

The cover features a background image of a forest nursery. The top half shows a row of tall, dark evergreen trees against a light sky. The bottom half shows a vast field of young, light-colored seedlings planted in neat, parallel rows that recede into the distance.

FOREST NURSERY MANUAL

PRODUCTION OF BARERoot SEEDLINGS

EDITED BY

MARY L. DURYEA and THOMAS D. LANDIS

Martinus Nijhoff/Dr. W. Junk Publishers
for Forest Research Laboratory, Oregon State University

To order copies

A limited number of softbound copies of the *Forest Nursery Manual* are available for \$39.50 (U.S. funds only) from:

College of Forestry Oregon
State University Corvallis,
Oregon 97331 U.S.A.

Hardbound copies and future softbound editions may be obtained from Martinus Nijhoff/Dr W. Junk Publishers. Post Office Box 566,
2501 CN The Hague, The Netherlands.

Forest Nursery Manual: Production of Bareroot Seedlings

Duryea, Mary L., and Thomas D. Landis (eds.). 1984. *Forest Nursery Manual: Production Of Bareroot Seedlings*. Martinus Nijhoff/Dr W. Junk Publishers, The Hague/Boston/Lancaster, for Forest Research Laboratory, Oregon State University, Corvallis. 386 p.

The Forest Nursery Manual presents state-of-the-art information about current bareroot-nursery practices and research in the northwestern United States and Canada. Information on practices was gathered through a detailed nursery survey and incorporated into 30 chapters written by leading scientists and nursery managers. The Manual emphasizes the major stages of seedling production-selecting and developing the optimal site, assuring seed quality and vigorous early seedling growth, managing the soil and water, culturing bareroot seedlings, and harvesting and outplanting. A section on upgrading nursery practices is intended to stimulate thinking towards improving nursery management. A comprehensive glossary and tables of nursery conversion factors are included as appendices.

Forest Nursery Manual: Production of Bareroot Seedlings

Edited by Mary L. Duryea and Thomas D. Landis

A cooperative project of

Nursery Technology Cooperative
Department of Forest Science
Oregon State University
Corvallis, Oregon 97331 U.S.A.

and

U.S.D.A. Forest Service
State and Private Forestry
Pacific Northwest Region
Portland, Oregon 97208 U.S.A.

1984 • Martinus Nijhoff/Dr W. Junk Publishers
The Hague/Boston/Lancaster

for Forest Research Laboratory, Oregon State University
Corvallis

Managing Editor: Carol R. Perry
Cover Design: Don Poole

Distributors

For the United States and Canada: Kluwer Boston, Inc., 190 Old Derby Street, Hingham, MA 02043 U.S.A.

For all other countries: Kluwer Academic Publishers Group, Distribution Center, P.O. Box 322, 3300 AH Dordrecht, The Netherlands.

Library of Congress Cataloging in Publication Data

Main entry under title:

Forest nursery manual.

(Forestry sciences)

"Cooperative project of Nursery Technology Cooperative, Department of Forest Science. Oregon State University . . . and USDA Forest Service, State and Private Forestry, Region 6."

Papers presented at the Bareroot Nursery Technology Workshop held at OSU in October 1982.

Includes index.

1. Trees-Seedlings, bareroot-Handbooks, manuals, etc. 2. Forest nurseries-Handbooks, manuals, etc. I. Duryea, Mary L. II. Landis, Thomas D. III. Oregon State University. Nursery Technology Cooperative. IV. United States. State and Private Forestry. Pacific Northwest Region. V. Bareroot Nursery Technology Workshop (1982: Oregon State University). VI. Series.

SD404.25.F67 1983 634.9'564 83-17347

ISBN 90-247-2913-0

ISBN 90-247-2914-9 (pbk.)

The material contained in this publication is supplied with the understanding that there is no intended endorsement of a specific product or practice. Users of pesticides should always consult the appropriate regulatory agencies for the latest information on registration and application. Individual authors are responsible for the opinions expressed in and content of their chapters.

Copyright

© 1984 by Martinus Nijhoff/Dr W. Junk Publishers. The Hague.

All rights reserved. No part of this publication may be reproduced, stored in a retrieval system, or transmitted in any form or by any means, mechanical, photocopying, recording, or otherwise, without the prior written permission of Martinus Nijhoff/Dr W. Junk Publishers. Post Office Box 566, 2501 CN The Hague, The Netherlands.

Printed in the U.S.A.

Contents

List of Contributors	viii
Acknowledgments	x

Introduction

Chapter 1	
Development of the <i>Forest Nursery Manual: A Synthesis of Current Practices and Research</i>	
M. L. Duryea and T. D. Landis	3

Developing A Forest-Tree Nursery

Chapter 2	
Nursery-Site Selection, Layout, and Development	
F. E. Morby.....	9
Chapter 3	
Equipment for Forest Nurseries	
R. G. Hallman	17

Starting the Bareroot Seedling

Chapter 4	
Assuring Seed Quality for Seedling Production: Cone Collection and Seed Processing, Testing, Storage, and Stratification	
Y. Tanaka.....	27
Chapter 5	
Establishing a Vigorous Nursery Crop: Bed Preparation, Seed Sowing, and Early Seedling Growth	
B. E. Thompson.....	41

Managing the Soil and Water

Chapter 6	
Physical Properties of Forest-Nursery Soils: Relation to Seedling Growth	
B. P. Warkentin.....	53
Chapter 7	
Soil Fertility in Forest Nurseries	
R. van den Driessche.....	63
Chapter 8	
Soil and Tissue Analysis: Tools for Maintaining Soil Fertility	
C. T. Youngberg	75

Managing the Soil and Water (continued)

Chapter 9

Nursery Soil Organic Matter: Management and Importance

C. B. Davey 81

Chapter 10

Cover and Green Manure Crops for Northwest Nurseries

W. S. McGuire and D. B. Hannaway 87

Chapter 11

Water Management

R. I. Day 93

Chapter 12

Irrigation in Forest-Tree Nurseries: Monitoring and Effects on Seedling Growth

S. E. McDonald 107

Chapter 13

Land Drainage

D. E. Boyer 123

Culturing the Bareroot Seedling

Chapter 14

Plant Physiology and Nursery Environment: Interactions Affecting Seedling Growth

D. P. Lavender 133

Chapter 15

Nursery Cultural Practices: Impacts on Seedling Quality

M. L. Duryea 143

Chapter 16

Plug+ 1 Seedling Production

P. F. Hahn 165

Chapter 17

Genetic Implications of Nursery Practices

R. K. Campbell and F. C. Sorensen 183

Chapter 18

Weed Management in Forest Nurseries

P. W. Owston and L. P. Abrahamson 193

Chapter 19

Pest Management in Northwest Bareroot Nurseries

J. R. Sutherland 203

Chapter 20

Mycorrhiza Management in Bareroot Nurseries

R. Molina and I. M. Trappe 211

Harvesting and Outplanting the Bareroot Seedling

Chapter 21	
Lifting, Grading, Packaging, and Storing	
A. N. Burdett and D. G. Simpson	227
Chapter 22	
Nursery Storage to Planting Hole: A Seedling's Hazardous Journey	
J. W. Edgren	235
Chapter 23	
Assessing Seedling Quality	
G. A. Ritchie	243
Chapter 24	
Planting-Stock Selection: Meeting Biological Needs and Operational Realities	
R. D. Iverson	261

Improving Nursery-Management Style: Selected Topics

Chapter 25	
Sales and Customer Relations	
W. B. Ellington	269
Chapter 26	
Improving Productivity in Forest Nurseries	
S. M. Hee	273
Chapter 27	
Nursery Record Systems and Computers	
C. B. Royce	277

Upgrading Nursery Practices

Chapter 28	
Designing Nursery Experiments	
T. L. White	291
Chapter 29	
Problem Solving in Forest-Tree Nurseries with Emphasis on Site Problems	
T. D. Landis	307
Chapter 30	
Nurseries in the Northwest: A Unique Opportunity for Improving Forest Yield	
J. C. Gordon	315
Appendix A: Questionnaire # 1	319
Appendix B: Questionnaire # 2	345
Appendix C: Conversion Tables	361
Appendix D: Glossary	365
Index	377

List of Contributors

Lawrence P. Abrahamson, Senior Research Associate, College of Environmental Science and Forestry, State University of New York, Syracuse, New York 13210.

Donald E. Boyer, retired U.S.D.A. Forest Service, Route 3, Box 299, Newberg, Oregon 97132.

A. Nigel Burdett, Research Scientist, British Columbia Ministry of Forests, Research Branch, 1450 Government Street, Victoria, B.C. V8W 3E7 Canada.

Robert K. Campbell, Principal Plant Geneticist, U.S.D.A. Forest Service, Pacific Northwest Forest and Range Experiment Station, Forestry Sciences Laboratory, 3200 Jefferson Way, Corvallis, Oregon 97331.

Charles B. Davey, Carl Alwin Schenck Professor of Forestry, Soil Science, and Plant Pathology, North Carolina State University, Raleigh, North Carolina 27650.

Robert J. Day, Professor, School of Forestry, Lakehead University, Thunder Bay, Ontario P7B 5E I Canada.

Mary L. Duryea, Assistant Professor, Leader, Nursery Technology Cooperative, Department of Forest Science, Oregon State University, Corvallis, Oregon 97331.

James W. Edgren, Reforestation Specialist, U.S.D.A. Forest Service, Pacific Northwest Region, Post Office Box 3623, Portland, Oregon 97208.

Will B. Ellington, President, Lava Nursery, Inc., 5301 Culbertson Road, Post Office Box 370, Parkdale, Oregon 97041.

John C. Gordon, Dean, School of Forestry and Environmental Studies, Yale University, 205 Prospect Street, New Haven, Connecticut 0651 1.

Philip F. Hahn, Manager, Forest Research, Rex Timber, Inc., a subsidiary of Georgia-Pacific Corporation, Post Office Box 1618, Eugene, Oregon 97440.

Richard G. Hallman, Resource Staff Assistant, Missoula Equipment Development Center, Building 1, Fort Missoula, Missoula, Montana 59801.

David B. Hannaway, Assistant Professor, Department of Crop Science, Oregon State University, Corvallis, Oregon 97331.

Stephen M. Hee, Manager, Western Nurseries/Greenhouses, Land and Timber Production and Facilities, Weyerhaeuser Company, 7935 Highway 12 S.W., Rochester, Washington 98579.

Richard D. Iverson, Research Forester, Natchez Forest Research Center, Route 3, Box 312-B, Natchez, Mississippi 39120.

Thomas D. Landis, Western Nursery and Greenhouse Specialist, U.S.D.A. Forest Service, State and Private Forestry, Post Office Box 2 5127, Denver, Colorado 8022 5.

Denis P. Lavender, Professor, Department of Forest Science, Oregon State University, Corvallis, Oregon 97331.

Stephen E. McDonald, Research Forester, U.S.D.A. Forest Service, Timber Management Research, P.O. Box 2417, Washington, D.C. 20013.

William S. McGuire, Professor, Department of Crop Science, Oregon State University, Corvallis, Oregon 97331.

Randy Molina, Botanist, U.S.D.A. Forest Service, Pacific Northwest Forest and Range Experiment Station, Forestry Sciences Laboratory, 3200 Jefferson Way, Corvallis, Oregon 97331.

Frank E. Morby, Nursery Superintendent, U.S.D.A. Forest Service, J. Herbert Stone Nursery, 2606 Old Stage Road, Central Point, Oregon 97502.

Steven K. Omi, Research Assistant, Department of Forest Science, Oregon State University, Corvallis, Oregon 97331.

Peyton W. Owston, Principal Plant Physiologist, U.S.D.A. Forest Service, Pacific Northwest Forest and Range Experiment Station, Forestry Sciences Laboratory, 3200 Jefferson Way, Corvallis, Oregon 97331.

Gary A. Ritchie, Project Leader, Seedling Physiology, Weyerhaeuser Company, Western Forestry Research Center, 534 N. Tower Street, Centralia, Washington 98531.

Craig B. Royce, Nursery Manager, D. L. Phipps Oregon State Forest Nursery, Route 3, Box 193, Elkton, Oregon 97436.

David G. Simpson, Research Scientist, British Columbia Ministry of Forests, Kalamalka Research Station, 1450 Government Street, Victoria, B.C. V8W 3E7 Canada.

Frank C. Sorensen, Principal Plant Geneticist, U.S.D.A. Forest Service, Pacific Northwest Forest and Range Experiment Station, Forestry Sciences Laboratory, 3200 Jefferson Way, Corvallis, Oregon 97331.

Iack R. Sutherland, Research Scientist, Pacific Forest Research Centre, Canadian Forestry Service, 506 W. Burnside Road, Victoria, B.C. V8Z 1M5 Canada.

Yasuomi Tanaka, Forest Nursery Ecologist, Weyerhaeuser Company, Western Forestry Research Center, 534 N. Tower Street, Centralia, Washington 98531.

Barbara E. Thompson, Research Forester, International Paper Company, 34937 Tennessee Road, Lebanon, Oregon 97355.

James M. Trappe, Principal Mycologist, U.S.D.A. Forest Service, Pacific Northwest Forest and Range Experiment Station, Forestry Sciences Laboratory, 3200 Jefferson Way, Corvallis, Oregon 97331.

Robert van den Driessche, Senior Tree Physiologist, British Columbia Ministry of Forests, Research Branch, 1450 Government Street, Victoria, B.C. V8W 3E7 Canada.

Benno P. Warkentin, Professor and Head, Department of Soil Science, Oregon State University, Corvallis, Oregon 97331.

Timothy L. White, Supervisor, Western Research, International Paper Company, Post Office Box 3860, Portland, Oregon 97208.

Chester T. Youngberg, Professor Emeritus, Department of Soil Science, Oregon State University, Corvallis, Oregon 97331.

Acknowledgments

Producing a manual such as this requires the coordinated efforts, diverse skills and expertise, and continuing energies and commitment of many people.

Bob Tarrant headed the task force that proposed the establishment of the Nursery Technology Cooperative and recognized the need for an update on nursery technology.

We are grateful to Tim White, who was a valued sounding board throughout-providing excellent reviews of many stages of production, including the original outline of the Manual and the questionnaires.

We appreciate the hospitality of all nurseries and seed-processing plants who participated in the Oregon State University (OSU) Nursery Survey, conducted in fall 1981, and the thoughtful responses of managers and staff to our questionnaires. David Simpson of the B.C. Ministry of Forests deserves special mention for his efforts in surveying the Canadian organizations.

The Bareroot Nursery Technology Workshop, held at OSU in October 1982, previewed the Manual for over 250 people. The success and "smooth sailing" of the Workshop are largely attributable to the organizational talents of Pam Henderson and the contributions of Helen Dufur, Steve Omi, and Allan Doerksen.

The secretarial and clerical skills of Char Singkofer were invaluable in preparing the nursery questionnaires, workshop programs, and related correspondence. Julie Cone helped by typing some of the Manual chapters on word processor.

Special thanks are extended to all those individuals who took time from busy schedules to carefully review and critique chapters.

We are grateful for the production assistance of: Alan Smith for indexing; Steve Omi for developing the glossary and conversion tables; Martha Brookes, Tawny Blinn, Susan Bell, Tom Brookes, Beth Marshall, and Martha Burdick for proofreading; Allan Doerksen for photographic work; Don Poole for the cover and brochure designs; Joan Barbour for drafting and layout; Wes Patterson and Don Ferguson for typesetting; George Shaw and Dwayne Downing for printing; and Carol Perry for substantive chapter editing.

The organizational and creative talents of our managing editor, Carol Perry, were instrumental in the development of the Manual. Her professional insights and ability to visualize the comprehensive nature of the final product were invaluable. We are grateful for her help in making this an enjoyable project.

John Gordon provided continual support and encouragement. His foresight and belief in the need for this *Manual* motivated and inspired us. For this, and for his creative input, we are thankful.

We acknowledge with appreciation the financial support of both the Nursery Technology Cooperative and the Department of Forest Science, Oregon State University. The Division of State and Private Forestry of the Pacific Northwest Region, U.S.D.A. Forest Service, also provided financial assistance.

Finally, we are indebted to our chapter authors-without whose tremendous dedication, patience, diligence, persistence, and promptness this Manual never could have been produced.