at ¼ - 1" depth; rupture pericarps on circinatum, ginnala and negundo; treat seedbed with fungicide to prevent damping off.

Young, etc.: See dormancy discussion on pp. 14-15. Some general indications:

1) seed covering may inhibit/reduce water or air to embryo or mechanically restrict embryo growth;
2) removal of pericarp and testa may reduce pre-chilling requirement by two-thirds (testa may restrict outward flow of water, slowing leaching of germination inhibitors);
3) abscissic acid levels relevant;
4) cytokinins increase over the period of chilling (maximum level of 1 mo.) and interruption of chilling period reduces cytokinin levels and imposes secondary dormancy;
5) soaking up to 14 days reduced chilling requirement (in A. saccharum);
6) trifoliates have ligneous pericarp that delays germination for years; successful germination in 21 days of excised embryos in lighted incubator on culture w/10 mg per liter GA.

ARBORETUM RECORDS:

Species	**Times propagated**	**Highest Success %**
acuminatilobum	4	Y
acuminatum	1	Y
argutum	1	N
barbinerve	10	Y
buergerianum	12	Y
caesium ssp. giraldi	1	N
campbellii	1	Y

Species	Times propagated	Highest Success %
campbellii ssp. wilsonii	1	N
campestre	6	Y
campestre cv compactum	1	
capillipes	2	Y
cappadocicum	1	N
capadocicum var. sinicum	1	Y
carpinifolium	6	Y
caudatum ssp multiserratum	2	Y
caudatum ssp ukurunduense	3	N
caudatum var. prattii	2	N
circinatum	2	N
circinatum Pursh	1	N
cissifolium	2	N
crataegifolium	7	Y
davidii	6	Y
davidii ssp davidii	2	Y
distylum	2	Y
erianthum	2	N
fabri	1	Y
forresti	1	N
franchetii	3	Y
ginnala	4	Y
ginnala var. flame	1	Y
glabrum	2	Y
glabrum var. douglasii	3	N
glabrum var. torreyi	2	Y
grandidentatum	2	Y
griseum	21	Y
grosseri	3	Y
heldreichii	1	N
heldreichii ssp trautuetteri	2	Y
henryi	2	Y
hyrcanum	1	N
hyrcanum ssp sphaerocarpum	1	N
japonicum	4	Y
japonicum ‘Aconitifolium’	1	N
kawakamii	1	N
laxiflorum	2	N
macrophyllum	4	Y
mandshuricum	15	Y
maximowiczii	3	N
micranthum	2	N
maximowiczianum	1	N

Species	**Times propagated**	**Highest Success %**
miyabei	1	Y
miyabei ssp miaotaiense	3	Y
mono	11	Y
mono ssp mono	1	Y
mono var. macropterum	1	N
monspessulanum	2	Y
morrisonense	2	Y
nigrum	1	Y
nikoense	2	N
oblongum	1	N
okamotoanum	4	Y
oliverianum ssp oliverianum	1	Y
palmatum	3	Y
palmatum cv "Chishio'	1	N
palmatum ssp amoenum	2	Y
palmatum var. dissectum	2	Y
palmatum var. heptalobum	4	N
palmatum cv 'Matsumurae'	1	Y
palmatum cv 'Osakazuki'	1	N
palatum cv "Sangu-kaki'	1	N
pectinatum ssp maximowiczii	1	N
pensylvanicum	1	Y
pseudoplatanus	1	N
pseudosieboldianum	14	Y
rufinerve	8	Y
saccharum	1	N
saccharum "Caddo'	1	N
schneiderianum	1	N
semenovii	1	Y
serrulatum	2	Y
shirasawanum	4	N
sieboldianum	4	N
sinense	1	Y
spicatum	5	Y
stachyophyllum	3	N
stachyophyllum ssp. betulifolium	1	N
stachyophyllum v. pentanerum	1	Y
sterculiaceum ssp franchetii	2	N
takesimense	5	Y
tataricum	2	Y
tegmentosum	7	Y
tetramerum var betulifolium	1	Y
triflorum	25	Y

Species	Times propagated	Highest Success %
truncatum	5	Y
truncatum ssp mono	10	Y
truncatum ssp mono cv “Marmoratum’	1	N
tschonoskii	3	Y
tschonoskii var. rubripes	4	Y
tsinlingensis	1	Y
ukurunduense	5	Y

Note: Because of the extreme number of propagations, and because the vast majority utilized three months cold stratification, a spreadsheet was not completed. Highest success percentage indicates only whether the propagation attempt was successful (Y) or not (N). For future reference, refer to the Greenhouse copy of this project and to an updated Acer project for 2005 NACPEC and Polly Hill accessions.

GENUS: **Chionanthus**

TOTAL SPECIES: **3**

PROPAGATION ATTEMPTS: **13**

% SPECIES PROPAGATED SUCCESSFULLY: **100%**

RESEARCH:

Dirr & Heuser:

C. retusus – 1-3 mo. warm (watch for radicle emergence), then 2-3 months cold. May not germinate until second spring.

C. virginicus – "Dormancy is deep seated and appears to involve hard bony endocarp, inhibitors in the endosperm and dormancy in the shoot portion of the embryo." Stratify for 3 months warm followed by 3 months cold.

H.B. 450:

C. virginicus – Warm stratification for 3-5 months required for radicle emergence. "[C]old exposure during winter overcomes the shoot dormancy."

Young, etc.:

Cites Dirr & Heuser verbatim.

ARBORETUM RECORDS:

Species	**Times Propagated**	**Highest Germ. Rate**
retusus	3	7%*
virginicus	9	>1%*
yunnanensis	1	<1%

* See 2005-06 propagation attempts.

SUCCESSFUL STRATAGEMS:

C. retusus – The recommended stratification protocol has not been very successful at Morris. The highest percentage—7%-- yielded only one seedling and involved 3 months warm stratification and placement in the Medicinal House in February. It appears that it did take a second winter to produce germination. In Accession 93x563, ten seeds germinated; however, if germination is defined as emergency of the radicle (and it should be), germination alone does not produce a viable seedling since Chionanthus has shoot dormancy.

C. virginicus was most successful with 86x213, resulting in two dozen plants. It appears that seeds germinated with four months cold stratification only and no period of warm stratification, but without a germination date, it's unclear if a second winter was required.

UNSUCCESSFUL STRATAGEMS:

Direct sowing and placement of seed trays in the Medicinal House was not successful.

CONCLUSIONS:

Chionanthus has double dormancy involving both the radicle and the hypocotyl. The protocol suggested by Dirr is clearly not adequate. Research indicates that *Chionanthus* has a hard seed coat and that embryo excision is very successful. Short of excising the embryo, either acid scarification or a longer period of warm stratification may be useful to break down the seed coat. Giberellic acid has also been used to overcome the shoot dormancy (See Chien, et al. listed below).

BIBLIOGRAPHY:

Ching-Te Chien, Kuo-Huang, Shen , Zhang, Chen, Yang & Pharis, "Storage Behavior of *Chionanthus retusus* Seed and Asynchronous Development of the Radicle and Shoot Apex during Germination in Relation to Germination Inhibitors, Including Abscisic Acid and Four Phenolic Glucosides", Plant Cell Physiology, 45(9): 1158-1167 (2004).

GENUS: **Cornus**

TOTAL SPECIES: **19**

PROPAGATION ATTEMPTS: **94**

% SPECIES PROPAGATED SUCCESSFULLY: **79%**

RESEARCH:

Dirr & Heuser:

Species whose fruit ripens in summer will require warm stratification followed by cold. These include C. alba, C. racemosa, C. sericea, C. amomum & C. mas. Individual requirements as follows:

Species	Warm	Cold
C. alba		2-3 mo.
C. alternifolia	2-5 mo.	2-3 mo.
C. amomum		3-4 mo.
C. controversa	5 mo.*	3 mo.
C. florida		3-4 mo.
C. kousa		3 mo.
C. macrophylla	3 mo.	3 mo.
C. mas	4-5 mo.	3 mo.
C. officinalis	4-5 mo.	3 mo.
C. racemosa	2-5 mo.	3-4 mo.
C. sanguinea	3-5 mo.	3 mo.
C. sericea		2-3 mo.
C. walteri	4 mo.	4 mo.

* Research from Korea indicates that seed germinated with 3-4 hr. sulfuric acid scarification and 3 mo. cold. (Query: will acid replace warm requirement for other *Cornus* species?)

H.B. 450:

See table on p. 450 for specific requirements. "Seeds of all species show delayed germination due to dormant embryos; in most species hard pericarps also are present. Where both types of dormancy exist, warm stratification for at least 60 days…followed by a longer period at a much lower temperature is required. Immersion in concentrated sulfuric acid for 1-3 hours or mechanical scarification can be used in place of warm stratification. Soaking stones in gibberellic acid for 24 hours also has been successful for *C. drummondii* and *C. florida*."

Young, etc.: Ditto above.

ARBORETUM RECORDS:

Species	Times Propagated	Highest Germ. Rate
alba	1	100%
alternifolia	5	12%
amomum	2	>1%
bretschneideri	4	10%
capitata	2	>1%
chinensis	2	0%
controversa	6	<1%
drummondii	1	>1%
florida	11	67%
kousa	18	100%
macrophylla	7	100%
mas	11	66%
nuttallii	5	60%
officinalis	12	62%
poliophylla	2	33%
racemosa	1	0%
sericea	1	0%
walteri	2	>1%
wilsoniana	1	0%

SUCCESSFUL STRATAGEMS:

Cornus kousa was propagated most frequently. Three months cold stratification achieved germination percentages of 0 – 100%. The 100% was achieved with 22 seeds, and the next highest, 88%, was achieved with only 8 seeds. *C. officinalis* was successfully propagated in 7 of 12 attempts, but frequently required a second season to germinate.

UNSUCCESSFUL STRATAGEMS:

Soaking (presumably in hot water) on several occasions proved unsuccessful. There is no indication that any other type of scarification was attempted.

CONCLUSIONS:

Seed should be cleaned and stored properly to maintain viability, although there are no indications that the endocarp inhibits dormancy or that the seeds require a certain moisture content to remain viable. Dirr indicates that seed may be dried and stored in sealed, refrigerated containers for 2-4 years. Clearly, the MA experience would indicate that much of the seed propagated was not viable.

Dirr indicates that *Cornus officinalis* and *Cornus mas* need alternating warm/cold periods and may take 2-3 years to germinate. On at least two occasions (2001x230 and 93x583) MA succeeded in germinating with 4 months warm and 3-4 months cold. Other attempts required overwintering in the Medicinal House. The reasons for this would be interesting to explore.

H.B. 450 indicates that acid or mechanical scarification can replace warm stratification in at least one species of Cornus. Since MA has never tried this, it would be interesting to try scarification on those species requiring warm stratification.

GENUS: **Corylus**

TOTAL SPECIES: **7**

PROPAGATION ATTEMPTS: **12**

% SPECIES PROPAGATED SUCCESSFULLY: **86%**

RESEARCH:

Dirr & Heuser:

Two to six months cold stratification, with three months recommended. "Russian work noted that freshly harvested seed that were warm stratified for 3 weeks followed by 3 weeks at 40 deg. F. germinated best" for *C. avellana.*

H.B. 450:

"Germination is hypogeal. The seeds have a dormant embryo and germinate slowly without pretreatment…" Cold stratification of 2-6 months is required. "Seeds may benefit from alternations of warm and cold stratification, but the best methods have not been worked out."

Young, etc.:

Research indicates that "dormancy…is determined by relative levels of gibberelin and abscissic acid. Dormancy can be effectively overcome by either stratification, which potentiates gibberellin biosynthesis, or by exogenous application of gibberellin." (citing Jarvis and Brandbeer and Pinfield.[4]

ARBORETUM RECORDS:

Species	Times Propagated	Highest Germ. Rate
Americana	3	17%
colurna	2	67%
fargesii	1	>1%
heterophylla	2	>1%
mandshurica	2	30%
sieboldiana	1	0%
tibetica	1	87%

[4] Jarvis, B.C. & D.A. Wilson . 1978. Factors influencing growth of embryonic axes from dormant seeds of hazel. *Planta* 138:189-191.
Brandbeer, J.W. & N.J. Pinfield. 1967. Studies in seed dormancy. III. The effects of gibberellin on dormant seeds of *Corylus avellana*. *New Phytologist* 66:515-523.

SUCCESSFUL STRATAGEMS:

Treatment was most often cold stratification for 3-4 months. On one occasion, seeds were sown and placed in the Medicinal House in November and resulted in 67% germination. On three occasions, seeds were soaked in Gibberellic Acid; and each was successful. Concentrations of GA were either 1 ppm or 2 ppm for 24-48 hours. This is an extremely low concentration, and it may be that the concentrations were actually 1000 and 2000 ppm. The highest percentage of germination rate (87%) was obtained with soaking seeds for 48 hours in 1 ppm GA Soaking for 24 hours in 2 ppm, which would seem to be the equivalent, resulted in 30% germination, although the species were different.

UNSUCCESSFUL STRATAGEMS:

On one occasion, seeds were given two months warm stratification before cold stratification, resulting in 14% germination and only two seedlings. The warm stratification would seem to be unnecessary and perhaps detrimental to successful germination. Four months cold stratification appears to be excessive, with 3 to 3-1/2 months being the optimum time period.

CONCLUSIONS:

Experience at MA tends to validate the research cited above. Seeds germinate quickly after approximately three months of cold stratification and will frequently germinate in the bag. Since seeds are large, germinated seeds may be removed and the balance of seeds returned to cold stratification. MA records show low germination percentages with four months cold stratification; but since research indicates that seeds can be stratified for as long as six months, it might be interesting to try leaving ungerminated seeds in cold stratification for up to six months to see if it increases the germination percentage.

Placement in the Medicinal House will work, but risks delays in germination and damage by rodents.

Use of GA indicates improved germination, but repetition of previous attempts would help to clarify the concentrations needed. It would also be helpful to use two treatments, one with GA and one without, to determine if GA is the critical factor in successful germination.

GENUS: **Lindera**

TOTAL SPECIES: **16**

PROPAGATION ATTEMPTS: **53**

% SPECIES PROPAGATED SUCCESSFULLY: **75%**

RESEARCH:

Dirr & Heuser:

Three to four months cold stratification. Four months produced the best results for *L. angustifolia*, with three months for both *L. benzoin* and *L. obtusiloba*. With respect to *L. benzoin*, Dirr states that "…seed loses viability soon after maturity, but storage at low temperatures may prolong viability." (citing H.B. 450)

H.B. 450:

"…seed has a dormant embryo that responds to stratification for 30 days at 77 deg. F. followed by 90 days…at 34 – 41 deg. F.

Young, etc.:

Same as H.B. 450.

ARBORETUM RECORDS:

Species	**Times Propagated**	**Highest Germ. Rate**
sp.	1	>1%
aggregate	1	0%
benzoin	6	43%
cubeba	1	0%
erythrocarpa	4	6%
floribunda	1	>1%
fruticosa	1	>1%
glauca	16	<1%
neesiana	1	>1%
obtusiloba	6	71%
praecox	3	0%
reflexa	1	0%
salicifolia	2	>1%
sericea	2	20%
strychnifolia	1	7%

umbellata	6	50%

SUCCESSFUL STRATAGEMS:

Pretreatment has generally been 2-4 months cold stratification, with 3 months being the most common. A number of treatments have warm stratified for 30 days or given one week for uptake of water before cold stratification. Highest percentages were obtained as set forth below:

L. benzoin – 43% -- 1 mo warm/2 mo. cold
L. obtusiloba – 71% -- 3 mo. cold
L. umbellata – 50% -- 1 wk. warm/3 mo. cold

Clearly, stratification requirements differ from species to species. The *L. benzoin* treatment above was one of three given on the same accession, with the other two treatments being direct sown and yielding zero to .05% germination. Accessions of *L. benzoin* were also germinated with respectable percentages using one month warm and 3 months cold stratification or 3 months cold stratification only. No comparisons are available on the same accession to determine which protocol would be most successful.

Wide variations in germination percentages on species using the same germination protocol would seem to confirm the research indicating that seeds lose viability unless properly stored at low temperatures.

UNSUCCESSFUL STRATAGEMS:

It is unclear whether giving seeds a period of warm stratification prior to cold stratification is more successful than cold stratification only. Different treatments on the same accession would need to be conducted to determine the best pretreatment method of the two. Viability testing would aid in determining the validity of any pretreatment given *Lindera*'s tendency to lose viability.

It appears from the attached records that Lindera will germinate in the first year after collection. Overwintering in the Medicinal House has been unsuccessful and direct sowing and placement in the Medicinal House has yielded low germination percentages.

There is no indication that four months of cold stratification is better than three months.

CONCLUSIONS:

Seed should be cleaned and cold stored if it can't be processed immediately. Since this is not likely to happen on the Arboretum's plant exploration trips, received seed of *Lindera* should be tested for viability so that the validity of any pre-treatment can be assessed. Different treatments on the same accession should be conducted to determine if warm stratification is required prior to cold stratification. The default stratification protocol should be three months cold, but there are indications that this could be refined and improved upon.

GENUS: **Magnolia**

TOTAL SPECIES: **19**

PROPAGATION ATTEMPTS: **63**

% SPECIES PROPAGATED SUCCESSFULLY: **79%**

RESEARCH:

Dirr & Heuser:

Seeds exhibit embryo dormancy that is overcome by cold stratification at 32 – 41 deg. F. for 2-4 months.

Exceptions:

M. cordata 5 mo.
M. cylindrica 5 mo.

H.B. 450:

Germination is epigeal and occurs rapidly after proper stratification. Stratify 3-6 months at 32 – 41 deg. F.

Young, etc.:

See Dirr & H.B. 450.

ARBORETUM RECORDS:

Species	**Times Propagated**	**Highest Germ. Rate**
acuminata	4	55%
ashei	1	3%
biondii	1	<1%
campbellii	1	100%
cordata	1	0%
cylindrica	2	>1%
denudata	4	90%
fraseri	5	75%
hypoleuca	3	0%
kobus	7	53%
x loebneri	1	0%
macrophylla	6	21%

obovata	2	>1%
officinalis	2	88%
salicifolia	4	33%
sieboldii	9	>50%
sprengeri	2	100%
virginiana	7	92%
wilsonii	1	0%

SUCCESSFUL STRATAGEMS:

Seeds were generally cold stratified for 3 months, and this will usually lead to some germination. (Some species will germinate without cold stratification, but higher percentages will be obtained with stratification.) Both three and four months were successful with *M. sieboldii*, with four months seeming to yield a higher percentage.

UNSUCCESSFUL STRATAGEMS:

Four months stratification does not appear to improve germination percentage over three months stratification. Five months did not improve or promote germination of *M. virginiana* or *M. cordata* (1 attempt), but did prove successful with *M. cylindrica* (vs. 3 mo.).

CONCLUSIONS:

Magnolia seed should be cleaned as soon as possible, as there are indications that the fleshy covering contains germination inhibitors. Seed must not be allowed to dry, as it loses viability below 30% moisture content. Seed germinates rapidly after proper stratification (H.B. 450). To determine if the seed has received proper stratification, it can be examined for evidence of readiness. This may be evidenced by “gunk” around the distal end of the seed, or the seed can be split and examined under the microscope for evidence that the radicle is ready to emerge.

GENUS: **Picea**

TOTAL SPECIES: **14**

PROPAGATION ATTEMPTS: **31**

% SPECIES PROPAGATED SUCCESSFULLY: **86%**

RESEARCH:

Dirr & Heuser: Most species germinate promptly without pretreatment. If no cold stratification is given, seeds would be soaked in water for up to 24 hours to imbibe water. Under laboratory conditions, *P. engelmannii*, P. mariana and P. omorika require artificial light; *P. glauca*, *orientalis*, *rubens* & *sitchensis* require artificial light and alternating temperatures of 68-86 deg. F.

P. jezoensis. Difficult to germinate; 5 months cold stratification has shown some success.

P. rubens. Two months cold stratification.

P. sitchensis. No pretreatment required, but a period of cold stratification unifies and hastens germination.

Young, etc.: See table on p. 247.

H.B. 450: There is a fairly high percentage of empty seeds in any seed lot. Light of at least 50 foot-candles and alternating temperatures enhanced germination of many species. See table on page 593 for individual requirements.

ARBORETUM RECORDS:

Species	Times propagated	Highest Success %
sp.	1	>1%
asperata	2	39%
breweriana	2	>1%
engelmannii	2	27%
glauca	1	16%
jezoensis	5	>1%
koyamai	1	>1%
meyeri	3	>1%
obovata	2	>1%
orientalis	4	75%
rubens	4	0%
sitchensis	2	87%
spinulosa	1	0%

Species	Times propagated	Highest Success %
wilsonii	2	>1%

SUCCESSFUL STRATAGEMS:

Seed was either direct sown or given cold stratification of 1-5 months. It was often given one week to imbibe water before stratification, although the literature indicates that both are not required. Seeds should be treated with fungicide prior to sowing. Germination percentages are too infrequent to draw any reliable conclusions. Extended photoperiod was utilized on several occasions (and probably more often than indicated). Young indicates that newly germinated seedlings of red spruce require 16 hours or light daily or they will go dormant.

UNSUCCESSFUL STRATEGEMS:

When seeds were given more than one month of cold stratification, they often germinated in the bag, although the highest percentage obtained (100% of P. jezoensis) was obtained with 2 months cold stratification. There is no indication that seeds which were given one week of warm stratification to imbibe water achieved higher germination percentages than those that were not.

CONCLUSIONS:

Given the indication that many spruce seeds are empty, it would be helpful to give seeds the float test and separate them into sinkers and floaters to determine if this would be valid. If floaters are found to be empty and fail to germinate, future propagations could utilize this method to separate out the good seeds and achieve a higher germination percentage.

Seeds should be dusted with Captan to prevent fungal infections and subsequent damping off. Thirty days cold stratification appears adequate for most species, but the charts cited above should be referred to for species-specific requirements. Surface sowing would be recommended for those species requiring light to germinate.

GENUS: **Tilia**

TOTAL SPECIES: **16**

PROPAGATION ATTEMPTS: **47**

% SPECIES PROPAGATED SUCCESSFULLY: **45%**

RESEARCH:

Dirr & Heuser:

Americana: Sow in fall for spring germination. There is some indication that seeds harvested before seed's coat & wing turns brown will give better germination

Cordata: Same as above.

Dasystyla: 5 mo. warm/3 mo. cold (low germination)

Platyphyllos: 3-5 mo. warm/3 mo. cold

H.B. 450: "Basswood seed shows delayed germination because of an impermeable seedcoat, a dormant embryo and a tough pericarp." Recommendations for best germination:

Harvest & treat seeds early;
Remove pericarp or soak in concentrated sulfuric acid for 40 min. and
then force through a screen;
Etch seedcoat in concentrated sulfuric acid for 10-15 minutes;
Stratify in moist medium for 3 mo. at 34 – 38 deg. F.

Americana: Increased germination if seeds treated with sulfuric acid 5 mo. before sowing (assume cold strat in the interim).

Cordata: Sow dry-stored seed in June or July following harvest.

Young, etc.:

"…seeds show delayed germination because of impermeable seedcoats, embryo dormancy, and a hard pericarp. Scarification to break both the pericarp and seedcoat has been used to enhance germination. The planting of early collected fruits before they have a chance to dry has sometimes given good results."

Scarify in concentrated sulphuric acid or soak in 70 deg. C water and dry 5 times. Germination is epigeal; capacity is about 30%.

ARBORETUM RECORDS:

Species	Times Propagated	Highest Germ. Rate
americana	3	27.00%
americana var heterophylla	2	0.05%
amurensis	6	1.00%
chinensis	3	1.00%
cordata	2	1.00%
dictyoneusz	1	0.00%
intonsa	1	0.00%
koreana	1	1.00%
japonica	5	1.00%
mandshurica	6	1.00%
maximowicziana	4	1.00%
megaphylla	2	0.00%
mongolica	5	1.00%
oliveri	1	0.00%
paucicostata	1	0.00%
platyphyllos	1	0.00%
sp.	1	11.00%
tomentosa	2	1.00%

SUCCESSFUL STRATAGEMS:

The standard MA protocol has been acid scarification for 15 minutes and 3 months cold stratification. This usually required additional stratification by overwintering in the Medicinal House. While the highest germination percentage ascertainable was 27% for T. americana using this protocol, there were also numerous times when the same protocol failed to work.

T. dasystyla responded to 5 months' warm stratification followed by 3 months' cold stratification without acid scarification. When scarified, it germinated with only 3 months' cold stratification. It would appear that warm stratification may be substituted for acid scarification.

T. mongolica on two occasions germinated in the bag during cold stratification and after acid scarification.

UNSUCCESSFUL STRATAGEMS:

Hot water soak for five hours in place of acid scarification was unsuccessful the two times it was utilized. Acid scarification for 7 minutes and 25 minutes was either unsuccessful or showed no appreciable improvement in germination. Seven months' cold stratification following acid scarification resulted in rotting seeds.

BIBLIOGRAPHY:

American Basswood, www.osu.edu

GENUS: **Viburnum**

TOTAL SPECIES: **32**

PROPAGATION ATTEMPTS: **102**

% SPECIES PROPAGATED SUCCESSFULLY: **84%**

RESEARCH:

Species	Dirr & Heuser		H.B. 450	
	Warm	Cold	Warm	Cold
acerifolium	6-17	2-4	6-17	2-4
alnifolium	5	2.5	5	2.5
betulifolium		5 c/3 w.		
bitchiuense	2	2		
bracteatum	5	3		
carlesii	2	2		
cassinoides	2	3	2	3
cylindricum		3		
dentatum	12-17	.5 – 1		
dilatatum	5-7	3-4		
erosum	3-5	3		
hupehense	5	3		
lantana		2		70 days
lentago	5-9	2-4	5-9	2-4
lobophyllum	5	3		
nudum	0	0		
opulus			2-3	1-2
prunifolium	5-9	1-2	5-9	1-2
pubescens	4	3		
rufidulum	6-17	3-4		
sargentii	2-3	1-2		
setigerum	3-5	3		
sieboldii	1-2	3		
trilobum	4	3		
wrightii	5-7	3-4		

H.B. 450:

Most seeds of viburnum are doubly dormant, requiring a warm period for root development and a cold period to overcome epicotyl (shoot) dormancy. Seeds of northern species seldom germinate naturally until the second spring after ripening. Some southern viburnums do not exhibit epicotyl dormancy or require cold stratification. Scarification has not proven effective in overcoming dormancy mechanisms.

ARBORETUM RECORDS:

Species	Times Propagated	Highest Germ. Rate
sp.	3	>1%
acerifolium	9	6%
betulifolium	4	>1%
bitchuense	6	>1%
burejaeticum	2	40%
cassinoides	6	40%
cylindricum	1	<1%
davidii	1	0%
dentatum	3	36%
dilatatum	4	>1%
edule	1	>1%
erosum	18	70%
furcatum	3	71%
hengrhanicum	1	0%
koreana	1	>1%
lantana	1	0%
lantanoides	6	40%
lentago	1	0%
luzonicum	2	>1%
macrocephalum	1	0%
mongolicum	2	30%
nudum	1	67%
opulus	2	>1%
phlebotrichum	1	8%
prunifolium	5	5%
rafinesquianum	1	0%
recognitum	2	3%
rufidulum	2	50%
sargentii	8	63%
schensianum	2	20%
utile	1	20%
wrightii	1	1%

SUCCESSFUL STRATAGEMS:

Stratification has involved warm periods of 1-12 months followed by cold stratification of 1-4 months. MA records confirm that viburnums germinate (emergence of radicle) during warm stratification. The notes often indicate that seeds “germinated in bag” or “germinated during stratification”. The germination percentage figure is irrelevant in this case because germination does not guarantee shoot emergence and a viable seedling. Based on the number of seedlings obtained, there have been a few successes. Viburnum cassinoides was successfully germinated using the recommended criteria of 2 warm/3 cold. When seeds were given five months warm and overwintered in the Medicinal House, they were discarded.

V. koreana was one of only a few accessions in which more than one treatment was utilized. Stratification for 2/2 and 3/2 was unsuccessful, but 4/4 yielded 5 seedlings. Based on notations relative to germination, it appears that at least four months warm stratification is needed for germination.

Numerous strategies were used on V. sargentii, with the most successful appearing to be two months warm and 1-2 months cold. Stratification of 3 and 5 months was not successful.

V. prunifolium was successfully propagated (93x047 – 78 seedlings) using 9 months warm stratification followed by 2 months cold. All other attempts to propagate this species were unsuccessful using less than 9 months warm stratification.

UNSUCCESSFUL STRATAGEMS:

It appears that overwintering in the Medicinal House is not an overwhelming success. The source books indicate that a second season of stratification may be necessary, but this contradicts the criteria set forth in both cited references for germination and the MA experience.

CONCLUSIONS:

There are inferences in the source books suggesting that Viburnum seeds should be sown immediately upon collection and that time of collection and ripeness of seeds is a consideration. This theory may be tested by collecting seeds locally, but it's probably irrelevant with wild-collected seeds because of the lack of control over the collection process.

It would seem a good practice to sow seeds and stratify them in flats rather than in baggies. Since seeds should be germinating during warm stratification, the root/radicle would have a medium to support it during the cold stratification required for shoot emergence. GA might be tried to overcome the epicotyl dormancy.

BIBLIOGRAPHY:

Hidayati, Siti N., J. Baskin & C. Baskin, Epicotyl Dormancy in Viburnum acerifolium (Caprifoliaceae), Am. Midl. Nat. 153:232-244.

GENUS: **Zelkova**

TOTAL SPECIES: **3**

PROPAGATION ATTEMPTS: **14**

% SPECIES PROPAGATED SUCCESSFULLY: **100%**

RESEARCH:

Dirr & Heuser: Pretreatment not required, but germination percentage increased with 2 months cold stratification at 41 deg. F. (Z. serrata)

Young, etc.: Pretreatment not required, but speed and uniformity of germination are enhanced by prechilling for 2-3 months; seeds should not be allowed to dry.

ARBORETUM RECORDS:

Species	**Times propagated**	**Highest Success %**
carpinifolia	4	>1%
serrata	8	>1%
sinica	2	60%

SUCCESSFUL STRATAGEMS:

Stratification ranged for 2-4 months cold, with no clear indication of whether the longer period increased germination rates. Sixty percent germination was obtained with two months' cold stratification of Z. sinica. Germination during the period of cold stratification for all species was common.

UNSUCCESSFUL STRATEGEMS:

Soaking seeds in water to allow for imbibition of water was unsuccessful. Two attempts indicate zero percent germination.