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A Germination Protocol for Small Seed Lots[1]

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Abstract

The nursery industry depends on public gardens to supply propagation material for newly introduced plant species grown from seed. Most seed obtained by public gardens is received in small quantities and must be handled efficiently to assure at least minimal germination. A seed germination protocol is proposed which leads the propagator through a series of steps including a systematic search of the literature, a comparison of species about which little or nothing is known to related species with known propagation methods, a study of the climatic conditions present in the seeds' native area, a study of ecological factors that may affect germination, and finally to the propagation process itself. Examples are provided which illustrate how the protocol is used.

Index words: seed dispersal, seed ecology.

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Significance to the Nursery Industry

To a great degree the viability of the nursery industry depends on acquiring and producing new and different plants for the consuming public. Common sources of new plants are public horticultural facilities such as botanical gardens and arboreta. Through *Index Seminum*, a worldwide system of exchange and distribution of seeds, botanic gardens and arboreta can obtain an almost endless variety of species, many of which may be completely new to the industry. Botanic gardens and arboreta also send collectors to foreign lands to collect new and untried species. A seed germination protocol takes a systematic approach to the treatment of seeds, thus assuring the highest possible rate of germination. From these newly propagated plants, nursery growers can obtain stock plants for further production and testing. As a result, the nursery industry benefits from a more diversified plant list and the means to meet the demands of increasingly sophisticated customers.

Introduction

Plant propagators, particularly those employed by arboreta and botanic gardens, often can obtain only very small quantities of seeds, with unknown or largely unknown pregermination requirements. When quantities are small, seeds often must be handled as one treatment, with little possibility of experimental alternative techniques. For these propagators, success often means getting at least one seed to germinate and grow to transplanting size. This measure is acceptable for commercial production, however, only if it results in a stock plant from which subsequent propagation can be made. The purpose of this paper is to propose a systematic method which assures the greatest probability for success using reference searches and considerations of systematic and ecological relationships.

Materials and Methods

Information and data were gathered from two main sources: the available literature regarding plant propagation and the ecology of seed plants, and the personal experience of the authors based on their combined total of 36 years of experience in plant propagation including both trial and error and careful observations of various formal and informal experiments. Two-hundred-thirty-eight genera of woody plants with temperate representatives were analyzed and categorized by their dispersal method and natural habitat. Using the authors' experience propagating these genera and from the written reports of others (4) a general germination protocol was assigned to each genus. If seed would germinate readily upon sowing or if it only required 1–3 months of cold stratification to facilitate germination it was categorized as an easy to germinate seed. Should the seed require scarification, a long stratification, a warm/cold stratification or have a double dormancy the seed was labeled as difficult to germinate. Genera for which there was sufficient data were grouped into categories based on dispersal, habitat, and ease of germination (Tables 1 through 6).

Results and Discussion

A. Suggested Protocol. *Literature search.* The propagator should initially consult those sources that provide the greatest amount of precise information. All plant propagators should either own or have direct access to the following: (a) *Seeds of Woody Plants in the United States,* USDA Handbook No. 450 (11, 14). Besides providing specific pregermination requirements for numerous species, this text contains information on seed cleaning, storing, and handling, and techniques for stratification and scarification as well as information on the nativity and habitat of many species. (b) *Plant Propagation: Principles and Practices*, 5th edition, by Hartmann, Kester, and Davies (7) and *The Reference Manual of Woody Plant Propagation* by Dirr and Heuser (4). These are the comprehensive guides of both sexual and asexual plant propagation for many growers. (c) The Combined Proceedings of the International Plant Propagators' Society (1951–present) contain significant information regarding the propagation of unusual species. (d) Many regional or special publications deal with propagation of wildflowers (3) and native plants (1, 2, 5). (e) Horticultural periodicals, such as the *Journal of Environmental Horticulture* and *HortScience*, also yield valuable information. (f) Specialty journals dedicated to a particular genus or grouping of plants can also be a good source of data. Examples of these are *Magnolia*, journal of the Magnolia Society, or the *American Conifer Society Bulletin.* (g) Trade journals, such as *American Nurseryman*, may contain specific articles of

[1]Received for publication February 18, 1994; in revised form September 6, 1994.

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great value, and some occasionally devote an entire issue to the subject of propagation.

Propagation of close relatives. If no specific data for the species in question exist or if existing data are insufficient, determine the germination requirements of a close relative (within family or genus) from the previous references if possible. While there is no guarantee that the germination requirements of the relatives will be identical to the species to be propagated, this information may nonetheless suggest one or more possible useful methods. For example, in attempting to germinate an obscure species of the maple genus, *Acer*, by consulting Dirr and Heuser (4) one notices that the requirement for cold-moist stratification varies considerably, depending on the maple species. Reference manuals such as *Hortus Third* (12), Fernald (6) or Rehder (9) can be consulted to determine species relationships, such as section or tribe, and/or nativity and the unknown species can be compared with a close relative about which germination requirements are known. The propagator should be careful with genera containing both temperate and tropical species and compare relatives from similar zones only.

Climatic factors. If necessary, consider the nativity of the species and the annual climatic conditions of the site of origination. Rainfall amounts and patterns of distribution, annual maximum and minimum temperatures, and other climatic factors may affect seed germination. By examining seasonal temperature variations, one can determine if seeds from a given area are naturally exposed to periods of moist-chilling. Although the seeds may or may not benefit from moist-chilling, if they are found in a locale with cool or cold temperatures at times during the year, they will unlikely be harmed by such a treatment. In addition, one may be able to ascertain conditions such as the levels of moisture and temperature that may be present at time of germination. Microclimates may also exist within the range of the species and therefore seeds may have different germination requirements than overall climatic conditions suggest.

Observing ecological processes and systems. When determining pregermination treatments it is helpful to learn as much as possible about the plant in its natural setting. Two factors in particular offer clues to seed pregermination requirements: how the seeds are disseminated in nature and the specific habitat a species occupies in the natural landscape. See Section B, below, for a detailed analysis of ecological factors.

The propagation process. Decide whether or not to handle all the seeds as one treatment or to divide the lot into two or more treatments. Often one is forced to use only one treatment because of the dearth of seeds. An arbitrary figure of at least twenty seeds in each treatment when employing multiple treatments seems reasonable since at least five percent viability can be expected for most seeds, even among those with known low viability. Whenever possible it is advisable to have more than one treatment since the more treatments one can provide, the greater the likelihood of some germination. Some treatments are not mutually exclusive, however, and can be combined. For example, seeds with suspected hard seed coats (almost universal in the *Leguminosae* or *Fabaceae*) and the suspected need for moist-chilling can

Table 1. Wind dispersed seed of understory genera.

Abeliophyllum	Elliotia	Neillia
Acer	Enkianthus	Neviusia
Andromeda	Erica	Philadelphus
Aristolochia	Exochorda	Phyllodoce
Bignonia	Fontanesia	Physocarpus
Bruckenthalia	Forsythia	Pieris
Buddleia	Hibiscus[z]	Potentilla
Calluna	Holodiscus	Ptelea
Campsis	Hydrangea	Pterostyrax
Chamaedaphne	Hypericum	Rhododendron
Clematis	Itea	Salix
Clethra	Kalmia	Sibiraea
Cliftonia	Kalmiopsis	Sorbaria
Colutea[z]	Kolkwitzia	Spiraea
Cotinus[z]	Ledum	Staphylea[z]
Cyrilla	Leiophyllum	Syringa
Daboecia	Leucothoe	Tripterygium
Deutzia	Lyonia	Weigela
Diervilla	Menziesia	Zenobia

[z]Difficult germination requirements.

Table 2. Wind dispersed seed of canopy genera.

Abies	Eucommia	Populus
Ailanthus	Fraxinus	Pseudolarix
Alnus	Fitzroya	Pseudotsuga
Betula	Halesia[z]	Pterocarya
Carpinus[z]	Larix	Sciadopitys[z]
Catalpa	Libocedrus	Sequoia
Cedrela	Liquidambar	Sequoiadendron
Cedrus	Liriodendron	Taxodium
Cercidiphyllum	Metasequoia	Thuja
Chamaecyparis	Ostrya[z]	Thujopsis
Cladrastis[z]	Oxydendrum	Tsuga
Cryptomeria	Paulownia	Ulmus
Cunninghamia	Picea	Zelkova
Cupressus	Pinus	
Dipteronia	Platanus	

[z]Difficult germination requirements.

Table 3. Bird dispersed seed of understory genera.

Acanthopanax[z]	Euonymus[z,y]	Pernettya
Amelanchier[z,y]	Garrya[z]	Phillyrea[z,y]
Ampelopsis	Gaultheria[y]	Photinia
Aralia	Gaylussacia[z,y]	Podocarpus[z,y]
Ardisia	Hedera[z,y]	Prinsepia
Aronia	Hippophae[y]	Prunus[z,y]
Aucuba[z]	Ilex[z]	Punica
Berberis[z,y]	Juniperus[z,y]	Pyracantha[y]
Callicarpa[y]	Koelreuteria[z]	Rhamnus
Celastrus	Ligustrum[z,y]	Rhus[z,y]
Cephalanthus	Lindera[y]	Rosa[z,y]
Chionanthus[z,y]	Lonicera[y]	Rubus[z,y]
Clerodendron[y]	Mahonia[z]	Sambucus[z,y]
Comptonia[z,y]	Malus	Sassafras[z,y]
Corema[z,y]	Mitchella[y]	Skimmia
Cornus[z,y]	Morus[y]	Sorbus[z,y]
Cotoneaster[z,y]	Myrica	Symphoricarpos[z,y]
Crataegus[z,y]	Nemopanthus[z]	Symplocos[z,y]
Daphne[z,y]	Oplopanax[z]	Taxus[z,y]
Dirca[z,y]	Osmanthus[z,y]	Vaccinium[y]
Elaeagnus[z]	Pachysandra[z]	Viburnum[z,y]
Eleutherococcus[z]	Paeonia[z,y]	Vitis[z,y]
Empetrum	Parthenocissus[y]	Zanthoxylum[z,y]

[z]Difficult germination requirements.
[y]Cited in Ridley (10).

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Table 4. Bird dispersed seed of canopy genera.

Araucaria	Idesia	Sapindus[z,x]
Celtis[z,y]	Kalopanax[z]	Tilia[z,x]
Evodia	Magnolia	
Hovenia[z]	Nyssa[y]	

[z]Difficult germination requirements.

[y]Cited in Ridley (10).

[x]Cited in USDA Woody Plant Seed Manual (11).

Table 5. Mammal dispersed seed of understory genera.

Actinidia	Corylus[y]	Purshia
Akebia	Cytisus[z]	Pyrularia[z]
Alangium[z,y]	Eriobotrya	Pyrus[y]
Amorpha[z]	Fremontodendron[z,x]	Ribes[z,y]
Arctostaphylos[z]	Garrya[z,x]	Robinia[z]
Buckleya[z]	Genista[z]	Sheperdia[z]
Calycanthus[z,x]	Indigofera[z]	Stephanandra[z]
Camellia[z,x]	Laburnum[z]	Stewartia[z]
Caragana[z]	Lespedeza[z]	Styrax[z]
Ceanothus[z]	Maackia[z]	Wisteria
Cephalotaxus[z]	Maclura[y]	Xanthoceras
Cercis[z]	Mespilus[z]	Zizyphus[z,y]
Chaenomeles	Poncirus	
Chimonanthus[z,x]	Pseudocydonia	

[z]Difficult germination requirements.

[y]Cited in Ridley (10).

[x]Cited in USDA Woody Plant Seed Manual (11).

Table 6. Mammal dispersed seed of canopy genera.

Aesculus[y]	Davidia[z]	Juglans[y]
Albizia[z]	Diospyros[y]	Quercus[y]
Asimina	Fagus[y]	Sophora[z]
Carya	Ginkgo[z]	Torreya[z]
Castanea[y]	Gleditsia[z]	Umbellularia[z,x]
Castanopsis	Gymnocladus[z]	

[z]Difficult germination requirements.

[y]Cited in Ridley (10).

[x]Cited in USDA Woody Plant Seed Manual (11).

be handled as one lot by treating for one condition and then the other, respectively.

To maximize germination success, especially when only small quantities of seed are available, sanitation is critical. Everything that comes into contact with the seed should be as aseptic as possible. Germination media should be pasteurized if not constructed of already sterile components. Pots, flats, tools, benches, hose nozzles, and hands should be kept as clean as possible. Even if the seeds are sown in outdoor ground beds steps should be taken to reduce the occurrence of destructive diseases and pests.

Other critical factors to consider include humidity, temperature, light, moisture, and the presence of natural agents such as beneficial mycorrhizae and other beneficial microorganisms. Again, a thorough study of climatic conditions of the plant's nativity provides clues on the nature of these factors. A universally beneficial treatment is soaking the seeds prior to sowing to ensure maximum imbibition of water. Soaking seeds can also be helpful in removing inhibitors, which may prevent germination until adequate precipitation has occurred to allow for maximizing the germination process. Soaking with aeration or running water, which usually allows for sufficient aeration, is more preferable than soaking without aeration, particularly when soaking or leaching is done for four or more hours. The primary references cited earlier provide details for soaking seeds of both woody and herbaceous species.

Record keeping. Keep complete written records of the methods employed to effect germination, both successful and unsuccessful. These records should be as specific as possible, providing details of each treatment, number of seeds per treatment, germination rate and total germination percentage. If new information is obtained the results should be submitted for publication in, for example, the *North American Plant Propagator*, so that they become part of the literature of plant propagation.

B. Analysis of Seed Dispersal. In temperate zones, seeds are disseminated by a number of agents: wind, water, birds, mammals, reptiles, fish, insects (primarily ants) and gravity (10, 13).

Wind-dispersed seed are usually winged, as in *Fraxinus*, plumed or tufted as in *Populus* and *Salix*, or are dustlike as in many Ericaceae (Tables 1 and 2).

Birds rely predominantly on visual clues to find seeds. Bird dispersed seeds are generally small and enveloped in a conspicuously colored fleshy red, blue, or black integument or pericarp which contrasts well with green foliage. However, even some larger or dull-colored seeds are dispersed by birds. For example, seeds of *Quercus* and *Fagus* are cached by blue jays in North America and by the rook in Europe, although these birds are probably not their predominant agents of dispersal (10) (Tables 3 and 4).

Mammal-dispersed seeds are often larger, possess more oil, and are more aromatic than bird dispersed seed. Color is "useless to all fruit eating mammals" (10) since many mammals are color blind. Consequently, there are many dull or non-contrasting fruits that are the staple of mammals (Tables 5 and 6).

As can be expected, this type of analysis is done on a very broad scale, with emphasis at the genus level. Within a genus such as *Acer*, some species have very different pregermination treatments from others, although most germinate readily. Considering habitat, a number of *Acer* species are canopy trees. But if one consults a botanical encyclopedia such as Rehder (9) or Krüssmann (8) it becomes clear the majority of *Acer* species worldwide are small in stature and are probably understory species.

Other genera may be dispersed by a combination of different agents. For example, *Ribes* is eaten and disseminated by both birds and mammals. In such cases what appeared to be the dominant dispersal method and habitat for a genus was selected and listed only in a single category. Additional categories could also be created for more specific habitats (riparian, edge, or alpine) or even for more specific disseminators (squirrel, rook, or wren).

Table 7 summarizes the categories of dispersal and habitat and whether the germination of the genera's seed is predominantly easy or difficult. In many cases information regarding propagation requirements, dispersal method, or habitat of a genus was non-existent and these, therefore, were deleted from the list.

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Table 7. Dispersal agent, habitat, and relative ease of germination.

Dispersal agent	Habitat	Genera (No.)	Easy germination (%)	Difficult germination (%)
Wind	Understory	57	93	7
Wind	Canopy	43	88	12
Bird	Understory	71	40	60
Bird	Canopy	10	50	50
Mammal	Understory	40	30	70
Mammal	Canopy	17	47	53

Out of the 100 wind-dispersed genera, 93% of those which were understory genera were easy to germinate while 88% of those which were canopy genera germinated easily. Of the 81 genera categorized as bird dispersed, 40% of the understory genera germinated easily while 50% of the canopy genera germinated easily. For the 57 mammal dispersed genera, 30% of the understory genera germinated easily and 53% of the canopy genera germinated easily.

Based on the findings of this study a few general rules can be suggested for woody temperate genera: wind dispersed seeds tend to lack dormancy altogether, or have simple dormancy patterns; mammal and bird dispersed seed are more likely to have complex pregermination requirements; and canopy genera are more likely to have simpler dormancy patterns than understory genera.

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