Forest Nursery Notes

April 1993

This Technology Transfer Service is provided by:

USDA Forest Service
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April 1993

THOUGHT FOR THE DAY

"Bureaucracy occurs whenever process interferes with function "

Contents

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USDA Forest Service subscribers—please indicate your DG mailing address on the Literature Order Form, so that we can communicate by computer.

Nursery Meetings

Two ***Seed Testing Workshops*** are being scheduled at the National Tree Seed Laboratory this year: ***May 18-20*** and ***Sept. 21-23,1993***. The intent of these workshops is to give participants a thorough understanding of how the various seed tests are conducted so that they will understand the biology of seeds, the use of seed tests, and the factors that affect test results. The sessions will feature short lectures followed by "hands-on" laboratory exercises where actual seed tests will be performed. These workshops are FREE but maximum enrollment must be limited to 12 persons. Register early, because applicants will be accepted on a first-come, first-served basis. For more information, contact:

National Tree Seed Laboratory
5156 Riggins Mill Road
Route 1, Box 182-B
Dry Branch, GA 31020-9696

PHONE: 912-744-3312
FAX:912-744-3314

A symposium on ***Genetic Conservation and Production of Tropical Forest Tree Seed*** will be held in Chiang Mai, THAILAND on ***June 14-16,1993***. Organized by the ASEAN-Canada Forest Tree Seed Centre Project, the symposium will feature presentations on a variety of interesting subjects, including management of seed production areas and orchards and alternative propagation techniques. Two field tries will follow the technical sessions. If you would like more information, contact:

Symposium Secretariat
ASEAN-Canada Forest Tree Seed Centre
Muak-Lek, Saraburi, 18180
THAILAND

PHONE: 036-341-305
FAX: 036-341-859

The ***Fourth International Symposium on Windbreaks and Agroforestry*** is scheduled for ***July 26-39, 1993*** in Hedeselskabet, Viborg in DENMARK. The main theme for the meeting will be how agroforestry can contribute to future energy supplies and improve the environment. Nurseries are specifically mentioned in the program. Viborg is an ideal location for the symposium because it is the headquarters for the Danish Land Development Service and the Agricultural School. If you would like to present a volunteer paper or poster, or just want more information, write to the following address:

4th International Symposium
Hedeselskabet
P.O. Box 110
DK-8800, Viborg
DENMARK

The only nursery workshop in the US this summer will feature a special joint meeting of the ***Northeastern Area State, Federal and Provincial Nurseryman's Association***, the ***Intermountain Conservation Nursery Association***, and the ***Midcontinent Nursery Pathologists***. The technical sessions will be held at the Holiday Inn Riverfront in St. Louis, MO on ***August 2-5,1993*** and will feature focus topics on Soil Compaction, Organic Matter Management, Integrated Pest Management/Biocontrol, as well as General Nursery Topics. A field trip to the George O. White State Forest Nursery, which produces over 40 species of conifers, hardwoods, and shrubs, will feature a discussion of the new nursery GIS soil mapping program and equipment demonstrations. Several other local tours are interspersed throughout the program. Call me about the technical sessions or, for information on local arrangements, contact:

Bill Yoder
George O. White State Nursery
Route 2, Box 465
Licking, MO 65542

PHONE: 314-674-3229

The ***Third North American Agroforestry Conference*** will be held at Iowa State University in Ames, Iowa on ***August 15-18,1993***. The theme is "Opportunities for Temperate Zone Agroforestry - Worldwide" and the agenda will include technical presentations, workshops, and field trips. Submit an abstract of 250 words or less by April 1, 1993 if you would like to make a presentation. For more information, contact:

Richard C. Schultz
Dept. of Forestry
251 Bessey Hall
Iowa State University
Ames, Iowa 50011

PHONE: 515-294-7602
FAX:515-294-1337

The 24th Biennial meeting of the ***Canadian Tree Improvement Association*** will be held in Fredericton, New Brunswick on ***August 17-19,1993***. The theme for the symposium will be "Future Forests -Options and Opportunities" and the agenda will include technical sessions, workshops, and field trips. For further information, contact:

Kathy Tosh
Dept. of Natural Resources
Kingsclear Provincial Forest Nursery
RR #6
Fredericton, NB
CANADA E3B 4X7

PHONE: 506-453-9101

The ***Western Region of the International Plant Propagators' Society*** will be meeting at the Red Lion Motel in Bellevue, WA on ***Sept 8-11,1993***. The agenda is still being organized, but I promise to have more information by the July, 1993 issue of FNN.

The annual meeting of the ***Forest Nursery Association of British Columbia*** is being planned for the Florence Filberg Centre in Courtney, B.C. on ***Sept 13-15,1993.*** The organizers are soliciting papers on the theme "Changing Forestry Practices—Meeting the Challenge", which will explore the impact of future forestry practices on nurseries. Suggested topics include: species selection, seedling quality, stock types, cultural practices, and implications on genetic diversity. If you would like to present a paper, or just need more information, contact:

A. L. (Drew) Brazier
B.C. Ministry of Forests, Silviculture Branch
3rd Floor, Bastion Square
Victoria, BC
CANADA V8W 3E7

PHONE: 604-387-8936
FAX: 604-387-1467

The ***Intermountain Container Seedling Growers' Meeting*** will be held in Lewiston, ID on ***Sept. 23-24, 1993.*** The first day will be devoted to presentations on pesticides, chemigation and the new EPA Worker Protection Standards-note that this session can be used as credit towards your State Pesticide Certification. On the second day, we will be having open discussions on container nursery culture with a special emphasis towards nursery equipment. In addition, we will be taking tours of the Potlatch and Western Forest Systems nurseries. For more information, contact:

Kas Dumroese
Forest Research Nursery, University of Idaho
Moscow, ID 83844-1137

PHONE: 208-885-7017
FAX: 208-885-622

The ***IUFRO Working Party S2.-7-09 (Diseases and Insects in Forest Nurseries)*** will meet on ***Oct 3-10,1993*** in Dijon, FRANCE. Anyone interested in more information should contact:

Dr. Robert Perrin Station de recherches sur la flore pathogene dans le sol
INRA, 17, Rue Sully, B.P. 1540
21034 Dijon Cedex
FRANCE

FAX: 33-80-63-3232

Way out in 1994, the ***Western Forest Nursery Association*** will be meeting in conjunction with the ***Forest Nursery Association of British Columbia*** in Moscow, ID. We have reserved the conference center at the Best Western University Inn for the dates of ***August 15-19,1994****. I* know that it's a long way off, but this will be a meeting that you won't want to miss. For more information, contact me or:

Kas Dumroese
Forest Research Nursery, University of Idaho
Moscow, ID 83843

PHONE: (208) 885-7017
FAX: (208) 885-6226

National Nursery Issues

Methyl Bromide Fumigants - An Update

As predicted in the last several issues of FNN, the US Environmental Protection Agency (EPA) has officially proposed listing methyl bromide (MB) as a Class I Ozone Depletor under the Clean Air Act. The action was published in the March 18, 1993 issue of the Federal Register and will result in a freezing of MB production at 1991 levels and a total ban of the fumigant by the end of the century. It is possible that "essential uses" will be exempt from the ban if no acceptable substitutes are found. Note that this is only a proposal and the EPA is accepting comments on the listing until May 3, 1993. An extension to this short comment period has been requested but don't count on it. So, if you have strong feelings about the possible loss of MB fumigation in your nursery, then please take a few minutes and write a letter to the EPA and your congressional representative. A firm called Economists Incorporated is working on an economic impact statement and they can FAX you a short form to fill out:

U.S. Environmental Protection Agency
Attn: Air Docket No. A-92-13
401 M Street SW
Washington, DC 20460

Susan Dudley
Economists Incorporated
1233 20th St. NW, Suite 600
Washington, DC 20036

PHONE: 202-833-5201
FAX: 202-296-7138

In the meantime, a team of government agricultural experts is looking at alternatives to MB fumigation, analyzing current research, and making a priority list of new research needs. The team's report will be used to develop a workshop on MB alternatives to be held this June. Two USDA-Forest Service (FS) research pathologists, Dick Smith and Steve Fraedrich, are analyzing MB alternatives for forest and conservation nurseries. Last month, they sent questionnaires to federal, state, and private nurseries throughout the US. In addition, they are working with other FS scientists to determine what studies are currently underway on soil fumigation, determine what looks promising, and outline future research needs. One possible outcome from this analysis is the establishment of a FS research program on control of forest nursery pests, including alternatives to soil fumigation.

The FS Forest Pest Management group has recently funded a multi-year study on alternative controls for soilborne diseases. A team of nursery pathologists will be working in forest and conservation nurseries in Florida, Idaho, California, Oregon, and Washington with the following objectives:

1. To develop and evaluate cultural regimes that minimize soilborne disease and maximize seedling quality and outplanting performance
2. To evaluate beneficial microorganisms and "suppressive" soils as disease management tools
3. To develop sampling and assessment methods for predicting soilborne disease.
4. To compare costs and benefits of nursery management with and without fumigation.

Of course, MB fumigation in forest and conservation nurseries is just a small percentage of total agricultural use. Some states have already instituted new restrictions on the use of MB; for example, California now requires that a 1,500 foot buffer strip be left between fumigated areas and inhabited structures. Groups such as the American Association of Nurserymen and the Horticultural Research Institute are also active working on the situation. Two Methyl Bromide Alternative Conferences were held last month in California to discuss soil and commodity fumigation and plan new research on possible alternatives.

Regardless of new research findings, MB will continue to come under attack. Environmental organizations, such as the Natural Resources Defense Council, are already convinced that MB is doing "5 times the ozone damage of chlorofluorocarbons" and will continue to push for its immediate ban.

References:

Anonymous. ***Methyl bromide approaches the end of the road.*** American Nurseryman 177(7): 75.

Bonvie, L.; Bonvie, B. 1993. ***A crisis of complacency: ozone enemy continues to elude phaseout***. E: The Environmental Magazine 4(2):20-23.

Update. American Association of Nurserymen, March 10, 1993.

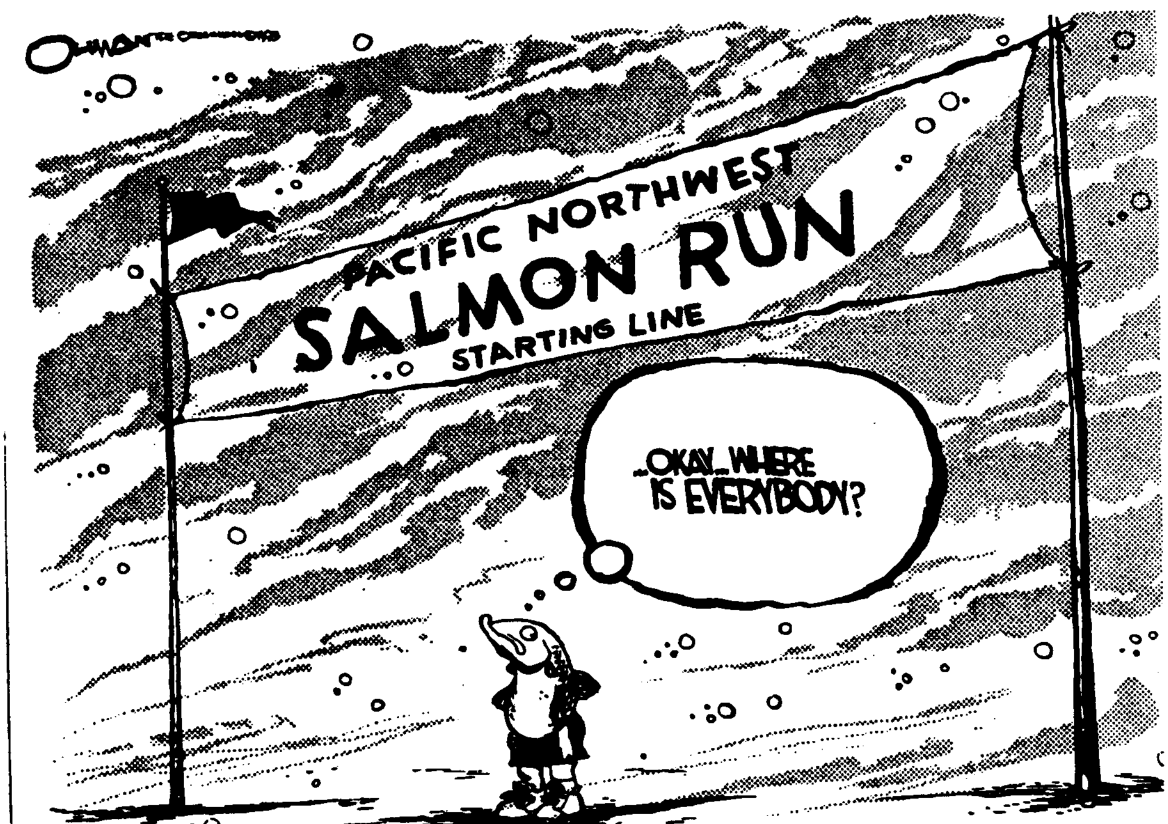
Johnson, B. 1992. ***Sudden impact: strawberry, cut flower and other growers say the prospect of losing methyl bromide—an invaluable fumigant—is frightening***. California Farmer, Dec. 1992: 6-7.

New National and International Emphasis on Reforestation

The details are still sketchy but a couple of new tree planting initiatives are reportedly in the works. The president and vice-president have repeatedly mentioned a new emphasis on reforestation programs on both the national and international level. "Trees for The Future" is the name for a proposed tree planting program that would be coordinated through the Cooperative Forestry Branch of the USDA-Forest Service. Rob Mangold, National Nursery and Tree Improvement Specialist, will be the contact person for these new programs and you can give him a call for the latest details:

Rob Mangold
USDA Forest Service, CF
P.O. Box 96090
Washington, DC 20090-6090

PHONE: 202-205-1379
FAX: 202-205-1271



Innovation in Recycling

I recently ordered some articles from Forestry Suppliers and, on opening the box, had a pleasant surprise. Instead of those annoying plastic packing "peanuts" that electrostatically adhere to everything and can't be recycled, the box was packed with Eco-Foam[R] pellets. These packing pellets look and function just like their plastic predecessors, but they completely biodegrade and do not contain any chlorofluorocarbons. EcoFoam[R] is a product of the National Starch and Chemical Company and are composed of 95% corn starch and 5% organic polymers. What makes them unique is that they can be saved and used over again but, when you put them in water, they biodegrade right More your eyes-instantly and completely.

To me, this is what the recycling movement should be about, not merely trying to find ways to reuse existing materials but developing new innovative products that solve a pre-existing problem. Hopefully, the new administration will institute a recycling awards program that will give proper recognition to these eco-friendly new products.

A Practical Look at Mycorrhizal Fungi in Nurseries - Part 1

The movement towards ecosystem management and biodiversity is having several effects on nurseries. In order to establish self-sustaining vegetation that will develop into a functioning ecosystem, customers are requesting that their seedlings be inoculated with beneficial microorganisms. This is already quite common for restoration plantings and I predict that it will become routine for most forest and conservation nursery stock. Mycorrhizal fungi are the best known of these microbes, so let's begin with them.

Probably more research has been done on mycorrhizae than on any other single aspect of nursery culture. Yet, most nursery managers that I talk to are either unsure about whether their seedling have mycorrhizae, or have no idea of which organisms are involved. So, I am going to try and review the subject of mycorrhizae and their use in forest and conservation nurseries. Because it is such a large subject, we will examine the basic biology of mycorrhizae, their benefits, and how to determine if you have a mycorrhizal problem in this issue. Then, in the July issue of FNN, we can look at types of mycorrhizal inoculum, how and when to inoculate, and the effect of nursery cultural practices.

What are mycorrhizae?

I'm sure that many of you have observed ectomycorrhizae on the roots of your conifer seedlings. Although they are sometimes visible on bareroot stock, ectomycorrhizae are most obvious on the outside of the root plug of container seedlings. But what are mycorrhizae?

Many people mistakenly think that mycorrhizae are fungi, but that answer is only half right. A mycorrhizae is an anatomical structure that results from the symbiotic association between a plant root and a fungus. There are two main types which are distinguished by their morphology: ectomycorrhizae and endomycorrhizae, which are more correctly known as vesicular-arbuscular mycorrhizae. What type you have in your nursery will depend on what species of seedlings you are growing.

Ectomycorrhizae (ECM)—These are the mycorrhizae that are most often noticed in forest and conservation nurseries because the colored sheath of fungal hyphae is obvious on the short feeder roots. Many of the fungi form typical mushroom fruiting bodies which are also evident in seedbeds (Figure A), or growing from containers. In addition to the fungus mantle on the roots, hyphae also grow between the epidermal and cortical cells in the roots, and also branch out into the soil or growing medium (Figure B). Conifers in the Pinaceae family and hardwoods in the Betulaceae and Fagaceae families develop ECM with fungi in the genera Boletus, Amanita, Cenococcum, Thelohora, Laccaria, Pisolithus, Rhizopogon, Hebeloma, and many others.

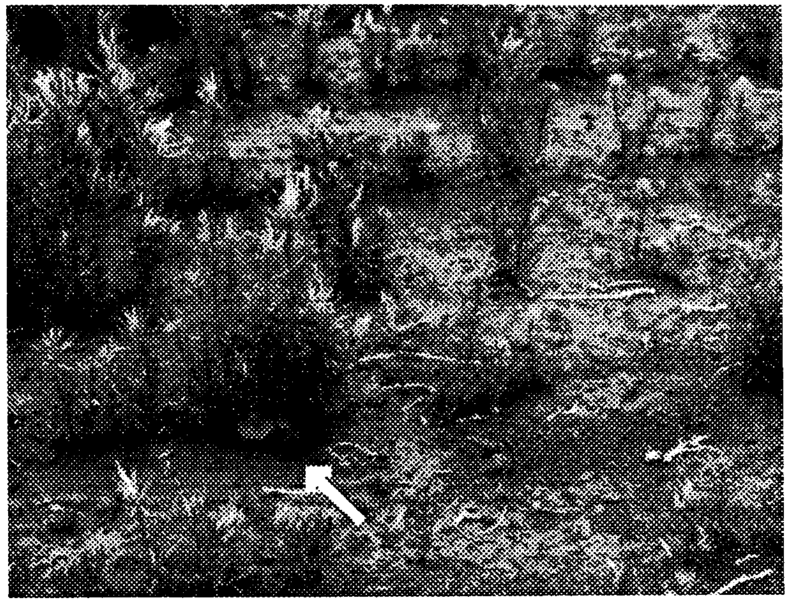


Figure A— Fruiting bodies ("mushrooms") of mycorrhizal fungi can often be seen in nursery seedbeds. In this picture, the mycorrhizal seedlings (arrow) are much larger and healthier than those without mycorrhizae.

Vesicular-arbuscular mycorrhizae (VAM)—This group of mycorrhizae are essentially invisible because the fungus exists as vesicles (lipid-filled sacs) and arbuscules (finely-branched structures) within the host roots. Although most of the structures are internal, thin fungal mycelia also extends from the roots out into the soil where relatively large spores form singly or in small clumps (Figure B). VAM fungi such as Glomus, Gigasl2ora, and Acaulospora colonize the roots of many broadleaved trees, some conifers, shrubs, grasses, and herbs.

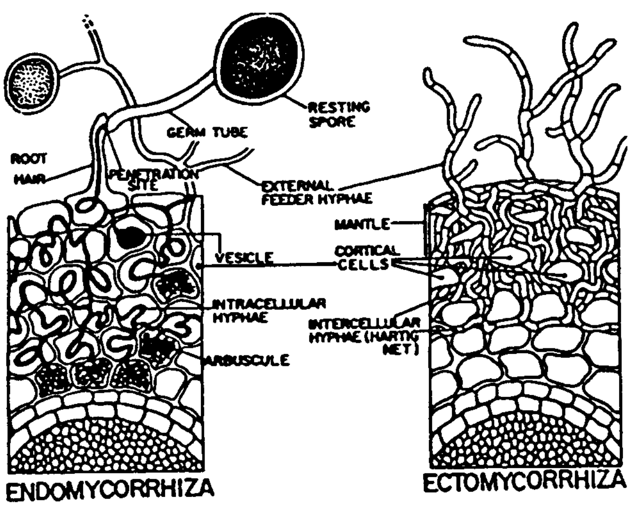


Figure B— Anatomical differences between the two major types of mycorrhizae--ectomycorrhizae and endomycorrhizae--shown in cross section (Linderman and Hoefnagels 1993)

Benefits of Mycorrhizae

Mycorrhizae are one of the most fascinating symbiotic relationships in nature. The host roots provide a convenient substrate for the fungus, and also supply food in the form of simple carbohydrates. In exchange for this free room-and-board, the mycorrhizal fungus offers several benefits to the host plant:

Increased nutrient uptake - This is probably the most significant single benefit of mycorrhizae, and is more important with some nutrients than others. Immobile mineral nutrients such as phosphorus often become limiting to plants, especially seedlings with their relatively small root systems. Mycorrhizae increase the root surface area, and the external hyphae can access nutrient sources beyond the reach of the roots. Apparently, mycorrhizal fungi can also act as biochemical intermediaries and convert nutrients to a more available form.

Drought resistance - The formation of mycorrhizae on tree seedling roots increases the size of the root surface area, and the external hyphae also expand the amount of soil that a plant is able to access. Mycorrhizae also provide some degree of drought resistance to tree seedlings, either through increased water uptake (ECM) or through phosphorous-mediated drought resistance (VAM).

Disease protection - Some mycorrhizal fungi have been shown to protect seedling roots from soilborne diseases. This can happen either directly through the protective mantle (ECM) and the production of antibiotics, or indirectly by improved seedling vigor. Although less-widely appreciated than the previous benefits, disease protection may be one of the most important reasons to culture mycorrhizae in forest and conservation nurseries.

Better Outplanting Performance - Of course, one of the most-widely acknowledged benefits of mycorrhizae is increased survival and growth on the outplanting site. The literature is replete with examples, so I'll just summarize and say that mycorrhizae are generally beneficial on restoration projects and have also produced benefits on more routine reforestation projects. There are some situations, however, where mycorrhizae may not always be necessary. In early-successional habitats, where plant competition is relatively low and the soil is temporarily rich following a disturbance, there is less need for mycorrhizae to aid in nutrient uptake. Similarly, on fertile outplanting sites, mycorrhizae may cause a carbohydrate drain to seedlings that is not offset by other benefits.

Customer Acceptance - One of the most important benefits is from a marketing standpoint, because seedlings with well-developed mycorrhizae are widely-accepted as high quality nursery stock. And, as mentioned earlier, more and more nursery customers are becoming aware of the advantages of mycorrhizae and are requesting that their seedlings be inoculated with specific fungi.

Do You Have a Mycorrhizae Problem?

I like to separate mycorrhizal problems into two categories: *nursery effects,* and *outplanting effects*.

Nursery Problems - Sometimes mycorrhizal problems in forest and conservation nurseries are all too apparent, but generally the effects are more subtle, so often go unnoticed. Because all of the factors limiting seedling growth can be supplied more easily in containers, I have never seen a mycorrhizae problem in nurseries using artificial growing media. And this makes sense, considering the benefits of mycorrhizae that we just discussed. All the necessary mineral nutrients and water can be easily supplied in container nurseries, and they also remain readily available in artificial growing media. Root pathogens should not be a serious problem with sterile media and good pest exclusion practices.

The situation is different in bareroot nurseries, however. Even under sound fertilization and irrigation regimes, mineral nutrients such as phosphorus and iron can be immobilized in native soil and therefore become limiting to plant growth. One common symptom of mycorrhizal deficiency in bareroot seedlings is what I call "mosaic stunting", in which patches of normal seedlings are interspersed with patches of stunted, chlorotic ones (Figure A). This symptom is frequently observed in nurseries that fumigate and is most common with species that have VAM mycorrhizae. I am convinced that this symptom is primarily caused by an induced phosphorus deficiency because, in some cases, it can be remedied by proper fertilization. Root pathogens frequently cause severe losses in bareroot nurseries, so seedlings with a good complement of mycorrhizal fungi should have a definite advantage.

Outplanting Effects - Unfortunately, the symptoms of a mycorrhizal problem are much more difficult to diagnose on the outplanting site. As you know, it is extremely hard to identify the reasons for poor seedling performance, especially if the stock survives, but fails to growth normally. Most standard reforestation sites already support a complement of mycorrhizal fungi, which quickly infect the planted seedlings within a few months. Problems can occur, however, on restoration sites that have degraded to the point that the normal mycorrhizal fungi have been lost. Seedlings planted on extreme sites, such as very hot burns or mining spoils, will have poor survival and growth unless they are inoculated at the nursery or at the time of outplanting.

Next Issue - I plan to present a list of all the commercial suppliers of mycorrhizal inoculum, and would be most grateful if you would drop me a note and let me know if you have been inoculating your seedlings. Your thoughts on any other aspect of the inoculation process would be most welcome also.

References:

Sally Campbell, USDA-FS, helped with the development of this segment and her efforts are gratefully acknowledged.

Castellano, M.A.; Molina, R 1989. Mycorrhizae. In: Landis, T.D.; Tinus, RW.;

McDonald, S.E.; Barnett, J.P. ***The Container Tree Nursery Manual**,* Volume 5. Agric. Handbk. 674. Washington, DC: U.S. Department of Agriculture, Forest Service: 101-167.

Linderman, R.G.; Hoefnagels, M. 1993. ***Controlling root pathogens with mycorrhizal fungi and beneficial bacteria.*** In: Landis, T.D. tech. coord. Proceedings, Western Forest Nursery Association.; 1992 September 14-18; Fallen Leaf Lake, CA. Gen. Tech. Rep. RM-221. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station: 132-135.

St. John, T.V. 1990. ***Mycorrhizal inoculation of container stock for restoration of self-sufficient vegetation***. In: Bergen J.J. Environmental Restoration. Washington, DC: Island Press: 103111.

Torrey, J.G. 1992. ***Can plant productivity be increased by inoculation of tree roots with soil microorganisms?*** Can. J. For. Res. 22: 18151823.

Special Publications

ORDERING INFORMATION - The following publications are featured here because they are of special interest to nursery folks. If you would like a copy, there are two different ordering procedures. **Numbered** or **Lettered** publications can be requested by circling the appropriate listing on the Literature Order Form and returning it to me. Special Order (SO) publications are either too long or too expensive for us to provide free copies, but prices and ordering instructions are provided here and following the individual listings in the New Nursery Literature section.

#A ***Annotated Bibliography of Conifer Seedling Pests in Pacific Northwest*** Bareroot Nurseries. Rose, R; Campbell, S.; Edgren, J. eds. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Region. 1989. 215 p.

This softbound publication is the result of an extensive literature search and is arranged into three major sections: diseases, insects, and weeds. Although primarily oriented to the Pacific Northwest, it should be useful to nursery managers and pest specialists in other regions as well. Besides, the price is right!
COST: FREE - Check # A on the Literature Order Form in this issue.

SO. ***Proceedings, Western Forest Nursery Association.*** Landis, Thomas D., tech. coord.; 1992 September 14-18; Fallen Leaf Lake, CA. Gen. Tech. Rep. RM-221. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 1993. 151 p.

This softbound publication is a compilation of 25 articles two special focus topics: "Propagating Native and Adapted Plants for Ecosystem Management and Biodiversity Projects", and "Biocontrol Options in Forest and Conservation Nurseries".

COST: FREE.

ORDER FROM: USDA Forest Service
Rocky Mountain Research Station
Publications Distribution
240 W. Prospect
Ft. Collins, CO 80526-2098
PHONE: 303-498-1719
FAX:303-498-1660

SO. ***An evaluation of yard waste composting with regard to pesticides and other toxic residues.*** Kovacic, D.A.; Bicki, T.J.; Cahill, R.A. Project No. OSWR 02-011. Urbana, IL: University of Illinois, Institute for Environmental Studies. 1992. 360 p.

Many bareroot nurseries are using, or are considering using, municipal waste for organic matter supplements. This large spiral-bound report examines **the composting process and the** fate of organic and inorganic contaminants that may cause environmental problems. Chemical composition, degradation, and environmental persistence information is given on 100 commonly-used domestic pesticides that could be found in yard waste. A simple model is presented to help identify which pesticides or other pollutants may be potential problems in composts made from yard wastes.

COST: $22.90

ORDER FROM: Kathy Reeves
Institute for Environmental Studies
1101 W. Peabody Drive
University of Illinois
Urbana, IL 61801
PHONE: 217-333-4178

SO. ***Root trainers in seedling production systems for tropical forestry and agroforestry.*** Josiah, S.J.; Jones, N. Land Resources Series No. 4. New York: The World Bank, Asia Technical Dept., Agriculture Div. 1992. 37 p.

This softbound publication addresses the need for a better container nursery system in developing countries. Although poly-bags are commonly used in many nurseries, they have several serious technical and logistical disadvantages. The authors have coined the term "root trainer" to describe any container that has some sort of root controlling feature. The two main sections deal with the types of containers used around the world, and locally-made growing media. The publication is well-written and informative because it reflects the direct experience of the authors.

COST: FREE

ORDER FROM:
Forestry Advisor (AGRNR)
The World Bank
Agriculture Division
1818 H Street, N. W.
Washington, DC 20433
PHONE: 202-458-1916
FAX:202-477-1865

SO. ***Growing and propagating showy native woody plants.*** Bir, R.E. Chapel Hill, NC: The University of North Carolina Press. 1992. 192 p.

This handsome softbound book is oriented to native plant propagation in the Central East Coast of the US, and is divided into two sections. The first contains some good basic information for the beginning grower, while the second deals with specific propagation instructions for local native plants. Although this book would be most valuable for growers in the eastern states, the clearly-explained concepts, excellent line drawings, and good quality color photographs will appeal to a much-wider audience.

COST: $29.50

ORDER FROM:
The University of North Carolina Press
P.O. Box 2288
Chapel Hill, NC 27515-2288
PHONE: 800-848-6224
919-966-3561

SO. ***IPM Training Manual for Wholesale Nursery Growers***. Daar, S.; Olkowski, H.; Olkowski, W. Berkeley, CA: Bio-Integral Resource Center and Washington, DC: Wholesale Nursery Growers of America. 1992. 84 p.

The loose-leaf manual is an excellent review of the various facets of Integrated Pest Management (IPM) as applied to nurseries. The first two chapters discuss the basics of IPM and its advantages, and the next 2 concern how to design and implement a pest monitoring program. Chapter 5 looks at record keeping, and particularly how to determine injury and action levels. Chapter 6 discusses how to select various pest treatment strategies and the final chapter is devoted to how to make the transition to IPM. There are four helpful appendices that deal with the practical aspects of pest identification, monitoring, setting action levels, and also contain sample forms. A very useful guide for anyone who is considering starting an IPM program - that includes anyone who doesn't already have one! Highly recommended.

COST: $68.50

ORDER FROM: Bio-Integral Resource Center
P.O. Box 7414
Berkeley, CA 94707
PHONE: 510-524-25 67
FAX: 510-524-1758

Please Help

The following publications are in the process of being written or updated and we can use your help. Many of you have developed valuable information on seed or nursery practices which should be shared.

Seeds of Wood Plants of the United States. This classic publication, which was last published by the USDA Forest Service as Agriculture Handbook 450 in 1974, is going to be updated. I recently participated in a steering committee meeting where we made the following decisions:

* **Format** - The basic format will remain the same. Part I will again cover the basic concepts of seed development, collection, processing, testing, and seedling establishment. Part II will include specific information for seeds of different genera of woody plants.

* **Scope** - The new manual will cover all of North America including Hawaii and the US Territories. A two volume format is being considered to reduce the size of the book - one for temperate zone plants and one for subtropical plants.

* **Timetable** - We hope to have the new edition published in about 3 years.

* **Process** - The general sections in Part I will be completely rewritten and author assignments have tentatively been made. The chapters for each genus in Part II will only have to be updated because most of this information is still accurate. Chapters will be computer-scanned and converted to a standard word processing format to facilitate the inclusion of new information, which will be gathered by a computer search of the published literature.

You can help in two ways:

1) New Species - Look through your copy of Seeds of Woody Plants in the United States, and suggest new species to be covered in the revised edition. Limit the list to species that you have some experience with or would like to be able to grow, because only those with a certain minimum amount of information will be included.

2) Unpublished data - The computer literature search will only reveal formal published research, and we know that many of you have developed your own operational procedures. Send in any published "in-house" reports that you may have or just jot down anecdotal information.

Please take a few minutes to give this matter some thought, and fill out the form in the back of this issue. Of course, you will be given full credit for your contributions. We have set **a deadline of May 15** so please return this form as soon as possible.

Tropical Seed Manual. The Forest Tree and Shrub Seed Committee of the ISTA (International Seed Testing Association) is compiling information on the seeds of tropical trees for inclusion in a seed manual. Data is needed on flowering and fruiting, seed development, collection, cleaning, testing, and storing. All contributions will be properly cited and acknowledged. Please share any published or unpublished information with the project coordinator:

Karen Poulsen
DANIDA Forest Seed Centre
Krogerupvej 3A
DK-3050 Humlebaek
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As we have been discussing in the last four issues of FNN, plants need six different limiting factors for good growth, four of which are found in the ambient environment (see Figure A). This issue, we will close out the ambient factors with a look at carbon dioxide (CO_2)'

Limiting Factors - Carbon Dioxide

Carbon dioxide is an anomaly - of the 16 nutrients that are essential for plant growth, it is the only one that is obtained solely from the atmosphere. CO2 is a rare atmospheric gas, but about 40% of the dry weight of a typical plant is composed of carbon. Plants obtain CO_2 from the air through the stomata in the leaves in a very complicated physiological process that also involves water vapor and oxygen.

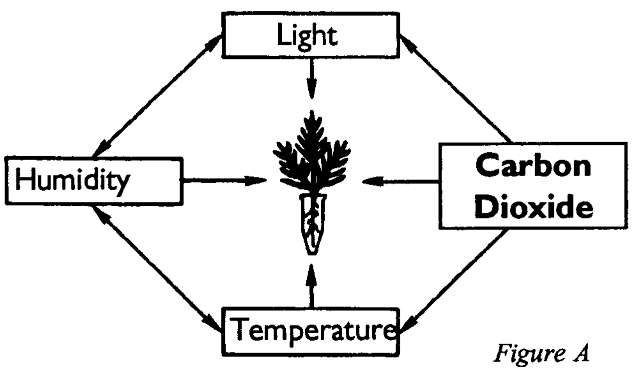

Figure A

But, although known to be a principal limiting factor of photosynthesis, $C0_2$ is rarely managed in forest and conservation nurseries. This should not be interpreted to mean that $C0_2$ is not important to tree seedling culture, however, as many research studies have shown that increased CO_2 levels can significantly accelerate photosynthetic rates. So, should nurseries managing this important limiting factor? Let's take a look.

Biophysics of carbon dioxide

Carbon dioxide is a colorless, odorless gas that exists in minute concentrations in the ambient atmosphere - currently around 0.035% (350 ppm). This was not always the case, however, as CO_2 was more common than oxygen in the primitive atmosphere. The rapid development of plant life quickly utilized this $C0_2$ and released oxygen, which made possible the evolution of larger and more advanced organisms. The CO_2 level of the earth's atmosphere appears to have stabilized at its lowest level (280 ppm) in the mid-1800's. Since that time, the industrial revolution has produced a gradual increase in ambient CO_2 concentrations. The combustion of fossil fuels, in combination with massive deforestation, have caused the atmospheric CO_2 level to increase 1 to 2 ppm per year. This trend is unlikely to change in the near future and has resulted in much-publicized concerns about "global warming".

The ambient CO_2 level around a nursery can vary from 200 to 400 ppm, depending on location; higher values can be found in industrial areas, due to combustion of fossil fuels, and in low wet areas, such as swamps and river bottoms, where plant materials are decomposing. Carbon dioxide concentration measured in weight per unit volume also decreases with elevation, decreasing about 40% from sea level to 4,500 m (14,800 feet).

In contrast to its positive effects on plants, high concentrations of CO_2 can adversely effect humans (Table 1). Dangerous levels could develop in greenhouses with faulty heating systems or poorly adjusted $C0_2$ generators.

Table 1 - Effects of carbon dioxide levels on plants and humans

Response	Carbon dioxide concentration (ppm)
Plant effects	
Negative growth	<100
CO_2 compensation	50-100
Reduced growth rate	100-350
Ambient CO_2 Level	350
Enhanced growth rate	350-1000
Marginal benefits	1,000-2,500
Possibility of adverse effects	>2,500
Human effects	
Worker exposure limit	5,000
Headaches and listlessness	> 5,000
Loss of consciousness and death	> 80,000

Measuring CO_2

Carbon dioxide levels can be described and measured in several different ways. Because it is a gas, CO_2 can be described in pressure units but these are not widely used for horticultural purposes. Plant physiologists measure photosynthesis by the amount of CO_2 consumed and commonly express it by weight in milligrams (mg) or volume in microliters (ul) per unit volume. However, for operational nursery work, concentration units—parts per million(ppm)—are the simplest and most appropriate way to measure CO_2.

Carbon dioxide measuring instruments vary considerably in cost and complexity. Small hand-pump CO_2 testers of reasonable accuracy are available for around $200; the air is pumped through a glass tube that contains a CO_2-sensitive chemical that changes color as an air sample is drawn through it. The more sophisticated and expensive infrared gas analyzer ($1,400), is much more accurate and precise. Because they can measure CO_2 continuously and can interface directly with environmental computer systems, infrared gas analyzers are often used in fully-controlled greenhouses.

Effects of CO_2 on seedling growth

Plants consume CO_2 during photosynthesis and give it off through respiration; during daylight hours these processes occur simultaneously. In plant leaves, when the CO_2 level reaches the **compensation point**, the point at which photo-synthesis and respiration are equal (Table 1), the seedling will not grow but only maintain itself. If CO_2 concentrations are enhanced above ambient levels, the photosynthetic rate increases because high CO_2 concentrations increase the diffusion gradient from the ambient air, through the stomata, to the mesophyll cells where the chloroplasts use CO_2 in photosynthesis. Seedling growth rate increases when the net photosynthate is exported from the leaves, where photosynthesis takes place, to the meristems, where growth occurs. There are numerous studies on the beneficial effects of enhanced CO_2 on tree seedling growth.

There is an upper limit to how much more CO_2 can use, however, as high concentrations of CO_2 can cause stomatal closure. Although the limits

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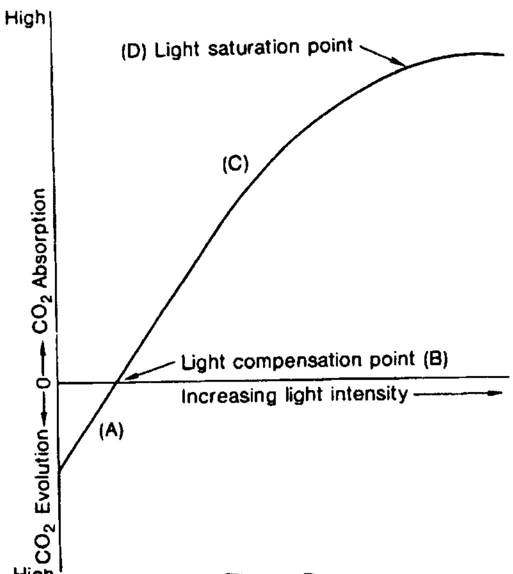

Figure B

vary considerably with light intensity and between different plant species, CO_2 levels over 1,000 ppm generally show diminishing benefits. Carbon dioxide concentrations over 2,500 ppm are rarely beneficial and may actually result in reduced growth (Table 1).

The effects of CO_2 cannot be considered alone, however, for they are highly interrelated to the effects of other factors limiting to plant growth, especially light, temperature, water, and mineral nutrients. As the CO_2 concentration changes and the photosynthetic rate varies, the optimum levels of the other environmental factors also change.

Light - Photosynthesis**,** as measured by CO_2 utilization, increases linearly with light until the light saturation point is reached (FIGURE B). As long as the other factors are not limiting, the light saturation point becomes progressively greater as light intensities and CO_2 concentration increase. In fact, high CO_2 levels can, to a degree, compensate for low light intensity, which often occurs on cloudy winter days. When supplemental photosynthetic lighting is used in greenhouse culture, CO_2 enrichment is essential in obtaining the full benefits from the additional light.

Temperature - Nursery seedlings are primarily cooled by transpiration under normal growing conditions. Because stomatal aperture controls both CO_2 and water loss, ambient CO_2 levels affect transpiration rates. Artificially high CO_2 levels, resulting from improperly adjusted CO_2 generators, could cause stomatal closure and subsequent heat injury to succulent nursery seedlings.

Water and mineral nutrients - The rapid growth rates of plants grown under CO_2 enrichment result in an increase in water and mineral nutrient uptake. Seedling water use will increase because the increased foliage has a larger transpirational surface. The increased growth resulting from the higher photosynthetic rate will also create a demand for more mineral nutrients. Often, the increased growth rate of the many seedlings under CO_2 enrichment does not persist, because mineral nutrient deficiencies are caused by the rapid growth.

Growers who supply extra CO_2 to their crops will have to be aware of these potential problems and make appropriate adjustments to their cultural regimes.

Modifying CO_2 in Nurseries

So, the potential of stimulating seedling growth by increasing CO_2 levels is high but is that really practical in an operational nursery? Actually, there are only two options: increasing air exchange, and CO_2 generators. The first is feasible in all types of nurseries, whereas the latter is only practical in enclosed growing environments like greenhouses.

Increasing air exchange - Good circulation of air is necessary to make CO_2 available at the leaf surface. Therefore, growers can stimulate seedling growth by merely encouraging good ventilation. During the day when the air is stagnant, the CO_2 concentration in the boundary air layer around a seedling can be considerably lower than the ambient conditions, so increasing the air flow over the leaves makes the gas more available for photosynthesis. In studies with field crops, researchers have shown that merely increasing the wind velocity over the leaf surface can significantly increase photosynthesis. Under calm

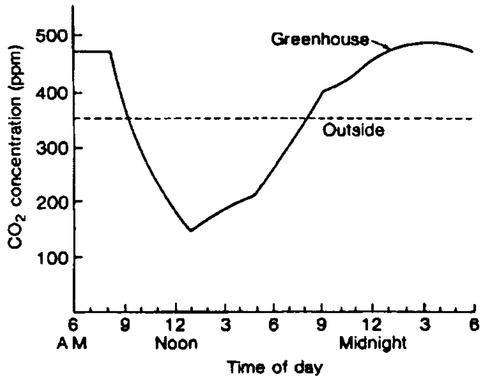

Figure C

conditions, CO_2 levels have been shown to be limiting in dense crops grown in open fields, resulting in a 10 to 20% decrease in photosynthetic rate. So, while it would be impossible to control the wind, bareroot nurseries can insure that all seedlings have access to adequate supplies of CO_2 by lowering seedbed growing densities.

Good air exchange can be more challenging in container nurseries, especially those with enclosed growing environments. Carbon dioxide levels follow a typical diurnal pattern in a closed greenhouse environment (Figure C). At night, green plants release CO_2 through respiration and so concentration in a closed greenhouse rises to over 400 ppm; however, at dawn, photosynthesis begins and the concentration drops rapidly. The CO_2 concentration can become critically low in a greenhouse on a cool, cloudy day when ventilation is not required; in a greenhouse with only two air exchanges per hour or less, the CO_2 concentration often drops below 200 ppm and so can limit photosynthesis (Table 1).

Research has shown that increasing the air flow rate to 50 cm/sec (99 feet per minute) is equivalent to a 50% increase in CO_2 levels. The potential for increasing ventilation is limited, however, as the wind velocity at maximum ventilation is around 42 cm/sec (83 feet per minute) in a fully-enclosed greenhouse. Because new energy-efficient greenhouses are much more air-tight than older ones, growers can no longer depend on normal air exchange to keep CO½2 levels adequate. Growers with shelterhouses should stimulate photosynthesis by raising the sides whenever air temperatures permit, and those with fully enclosed structures should use fan-jet ventilation systems that encourage good air mixing within the greenhouse. Even on days when outside temperatures are low, it may prove beneficial to bring in outside air and heat it, especially early in the morning when photosynthetic rates are highest.

***Carbon dioxide enrichment* -** The potential of CO_2 enrichment has been demonstrated in growth chamber experiments where growth of tree seedlings has been increased 50 to 100%, so CO_2 generators are often used in high-tech greenhouses. The feasibility of CO_2 enrichment depends on the type and the condition of growing structure and the proportion of the time the vents remain closed.

There are several potential ways of supplying CO_2 to greenhouse crops. Decomposing organic matter will eventually release 1.4 times its weight of CO_2 and, although the potential has been demonstrated for forest seedlings, this technique is not considered practical because of problems with sanitation and disposal. In modern container nurseries, there are two realistic options for supplying CO_2: injection of pure CO_2 and combustion of carbon fuels.

Injecting pure CO_2 from pressurized liquid tanks is the safest technique but it is expensive. Complete combustion of any carbon compound will produce CO_2. Kerosene was the first fuel to be used in greenhouses but its cost and concerns about sulfur dioxide phytotoxicity have made it unpopular. In modern container nurseries, natural gas and propane are more commonly used, and the difference is primarily one of cost and availability. Commercial CO_2 generators that burn propane or natural gas and the CO_2 production rate is controlled by modulation of the burner. The principal disadvantage of these CO_2 generators is that exhaust leaks or incomplete combustion can release phytotoxic gases into the greenhouse. Approximately 15 burners per hectare (6 per acre) should generate 1,000 ppm CO_2 in a well-sealed greenhouse. Microcomputer control systems use infra-red gas analyzers and a system of solenoid valves to regulate the CO_2 concentrations in the greenhouse to within 100 ppm. In spite of the proven potential for increasing seedling growth, CO_2 enrichment is not widely practiced in container tree nurseries. Only 17% of the nurseries in the United States and Canada reported CO_2 management programs in a survey for the Container Tree Nursery Manual.

Well, that rounds up our discussion of the atmospheric factors that can limit seedling growth: light, temperature, humidity and carbon dioxide. In the July, 1993 issue of FNN we'll take a look at mineral nutrients and various options for fertilization in forest and conservation nurseries.

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Editorial

The Need for Comprehensive Planning and Budgeting in Ecosystem Management

As you know, the trend towards ecosystem management is gaining strength and will undoubtedly change the way in which natural resources are managed. It's still early, but the Clinton Administration has given strong signals that they favor an ecosystem approach to natural resource management - especially restoration projects such as replanting riparian areas and forest health.

Restoration planting projects will generate a demand for a wide variety of plant materials, and forest and conservation nurseries are both willing and able to meet this demand (see Proceedings, Western Forest Nursery Association in Special Publications section). However, one of the most

Year	Activity	Months											
		J	F	M	A	M	J	J	A	S	O	N	D
One	Planning				•	•	•						
	Collect Seed								•	•	•	•	
	Stratification											•	•
Two	Stratification	•	•	•	•								
	Transplanting		•	•	•	•							
	Growing				•	•	•	•	•	•	•	•	•
Three	Growing	•	•	•	•	•							
	Hardening					•	•	•	•	•			
	Shadehouse								•	•	•	•	•

serious disadvantages of using nursery stock is the high initial cost - where is the money going to come from? Many government organizations have no established funding source for purchasing and planting non-commercial species; for example, the budget for nurseries and reforestation in the USDA Forest Service is closely tied to commercial timber sales. One proposal is to establish an "ecosystem management fund" using receipts from salvage timber sales, and the Forest Service has projected that $30 million could be used for ecosystem restoration projects. Other potential funding sources include initiatives for $246 million over the next four years to promote tree planting in urban areas and nonindustrial forest land, and $170 million for international programs, some of which would be used to reforest degraded lands.

Just as serious as the lack of established funding sources, is the need for good long-range planning. Many program administrators just don't understand that forest and conservation nursery stock is not an "off-the-shelf" item. As you know only too well, even after a seedling order is received it takes time to plan, order the seed, and stratify it even before it can be sown in the nursery. Many propagation schedules for the diverse species that will be used in ecosystem management projects take as long as 3 years (Figure A). One possible solution to this dilemma is mufti-year contracts. Growing contracts that extend across fiscal years are irritating to contracting officers or budget analysts, but they make sense from an ecosystem management standpoint. Mufti-year growing contracts also result in lower seedling cost and higher seedling quality. As nurseries become more proficient in growing a given species or stock type, per-unit costs will go down and seedling quality will go up. "Grow-and-plant" contracts, in which a nursery does everything from collecting the seed to outplanting their seedlings, make good sense from an ecosystem management standpoint and should also be more widely used.

Nursery managers also need to take more time for planning and marketing. Issues like biodiversity and ecosystem management mean that nursery managers will no longer just be dealing with traditional reforestation personnel. A variety of different resource professionals will be needing plant materials, so nursery managers will be communicating with wildlife biologists, recreation specialists, and other new, inexperienced customers. Nurseries that can provide a full range of services from seed collection and processing to seedling storage, and outplanting will also receive more business. Natural resource managers are specialists who do not want, or have the time, to work with a series of different businesses and so will prefer to work with one full-service facility.

The trend towards ecosystem management will change the way that forest and conservation nurseries interact with their customers. Successful nurseries will become proactive and devote a significant amount of time to marketing their products and services and establishing better communications with natural resource managers and planners.

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A Corporate Fairy Tale

Once upon a time an American aerospace company and an Asian rice cooperative decided to have a competitive boat race. Both teams practiced hard and long to reach their peak performance, and on the big day, both felt they were as ready as they could ever be.

The rice farmers won by a mile.

The American team was discouraged by the loss and suffered from sagging morale, so corporate management decided that a reason for the humiliating defeat had to be found. A Measurable Improvement Team was set up to investigate the problem and to recommend appropriate corrective action. They concluded the problem was: The Asians had eight people rowing and one steering, whereas the American team had one person rowing and eight steering.

So, the American team promptly hired a consulting firm to do a study and find a solution. After some months and millions of dollars, the consulting firm concluded that poor corporate communication was to blame and that a new "participative team approach" would solve this problem. One of the key concepts of this reorganization is that there would be a clear chain of command and that every team member would be "validated" with a special title. After several weeks of staff meetings, the new rowing team was reorganized so that the rower would be backed up by a steering manager, an assistant steering manager, as well as a full range of other support personnel. Instead of practicing rowing, the weeks before the next race were dedicated to a series of team building and training sessions so that each team member would understand the complexities of their new positions. An incentive program was also initiated to improve the team's performance - to give them "empowerment" and "enrichment".

The next race, the American team lost by two miles.

Humiliated, the American corporation laid off the rower for poor performance, halted development of a new boat, sold all the paddles, cancelled all capital investment for new equipment, gave a performance award to the consulting firm, and distributed the money saved as bonuses to senior executives.

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