



United States
Department of
Agriculture

Forest Service

Agriculture
Handbook
727

July 2008

The Woody Plant Seed Manual



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Cover photo

The scientific names for the seeds shown on the cover are identified by the key and photo below. Seeds 2 and 7 have had their wings removed by cleaning.

1. Green ash (*Fraxinus pennsylvanica* Marsh.)
2. Ponderosa pine (*Pinus ponderosa* P. & C. Lawson)
3. Northern red oak (*Quercus rubra* L.)
4. Witch hazel (*Hamamelis virginiana* L.)
5. Service berry (*Amelanchier arborea* (Michx. F.) Fern.)
6. Persimmon (*Diospyros virginiana* L.)
7. White fir (*Abies concolor* (Gord. & Glend.) Lindl. Ex Hildebr.)
8. Tulip poplar (*Liriodendron tulipifera* L.)



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The Woody Plant Seed Manual



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Dedication

This handbook on the seeds of woody plants would not be possible if not for the pioneering work of many individuals in past years. They worked without the modern laboratory and information retrieval services that we now routinely use and take for granted. Their early efforts in the first half of the 20th century solved many seed problems and pointed the way for later research on numerous subjects. Without them, our body of knowledge about the seeds of woody plants would not be what it is today. Many contributed, but for their extensive work and leadership, we dedicate this book to the following pioneers:

George S. Allen *Canadian Forestry Service & University of British Columbia*
Henry I. Baldwin *New Hampshire Forestry Department*
Lela V. Barton *Boyce Thompson Institute*
Claude E. Heit *New York Agricultural Experiment Station*
Nikolas T. Mirov *USDA Forest Service*
Paul O. Rudolf *USDA Forest Service*
Charles F. Swingle *USDA Bureau of Plant Industry*
W. R. Van Dersal *USDA Soil Conservation Service*
Philip C. Wakeley *USDA Forest Service*

Acknowledgments

The development and publication of this book was supported by the USDA Forest Service's Research and Development (R&D) and State and Private Forestry (S&PF) National Offices as well as by R&D's Southern and Northeastern Research Stations, which supported Dr. Bonner and Ms. Nisley, respectively. We especially thank Drs. Jerry SESCO and Robert Lewis, Deputy Chiefs (retired) for Research and Development; Dr. Peter Roussopoulos, Director of the Southern Research Station; Dr. Michael T. Rains, Director of the Northeastern Research Station; and Debra Dietzman, Communications Director at the Northeastern Research Station, for their continued financial and personal support.

We also thank John K. Francis (retired after many years at the International Institute of Tropical Forestry), Robert P. Karrfalt (S&PF, Regeneration, Nurseries, and Genetics Resources National Team), Susan E. Meyer (Rocky Mountain Research Station), Peyton W. Owston (retired from the Pacific Northwest Research Station), and John C. Zasada (retired from the North Central Research Station), the regional coordinators who solicited and organized the authors of the 236 genera.

We are grateful to Dr. Stanley R. Krugman for getting this effort going and sharing his experiences from the production of AH 450, *Seeds of Woody Plants in the United States* (1974). Sharon Friedman, Jacob L. Whitmore, Calvin Bey, Sam Foster, and Marilyn Buford served as our liaisons to the R&D National Office; Karl Dalla Rosa and Hal Brockman were the liaisons to S&PF; and Frank Burch to National Forest Systems. Becky Loth, at the National Seed Laboratory served admirably as the webmaster of our interim website, and Laura Cricco, Phyllis Grinberg, Jean B. Holland, Pamela Huntley, Barbara Johnson, and Kathy McManus, all of the Northeastern Research Station, provided much appreciated administrative and computer support.

Contents

Introduction v

How to Use This Book vii

Invasives vii

Part 1 Principles and General Methods of Producing and Handling Seeds

- Chapter 1 Seed Biology *Franklin T. Bonner* 3
- Chapter 2 Genetic Improvement of Forest Trees *Clark W. Lantz* 39
- Chapter 3 Seed Harvesting and Conditioning *Robert P. Karrfalt* 57
- Chapter 4 Storage of Seeds *Franklin T. Bonner* 85
- Chapter 5 Seed Testing *Robert P. Karrfalt* 97
- Chapter 6 Certification of Tree Seeds and Other Woody Plant Materials
Robert D. Mangold and Franklin T. Bonner 117
- Chapter 7 Nursery Practices *Thomas D. Landis* 125

Part 2 Specific Handling Methods and Data for 236 Genera

Part 3 Appendices

- Conversion Factors 1192
- Glossary 1193
- List of Families and Genera 1199
- Index of Authors 1202
- Addendum 1224

Introduction

The first comprehensive handbook on the seeds of trees and shrubs produced by the USDA Forest Service was USDA Misc. Pub. 654, *Woody-Plant Seed Manual*. The manuscript was ready for publication in 1941, but World War II delayed publication until 1948. The boom in tree planting in the 1950s and 1960s created a large demand for seeds and exposed the gaps in our knowledge concerning production and quality of seeds of woody plants in general.

Realization of this condition led to the revision and considerable expansion of the manual, resulting in publication of USDA Agric. Handbk. 450, *Seeds of Woody Plants in the United States*, in 1974. Seed data were presented for about 800 species, varieties, and sub-species in 188 genera, considerable more than the 420 species and 140 genera in the 1948 edition. The 1974 Handbook proved to be very popular both in this country and abroad, leading to five printings and translations in several other languages. More than a quarter-century after its publication, however, numerous advances in tree seed technology have dictated that a new revision is needed; the result is the current volume.

The major audience for this book, as for its two predecessors, is those who are involved in the growing and planting of trees and shrubs. Their involvement can be collection and sale of seeds, production of nursery stock (both bare-root and container), or planting itself. Planting for commercial forest production is the traditional mainstay of tree planting, but planting for wildlife food, watershed protection, urban environmental improvement, ornamental enhancement, wetland mitigation, and carbon sequestration are all on the increase. Ecosystem management, now commonly used in the management of many federal and other governmental forest lands, has decreased the use of planting to regenerate the forests and has increased the role of natural regeneration. Those who apply these practices will find this book useful also in the data on flowering and seed production. Although the book is not intended to be a detailed textbook on seed ecology and physiology, there is sufficient scope and depth to the material included to make it useful to anyone who studies seeds. For additional information on these topics, readers should consult the recent works by Baskin and Baskin (2000) and Farmer (1997).

The organization of this book follows that of the earlier manuals. Part 1 comprises seven chapters that provide general principles on seed biology, genetic improvement, harvesting and conditioning, storage, testing, seed certification, and nursery practices. The chapter on genetic improvement combines two chapters from the 1974 Handbook but does not include the extensive technical information provided in 1974. Genetic improvement of tree and shrub species is now too common and widespread to be covered adequately in a chapter in a seed manual. For complete treatments on this subject, readers are referred to Zobel and Talbert (1984). In

the same vein, pollen handling has been dropped; interested readers should refer to the handbook by Bramlett and others (1993). A chapter on nursery practices has been added to the current book, not to serve as a complete technical reference on the subject, but to point out the seed considerations in current nursery operations. Good technical manuals on nursery production of woody plants are those of Duryea and Dougherty (1991), Landis and others (1990–95), Liegel and Venator (1987), and Williams and Hanks (1976). Readers needing additional information on vegetative reproduction should consult Dirr and Heuser (1987).

Part 2 has been expanded to include almost 1,300 taxa in 236 genera. Most of the additions are either tropical species that are grown in Puerto Rico and the Virgin Islands, Hawaii, and the Pacific territories or native species that have increased in value for wildlife or environmental plantings in recent years. Many of these latter are shrubs from the western United States. Information is presented by genus in alphabetical sequence as before. Data have typically been grouped under the following headings: growth habit, occurrence, and use; flowering and fruiting; collection, extraction, and storage of seeds; pregermination treatments; germination tests; and nursery practices. For genera without much information, some of these headings have been combined. In general, the minimum standard for inclusion has been sufficient information to collect and germinate the seeds. Readers with wider interests in tropical species should consult Khullar and others (1991), Ng (1992), Schmidt (2000), Tompsett and Kemp (1996), and Vozzo (2002). An excellent reference on propagation of native plants of the Pacific Northwest is the work by Rose and others (1998).

If authors of the 1974 genus chapters were still working for the Forest Service, they were given the opportunity to write the updated version. Some did, and a number of retired authors also asked to be a part of the revision. If very little rewriting was done because of a dearth of new information about a genus since 1974 (and there were a few of these), names of the 1974 authors remain on the chapters. If new information required extensive rewriting, then the new authors got primary credit. In most cases, 1974 authors who are now deceased also got credit for their contributions. There were 95 authors engaged in the updating of this manual (page 1182), and they all deserve our thanks. Recruitment of authors and coordination of their activities were primarily carried out by a group of regional coordinators: Franklin T. Bonner, John K. Francis, Robert P. Karrfalt, Susan E. Meyer, Peyton Owston, and John C. Zasada.

One major change in the current book deals with nomenclature. A decision was made to use the nomenclature system under development by the USDA Natural Resources Conservation Service as part of a government-wide attempt to adopt standard nomenclature for plants, insects, etc. of North America. This on-line database (PLANTS 2004)

became the primary nomenclature resource. A second resource was needed for numerous non-native plants; for this purpose the USDA Agricultural Research Service Genetic Resources Program (GRIN 1999) was adopted. Other valuable data on plant nomenclature came from *Hortus third*, by the Liberty Hyde Bailey Hortorium at Cornell University (LHBH 1976). Use of these resources for nomenclature resulted in numerous name changes, which may be confusing in some cases. For example, *Libocedrus* (in the 1974 Handbook) is now *Calocedrus*; *Castanopsis* is now *Chrysolepis*. The Table of Contents for part 2 makes this transition easier by listing the old names where appropriate. Some genera have been divided or placed into different families also, and numerous species names have been changed. We have attempted to include all 1974 Handbook names that are now synonyms in the genus chapters. In addition, we have provided the scientific names and authorities for fungi from Farr and others (1989). Scientific names of insects, birds, and wild mammals have been taken from numerous accepted sources.

Another change in the current book is a shift from English to metric units. The metric system of measurements is now the “official” system of the United States, and it is commonly used in most USDA Forest Service publications. To assist users who are not yet comfortable with this, we have included both metric and English values for the most commonly used values in seedling production: number of seeds per unit weight (seeds per pound and seeds per kilogram), and number of seeds to sow per unit of bed area

(seeds per square meter and seeds per square foot). A table of conversion factors is again included before the glossary (page 1193).

The vast majority of the line drawings and photographs used in the 1974 Handbook have been used again in this volume. For new species, efforts were made to collect specimens for new photographs that are similar in style and background to those of the 1974 Handbook. In most cases this was done, but samples were not available for every new species. As a result, line drawings from other publications were utilized.

The glossary has been expanded by several dozen terms; a few have been dropped. Others have been altered to reflect current usage. Most terms of seed biology and seed technology have been defined according to the glossary of the IUFRO Working Party S2.01.06 “Seed Problems” (Bonner 1984).

Those who use this book should realize that much new information on seeds of woody plants has appeared in print since the current chapters were finalized. Efforts to improve the utilization of our forest and range resources continue, and new information is constantly discovered and put to use. Like the seed manuals published before, this one will not be the last, although the next revision may be a digital data base. Until another revision takes place, however, genus chapters will be periodically updated with new information on the website that was established during the current revision: *nsl.fs.fed.us*.

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Using This Book

Many difficult editorial problems developed as we worked on the Manual; some of them have no one best answer. The first was the metric versus “English” units question. This we resolved as discussed in the Introduction. Ironically, the English don’t use these units anymore, having made the switch to metric.

The next one was the problem of using common versus scientific names in the text. Switching back and forth from one to the other in the text (as was done in AH-450) can be very confusing, so we decided to use common names for the species and genera as consistently as possible in the text. All scientific names are provided in the text at first mention or in various tables listing the taxonomy of the genera; the preferred scientific name (according to PLANTS or GRIN 2004) are in listed in boldface.

We have also designated a preferred common name for a species in boldface. Please note that we have chosen these preferred common names with care. Although the other common names in use or found in various references are listed as well, we worked to provide preferred common names that are grammatically logical. Only those common names for a “true” genus stand alone as one word. Common names connected with hyphens or closed up as one word—such as Douglas-fir, mountain-laurel, mountain-ash, Cooke-pine, and Atlantic white-cedar, for example—indicate that these species are not members of the true fir, true laurel, true ash, true pine, or true cedar genera, respectively. The modifiers false mock, and pseudo, also indicate that the species is not a true member of the specified genus. Common names that include a person’s name are not in the possessive case; for example, Nuttall horsebrush, Gambel oak, Gardner saltbush, or Joshua tree. However, vernacular names such as eastern virgin’s-bower, traveler’s-joy, and squaw waterweed seemed best left as they were. Wonderful names like rubber rabbitbrush, tingiringy-gum, messmate stringybark eucalyptus, mountain misery and hearts-a-bustin’ provided some much needed humor during the editorial process.

Sometimes the correct or preferred word choice for a procedure or process is controversial or not in common use. For example, many of our authors used the traditional term “stratification”; others used the more current terms “chilling” or even “pre-germination chilling” (which is often shortened to “pre-chilling”).

Standard abbreviations for metric and “English” units are used throughout the book. Other words and units are shortened or abbreviated in the tables in the interests of saving space. The following abbreviations were used extensively in the references and text:

United States Government Departments and Agencies: USDA = United States Department of Agriculture, USDC = United States Department of Commerce, USDI = United States Department of the Interior. USDOE = United States Department of Energy. ARS = Agricultural Research Service, CFSTI = Clearinghouse for Federal Scientific and Technical Information, FS = Forest Service, OECD = Organization for Economic Cooperation and Development, NPS = National Park Service, NRCS = National Resources Conservation Service (formerly the SCS), NTIS = National Technical Information Service, SCS = Soil Conservation Service.

Non-governmental agencies and publishers: AOSA = Association of Official Seed Analysts, FAO = Food and Agriculture Organization of the United Nations, FNAEC = Flora of North America Editorial Committee, ISTA = International Seed Testing Association, IUFRO = International Union of Forestry Research Organizations, LHBH = Liberty Hyde Bailey Hortorium, NBV = Nederlandse Boschbouw Vereeniging, WFTSC = Western Forest Tree Seed Council.

Other: avg = average, dbh = diameter at breast height, max = maximum, min = minimum, mon = month(s).

In addition to the book, this Manual is being made available as a CD-ROM and can be read, downloaded, and printed at our website, which can be accessed at: nsl.fs.fed.us. There we plan to set up a system to update and add to the 236 genera that are included in the Manual.

Invasives

We remind our readers that listing species in this book is not necessarily a recommendation to use them! Many species that earlier in the twentieth century were recommended and even planted by various federal and state agencies as erosion control and wildlife plants—multiflora rose, autumn-olive, and Russian-olive, for example—are now considered invasive non-natives and are targets of eradica-

tion campaigns! Other plants that have escaped from horticultural uses—broom, burning bush, oriental bittersweet, Japanese barberry, etc.—are also members of this infamous company. Finally, there are invasive plants such as ailanthus and royal paulownia that arrived here accidentally. We sincerely hope that the information contained in this new manual may be of help in efforts to control woody invasives.

Part I Principles and General Methods of Producing and Handling Seeds

Chapter 1 Seed Biology

Franklin T. Bonner

- Introduction
- Flowering Plants
- Reproductive Cycles
- Flowering
- Fruit and Seed Development
- Dormancy
- Germination
- References

Chapter 2 Genetic Improvement of Forest Trees

Clark W. Lantz

- Introduction
- Concepts of Genetic Improvement
- Starting a Tree Improvement Program
- Deployment of Genetically Improved Materials
- Molecular Biology
- Tree Improvement Cooperatives
- The Future
- References

Chapter 3 Seed Harvesting and Conditioning

Robert P. Karrfalt

- Introduction
- Harvesting
- Seed Cleaning and Conditioning
- Post-Harvest Storage
- Extraction
- Cleaning and Upgrading
- Quality Control
- References

Chapter 4 Storage of Seeds

Franklin T. Bonner

- Introduction
- Factors Affecting Longevity of Seeds
- Storage Facilities
- Storage Recommendations
- Other Management Considerations
- References

Chapter 5 Seed Testing

Robert P. Karrfalt

- Introduction
- Sampling
- Sample Identification
- Moisture Tests
- Purity, Noxious Weed Content, and Seed Weight Tests
- Sowing Rates
- Buying and Selling Seeds
- Test Limitations and Variation
- Scheduling Seed Tests
- Commercial Trade of Tree, Shrub, and Native Plant Seeds
- References

Chapter 6 Certification of Tree Seeds and Other Woody Plant Materials

Robert D. Mangold and Franklin T. Bonner

- Introduction
- Certification in Agriculture
- Certification in Forestry
- Native Shrubs and Grasses
- Federal Seed Act and Labeling Laws
- Outlook for Certification
- References

Chapter 7 Nursery Practices

Thomas D. Landis

- Introduction
- Terminology
- The Target Seedling
- Types of Nurseries
- Propagation Options
- Bareroot Nursery Cultural Practices
- Container Nursery Cultural Practices
- Pest Management
- Summary
- References

Part 2 Specific Handling Methods and Data for 236 Genera

A

Abies 149
Acacia 199
Acer 204
Adenanthera 217
Aesculus 219
Ailanthus 224
Albizia (see also *Pithecellobium*) 227
Aleurites (see also *Vernicia*) 230
Alnus 232
Ambrosia 243
Amelanchier 245
Amorpha 250
Aralia 255
Araucaria 259
Arbutus 263
Arctostaphylos 266
Aronia 271
Artemisia 274
Asimina 281
Atriplex 283

B

Baccharis 291
Bauhinia 295
Berberis (see also *Mahonia*) 298
Betula 303
Bumelia (see *Sideroxylon*) 1047

C

Callicarpa 311
Calocedrus 313
Campsis 319
Caragana 321
Carnegiea 324
Carpenteria 326
Carpinus 328
Carya 333
Castanea 338
Castanopsis (see *Chrysolepis*) 404
Casuarina 342
Catalpa 345
Ceanothus 348
Cedrus 357
Celastrus 363
Celtis 366
Cephalanthus 369
Ceratonia 371
Cercis 374

Cercocarpus 381
Cereus (see *Carnegiea*) 324
Chamaebatia 385
Chamaebatiaria 387
Chamaecyparis 391
Chilopsis 396
Chimaphila 398
Chionanthus 401
Chrysolepis 404
Chrysothamnus 407
Cladrastis 413
Clematis 415
Clethra 419
Coleogyne 422
Colutea 426
Cornus 428
Corylus 434
Cotinus 438
Cotoneaster 442
Cowania (see *Purshia*) 879
Crataegus 447
Cryptomeria 457
Cupressus 459
Cytisus 466

D

Delonix 468
Dendromecon 470
Diospyros 472
Dirca 476

E

Ebenopsis (see also *Pithecellobium*) 482
Elaeagnus 484
Encelia 488
Enterolobium 490
Ephedra 492
Epigaea 495
Ericameria 497
Eriogonum 499
Eucalyptus 504
Euonymus 513
Eurotia (see *Krasheninnikovia*) 626

F

Fagus 520
Fallugia 525
Flindersia 528

Frangula (see also *Rhamnus*) 530
Franklinia 535
Fraxinus 537
Fremontodendron 544

G

Garrya 547
Gaultheria 550
Gaylussacia 557
Ginkgo 559
Gleditsia 562
Gordonia 565
Grayia (see also *Zuckia*) 567
Grevillea 573
Gutierrezia 575
Gymnocladus 578

H

Halesia 580
Hamamelis 582
Haplopappus (see *Ericameria*) 497
Heteromeles 585
Hippophae 588
Holodiscus 591
Hymenaea 595

I

Ilex 597

J

Juglans 601
Juniperus 607

K

Kalmia 615
Kalopanax 618
Kochia 620
Koelreuteria 624
Krascheninnikovia 626

L

Laburnum 631
Lagerstroemia 634
Larix 637
Larrea 651
Ledum 653
Lespedeza 655
Leucaena 658
Leucothoe 661

- Libocedrus* (see *Calocedrus*) 313
Ligustrum 663
Lindera 667
Liquidambar 670
Liriodendron 674
Lithocarpus 678
Lonicera 682
Lophostemon 689
Lupinus 691
Lycium 694
- M**
Maclura 697
Magnolia 700
Mahonia (see also *Berberis*) 706
Malosma (see *Rhus*) 954
Malus 712
Melia 718
Menispermum 720
Menodora 721
Metasequoia 723
Mitchella 726
Morella (see *Myrica*) 733
Morus 728
Myrica 733
- N**
Nama 738
Nandina 740
Nemopanthus 743
Nyssa 745
- O**
Oemleria 749
Olea 753
Olnya 757
Osmaronia (see *Oemleria*) 749
Ostrya 759
Oxydendrum 761
- P**
Paraserianthes (see also *Albizia*) 764
Parkinsonia 766
Parthenocissus 769
Paulownia 772
Penstemon 774
Peraphyllum 778
Persea 781
Phellodendron 783
Philadelphus 786
Photinia (see *Heteromeles*) 585
Physocarpus 790
- Picea* 793
Pieris 807
Pinus 809
Pithecellobium (see also *Albizia*) 848
Platanus 850
Platyclusus (see also *Thuja*) 854
Populus 856
Prosopis 872
Prunus 875
Pseudotsuga 891
Psorothamnus 907
Ptelea 910
Pterocarpus 913
Purshia 916
Pyrus 922
- Q**
Quercus 928
- R**
Rhamnus (see also *Frangula*) 939
Rhododendron 943
Rhodotypos 952
Rhus 954
Ribes 961
Robinia 969
Rosa 974
Roystonea 981
Rubus 984
- S**
Sabal 997
Salix 1000
Salvia 1010
Sambucus 1014
Sapindus 1019
Sapium (see *Triadica*) 1125
Sarcobatus 1022
Sassafras 1025
Schinus 1027
Sciadopitys 1030
Senna 1032
Sequoia 1034
Sequoiadendron 1037
Serenoa 1039
Shepherdia 1043
Sideroxylon 1047
Simmondsia 1049
Solanum 1052
Sophora 1055
Sorbaria 1057
Sorbus 1059
Spathodea 1065
- Spiraea* 1067
Styrax 1071
Swietenia 1075
Symphoricarpos 1078
Syringa 1083
- T**
Tamarix 1087
Taxodium 1089
Taxus 1092
Tectona 1099
Tetradymia 1102
Thespesia 1105
Thuja (see also *Platyclusus*) 1108
Tilia 1113
Toona 1119
Torreya 1121
Toxicodendron (see *Rhus*) 954
Triadica 1125
Tristania (see *Lophostemon*) 689
Tsuga 1127
- U**
Ulex 1140
Ulmus 1143
Umbellularia 1150
- V**
Vaccinium 1154
Vernicia (see also *Aleurites*) 1160
Viburnum 1162
Vitex 1168
Vitis 1171
- W**
Washingtonia 1173
- Y**
Yucca 1175
- Z**
Zamia 1178
Zanthoxylum 1180
Ziziphus 1183
Zuckia (see also *Grayia*) 1185