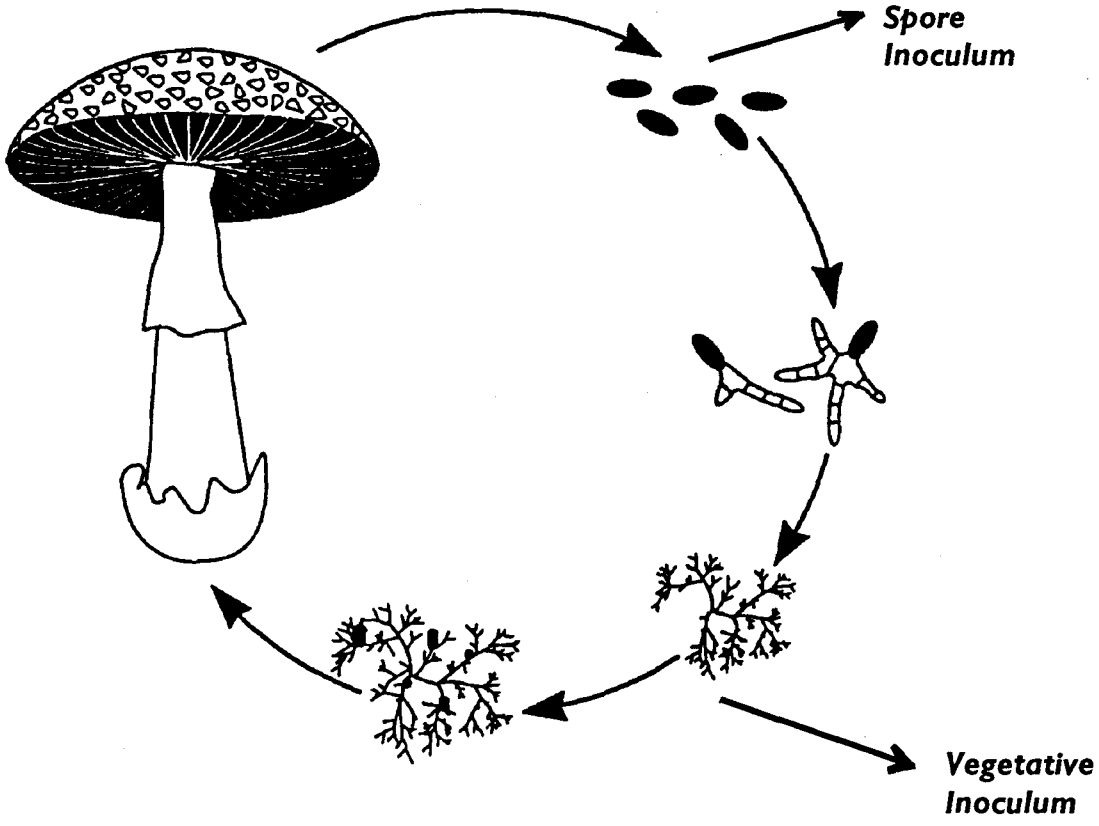
Forest Nursery Notes

July 1993



Two types of Mycorrhizal Inocula

This Technology Transfer Service Is Provided by:

USDA Forest Service
State & Private Forestry
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Forest Nursery Notes

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Thought for the day:

"Believe that you can make a difference"

How many mistakes did you find in the last issue?

Although it wasn't apparent from the many typos in the April, 1993 issue of FNN, I really do proofread the final draft before it goes to the printer. A few mistakes always slip through, but that issue must have been a record. Oh well, I'll try harder this time.

International Subscribers -

An information and literature service like *Forest Nursery Notes* generates a surprising amount of "spin-off ' work. People call up with all sorts of questions and requests. I keep up with it as best I can, but my primary responsibility is to provide technology-transfer to nurseries in the Western US. I'll try to respond to those of you who live in other countries but it's becoming increasingly difficult to keep up. I don't know what the solution is—we fill seem to have too much to do and too little time. One possible solution to this dilemma would be to use USDA Forest Service International Forestry funds to support Forest Nursery Notes and follow-up technical assistance for foreign subscribers. The initial response to this idea was cool, however, so we'll just have to see. In the meantime, those of you outside the US will just have to be patient, and I'll continue to do the best I can.

TL

Forest Nursery Notes, July 1993

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Nursery Meetings

The Fourth International Symposium on Windbreaks and Agroforestry is scheduled for **July 26-30,1993** 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

A special **Combined Nursery Meeting** in St. Louis, MO on **August 2-5,1993** will be the only forest and conservation nursery workshop in the US this summer. It will be attended by members of the Northeastern Area State, Federal and Provincial Nurseryman's Association, the Intermountain Conservation Nursery Association, and the Mid-continent Nursery Pathologists. The technical sessions will be held at the Holiday Inn Riverfront and will feature focus topics on Soil Management, Organic Matter Management, Integrated Pest Management, Biocontrol, as well as General Nursery Topics. A pre-conference trip to the Illinois Dept. of Conservation Mason State Nursery is scheduled for Sunday, August 1 - advance registration is required. On the following Tuesday we will be visiting our hosts, the George O. White State Forest Nursery, to view over 40 species of conifers, hardwoods, and shrubs as well as discuss their new nursery GIS soil mapping program and equipment demonstrations. Be sure and bring the family because the Riverfront is located across from the Gateway Arch and Jefferson Expansion Memorial and a full schedule of local sight-seeing excursions are planned. If you didn't get your registration packet call the nursery soon. There is a substantial savings by registering early. I look forward to seeing you there.

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

PHONE: 314-674-3229

The **Annual Symposium of the Seedling Growers Association of South Africa** will be sponsoring a workshop on **August 13-14,1993** at the Wild Coast Sun near Port Alfred, SOUTH AFRICA. The focus topics will be "Growing Medium: Physical Properties, Quality and Measurement" and "Nutrition, Water Quality, and Alkalinity" and the keynote speaker will be Australian growing medium expert, Kevin Handreck. For more information, contact:

Lolly Stuart
Seedling Growers Association of S.A.
P.O. Box 11636
Dorpspruit, 3206
REPUBLIC OF SOUTH AFRICA

PHONE: 331-425779
FAX: 331-944842

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. 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, CANADA 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 Hotel in Bellevue, WA on **Sept. 8-11,1993**. The program is still being developed but always contains an interesting mixture of topics of interest to growers. For more specific information, contact:

Wilbur Bluhm
743 Linda Ave., NE
Salem, OR 97303

PHONE: 503-393-2934

The annual meeting of the **Forest Nursery Association of British Columbia** will be held at the Florence Filberg Centre in Courtney, B.C., CANADA on **Sept 13-15, 1993**. The theme will be "Changing Forestry Practices - Meeting the Challenge", which will be explore the impact of future forestry practices on nurseries. Specific topics will include: species selection, seedling quality, stock types, cultural practices, and implications on genetic diversity. If you would like 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

A **Seed Testing Workshop** will be held at the National Tree Seed Laboratory in Macon, GA this year on **Sept. 21-23,1993**. This workshop will 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 session will feature short lectures followed by "hands-on" laboratory exercises where actual seed tests will be performed. This workshop is FREE but there is only bench space for 12 persons. So 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

The **Second Annual Advanced Forest Herbicides Course** is scheduled for **Sept. 27-Oct. 8,1993** in Sault Ste. Marie, Ontario, CANADA. This course is an intensive, practical program developed specifically for foresters, pesticide applicators, and others interested in improving their knowledge of pesticide use. For more details, contact:

Eileen Harvey or Fiona Ortiz
Forest Pest Management Institute
1219 Queen Street East
Sault Ste. Marie, Ontario
CANADA P6A SM7

PHONE: 705-949-9461
FAX:705-759-5700

This year's **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 Integrated Pest Management 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 equipment, seedling harvesting, and storage practices. The meeting will also include tours of Western Forest Systems and Potlatch Forest Industries nurseries, along with a jet-boat trip up the Snake River. For more information, contact:

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

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

The International Union of Forestry Research Organizations **(IUFRO) Working Party: Diseases and Insects in Forest Nurseries** will be meeting on **Oct. 3-10,1993** in Dijon, FRANCE. These meetings are an excellent opportunity to get together with other professionals and discuss common projects. If you are interested in attending, please contact:

Dr. Robert Perrin
Station de Recherches sur la Flore
pathogene dans le Sol
INRA, 17 rue Sully - B.V. 1540
21034 Dijon Cedex
FRANCE

FAX: 33-80-63-3232

A **Reforestation Contractors Workshop** is scheduled for **Oct. 27-28,1993** at the LaSells Stewart Center at Oregon State University in Corvallis. The objective of this session is to inform contractors, government agencies, and other interested individuals about all aspects of the contracting process. More and more work in nurseries and on the outplanting site is being contracted and so this workshop should be most helpful. For more information, contact:

Robin Rose or Diane Haase
Dept. of Forest Science
Oregon State University
Corvallis, OR 97331-5705

PHONE: 503-737-6580
FAX: 503-737-1393

The Virginia Department of Forestry will be hosting the **Southern Forest Nursery Association Meeting** in Williamsburg, VA on **July 11-14,1994**. The planning committee is circulating a questionnaire to members to get their ideas for the technical content and social activities for the meeting. If you would like to participate in the survey, contact Dwight Stallard, or if you want to get on the mailing list for the meeting, call Ronald Jenkins:

Dwight Stallard
19127 Sandy Hill Road
Courtland, VA 23837

Ronald S. Jenkins
Virginia Dept. of Forestry
P.O. Box 3758
Charlottesville, VA 22903
PHONE: 804-966-2201

In August of next year, 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. This promises to be a meeting that you won't want to miss, so mark it on your calendar. For the latest 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

National Nursery Directory

Cooperative Forestry is updating the very popular, but outdated, "Directory of Forest Tree Nurseries in the United States" which was last published in 1987. This directory is the only national listing of forest and conservation nurseries and is used by potential seedling buyers to locate seedlings, as well as others needing information on nursery location and production capability. Debie Okholm and Ray Abriel of our Portland Office will be circulating a short questionnaire to forest and conservation nurseries across the US this summer. Please take the time to fill it out promptly and completely so that we can make the fall publishing deadline. Any nurseries failing to respond will be deleted from the mailing list and will not be included in the directory. Free copies of the Directory will be announced in FNN sometime during the coming Winter. If you need more information, you can contact Debie or Ray at my address--see the inside cover page.

Methyl Bromide Fumigants

No, I don't have any earthshaking developments about the purported effect of methyl bromide on the ozone layer and probable ban on soil fumigation. See the last few issues of FNN for the latest technical and political details. The US Department of Agriculture sponsored a "Methyl Bromide Alternatives Research Workshop" late last month which was attended by participants from industry, university and government. Development of IPM systems to ameliorate the loss of methyl bromide was selected as a top research priority, along with the development of substitute chemicals and cultural controls. I'll keep my ear to the ground and report further developments in future FNN issues.

Legal Labeling of Growing Media

The "Horticultural Growing Medium Act" that is currently being considered in the state of Georgia is a result of a sharp rise in the number of problems with growing medium quality in the Southeast in recent years. Spot inspections of commercial brands of growing media have turned up mislabeled bags and improperly filled orders. Subsequent tests from unopened bags found pH levels over 7.0, ammoniacal nitrogen exceeding 100 ppm, and soluble salts greater than 2.0 mmhos/cm. Obviously, using media of this poor quality could cause serious problems, especially with young succulent seedlings. Growing media was also sampled from containers after 4-10 weeks of nursery culture and chemical tests showed that the pH of some samples had risen as high as 7.6 to 7.8.

The proposed law would require the growing medium producer to:

1. *Register their products with the state Department of Agriculture.*
2. *Clearly list growing medium components and amendments, and the date the bag was filled on the label or an accompanying data sheet.*
3. *Be able to support claims of product suitability by filing scientific proof with the Department of Agriculture.*

The label or data sheet would have to state the presence and form of nitrogen and other mineral nutrients, lime, soluble salts, initial pH, and expected pH change. The law would not require disclosure of proprietary components or mix ratios, and would not affect those who mix their own media. Obviously, some growing media suppliers have expressed concern but most prefer this to the alternative, which would be to regulate media under more restrictive fertilizer labeling rules.

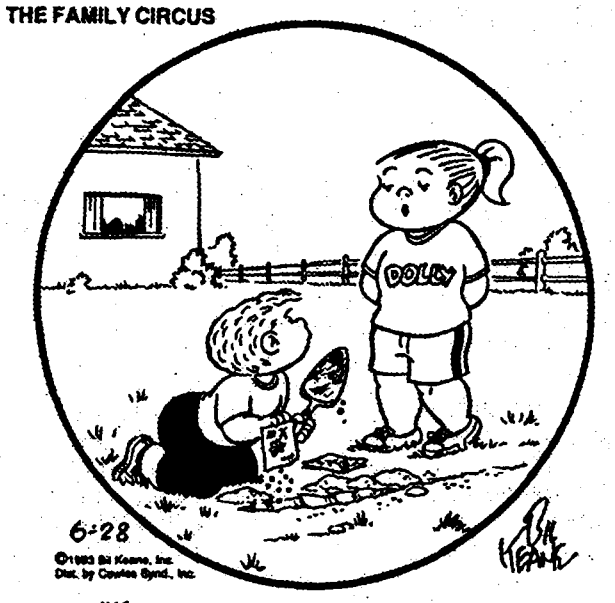
The law was passed by the Georgia Legislature in March of this year, and would tentatively take effect on July 1, 1994. This legislation could conceivably set an industry standard for other states, and so stay tuned.

Sources:

Kuack, D. Georgia media-labeling bill expected to pass. Greenhouse Manager 11(12): 70-71, 73-74. April, 1993.

Kuack, D. Growing problems prompt advisory. Greenhouse Manager 11(11): 82-84, 86. March, 1993.

Thomas, P. A. Bill targets producers of media. Greenhouse Manager 11(11): 88-90, 92-94. March, 1993.



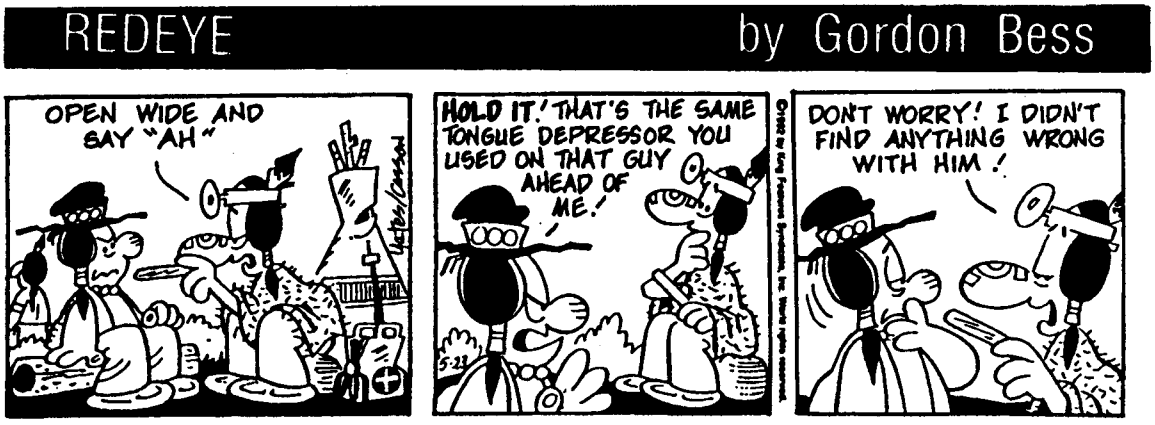
Ecological Alternatives

Potential Plastic Recyclers

Many of us are trying to recycle as much as we can but finding someone who will accept plastics is difficult. According to Nursery Suppliers Inc., the following firms will accept plastic containers and films, so you might want to give them a try:

Connecticut:	Ingenuity Corp., New Haven, CT. PHONE: 203-785-045 8. Obex, Stamford, CT. PHONE: 203-975-9094.
Massachusetts:	Webster Industries, Peabody, MA. PHONE: 508-532-2000.
New York:	North American Plastics Recycling Corp., Ft. Edward, NY. PHONE: 518-747-4195
Oregon:	Environmental Plastics, Oregon City, OR PHONE: 503-656-7072.
Texas:	Nation Plastics, San Antonio, TX. PHONE: 210-225-5556.
West Virginia:	Plastics Recycling Services, Parkersburg, WV. PHONE: 304-485-8062.

Source: *American Nurseryman, 177(10): 17. May 15, 1993.*



Disposing of Used Pesticide Containers

We used to get away with burning or disposing of used containers locally, but most municipal landfills exclude anything that has been associated with pesticides. There are some new options, however.

The easiest containers to dispose of are those which you haven't purchased yet. Can you buy pesticides in returnable or large refillable tanks? "Minibulk containers" hold a large volume of pesticide but remain the property of the manufacturer, and some large 30-55 gallon drums can be returned and reconditioned. Better still, why not do away with the container all together? Some pesticides can be purchased in soluble packaging ("toss packs") or dry tablet formulations. Yes, they are more expensive but may prove to be more economical if the cost and inconvenience of container disposal is considered.

Although finding a proper disposal site for pesticide containers can be hard, recycling used to be out of the question. Lately, however, many states are sponsoring new recycling programs. In Alabama, for example, used pesticide containers are collected, ground-up in a special machine, and re-sold to pesticide companies for use in new containers. Contact your State Department of Agriculture or Extension Service for more information.

Sources:

Something to Grow On: Alabama's Ornamental Newsletter, 3(2):1. 1992

Bellinger, R. Clean-up blues. American Nurseryman 177(10): 82-85. May 15, 1993.

A Practical Look at Mycorrhizal Fungi in Nurseries: Part Two

In the last issue of FNN we discussed what mycorrhizae are, the differences between ectomycorrhizae (ECM) and vesicular-arbuscular mycorrhizae (VAM), benefits of encouraging mycorrhizae in nurseries, and how to determine if you have a mycorrhizal problem. This time we will finish up with a discussion of the development of mycorrhizae in nurseries, the various types of mycorrhizal inocula, how and when to inoculate, and the effect of nursery cultural practices on mycorrhizal development.

Development of mycorrhizae in nurseries

Although wild plants become inoculated with mycorrhizal fungi soon after they germinate, inoculation in nurseries is slowed or even completely eliminated by cultural practices. However, considerable variation occurs between ECM and VAM and between bareroot and container nurseries.

Soil fumigation in bareroot nurseries eliminates all species of fungi and so mycorrhizal colonization is delayed. Reinoculation occurs more quickly with ECM fungi because they can spread either by airborne spores or by mycelial growth through the soil. Most fumigated soil becomes recolonized by the end of the first growing season. However, because VAM fungi lack an airborne spore stage, they can only slowly reinvade sterilized soil by mycelial growth or inadvertent transfer of colonized soil. It may take months or even years for VAM fungi to completely recolonize fumigated seedbeds.

Mycorrhizal colonization is much different in container nurseries because artificial growing media are essentially sterile and containers are sterilized between crops. And, as we discussed in Part 1, container seedlings grow perfectly normal without mycorrhizae because all the various growth-limiting factors are being provided culturally. In nurseries close to vegetation supporting the proper species of mycorrhizae, spores of ECM fungi do blow into container nurseries and colonize the seedlings. Some ECM fungi, such as *Thelephora terrestris,* thrive in the nurs-

ery environment, so this type of mycorrhizae is very common in container seedlings. The chocolate brown fungi can be seen growing out the bottom of containers, and sometimes forms a sheath around the stem of conifer seedlings (Figure A). Reinvasion of VAM fungi is completely inhibited when artificial growing media are used. So, considering the problems with natural reinvasion of mycorrhizal fungi in nurseries, some growers inoculate their nursery stock.

Inoculating nursery stock

When considering an nursery inoculation program, several things need to be considered:

1. *The proper species of fungi for each crop.*
2. *The most appropriate type of inoculum for your nursery system.*
3. *The proper timing and technique.*
4. *Cost effectiveness.*

Species selection

There are two possible routes to take when selecting a mycorrhizal fungi for inoculation: selection of a species adapted to a broad range of hosts or site conditions, or selection of a species adapted to a specific host or particular type of outplanting site. Obviously, the first step is to select a fungus that can colonize the plant species you wish to inoculate. Most VAM fungi and ECM species such as *Cenococcum geophilum, Pisolithus tinctorius,* and *T. terrestris* have broad host ranges. Broadly-adapted mycorrhizal fungi are advantageous because many nursery crops can be inoculated at the same time. Also, the inoculated seedlings would be adapted to a wide variety of outplanting site conditions. On the other hand, host-specific or site-specific mycorrhizal fungi will produce maximum seedling performance in a given application.

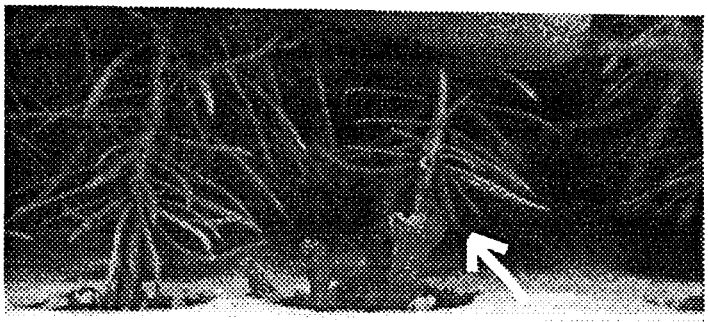


Figure A. Brown felt-like fruiting bodies of Telephora terrestris often fruit on the stem of seedlings , or on bottom of containers.

Types o f mycorrhizal inocula

There are two basic categories of inocula currently being used in forest and conservation nurseries: spores, or vegetative inoculum (Figure B). Fungal spores of ECM are obtained from fruiting bodies collected from wild stands, or VAM spores can be sieved from soil collected in the root zone of host plants. Vegetative inoculum is produced from fungal mycelia grown in pure culture on an artificial medium. Although several different ECM fungi have been successfully produced, VAM fungi are very difficult to grow in pure culture.

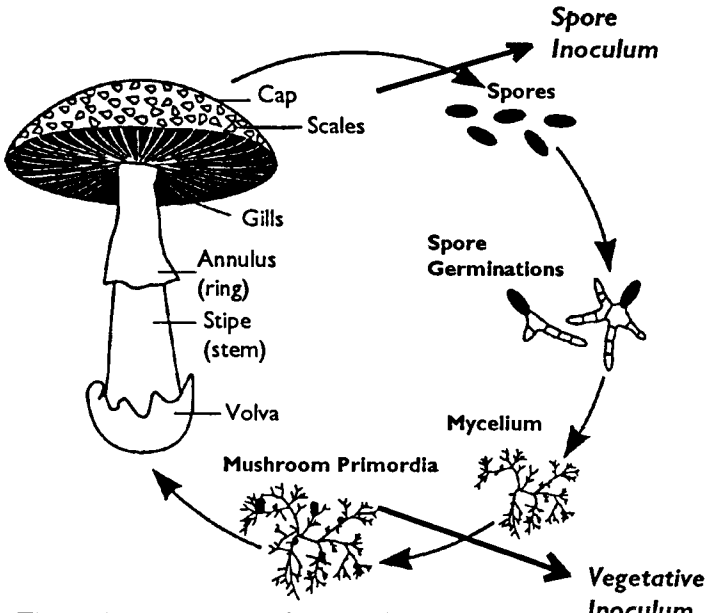


Figure B. Two types of Mycorrhizal Inocula (Modified from Molina and others, 1993)

ECM inoculum can also be obtained by collecting duff or soil from forest stands, or from around seedlings known to be colonized with the desired fungus. While simple and proven effective, this method has several drawbacks. Collecting soil is time-consuming, and the inoculum is bulky and expensive to transport. Besides, you never really know which fungi you are collecting, and this technique also carries the risk of introducing unwanted fungi, weeds or other pests into the nursery. Another option is to collect the mushrooms, puffballs, or truffles of the desired fungus in the wild and harvest the spores for inoculum. This method is relatively simply and inexpensive, and has been effectively used in several countries. Its main limitation is that identifying and collecting fruiting bodies of ECM fungi requires time and training, and it is restricted in some areas due to overharvest for commercial food markets.

Because VAM fungi have an extremely wide host range, some nurseries raise their own inoculum. Host plants are "pot cultured" or raised in special seedbeds, where the fungus is first inoculated on a host-like sorghum or clover, allowed to proliferate on that host, and then the mycelium, spores and host roots are used as inocula for the seedling crop. Some growers collect the relatively large VAM spores by wet sieving of soil. Other nurseries collect root trimmings of VAM hosts during seedling harvesting, and use them to inoculate the next crop. While having many of the same drawbacks as the collecting native soil or duff, there is less risk of pest introduction when using soil or seedling roots from pot cultures or from nursery beds.

Both spore inoculum and vegetative inoculum are available commercially. Several firms have developed sophisticated techniques for culturing both ECM and VAM fungi on artificial media. Other companies collect fruiting bodies of ECM fungi, harvest the spores, and sell them to nurseries (see list of suppliers at the end of this section).

How and when to inoculate

The method of inoculum application, and the required amount of inoculum will vary between container and bareroot nurseries. For either type of nursery, there are three possible times to inoculate: at the time of sowing, during the crop cycle, or during outplanting.

Bareroot seedlings can be inoculated with either VAM or ECM fungi by incorporating soil or duff containing native mycorrhizae into the top layer of the seedbed. Spore inoculum can also be applied to seed prior to sowing. Vegetative inoculum or spore inoculum can be mixed with a carrier and banded in the seed drill rows during sowing. Fluid drilling of a suspension of inoculum has also been tested and found to be fairly successful.

In container nurseries, ECM fungal spores can be applied to seed before sowing. Vegetative inoculum of ECM or VAM fungi can be incorporated into the growing media prior to filling the containers. ECM spores can also be applied in a water suspension either by hand, or through the existing irrigation system 6 to 12 weeks after sowing.

Seedlings could also be inoculated at the time of outplanting when vegetative inoculum could be added to the planting hole as the seedling is planted. However, inoculating during outplanting has many drawbacks and inoculation success is greater in the nursery.

Cost effectiveness

Mycorrhizal inoculation must make sense from an economic as well as biological point of view. If you feel that inoculation might improve the performance of your seedlings, the next step is to do a cost: benefit analysis. Compute the total cost of inoculation including inoculum price and application costs and compare that to the benefits either in the nursery or on the outplanting site. Document the savings associated with less fertilizer, disease reduction, higher seedling survival,

and increased growth. Be sure to consider the improved marketability of seedlings which have been inoculated with a specific mycorrhizal fungus. A nursery could advertise that their seedlings were mycorrhizal and the associated benefits, just like they do for seedling size, seed origin, and vigor.

Cultural practices affecting mycorrhizae

Mycorrhizal fungi are sensitive to several factors in the nursery environment, and so growers must modify some cultural practices following inoculation.

Fertilization

This is probably the most critical cultural factor because mycorrhizae develop most readily in soils or media of relatively low fertility. Many fungi are inhibited by the high fertilization rates commonly used in nurseries, especially nitrogen and phosphorus. Some fungal species, such as Laccaria laccata and *Rhizopogon vinicolor,* are less affected by high fertility and so are easier to manage in a nursery environment. The type and amount of fertilizer can also influence mycorrhizae formation (Figure C) and so slow-release formulations are recommended for some species.

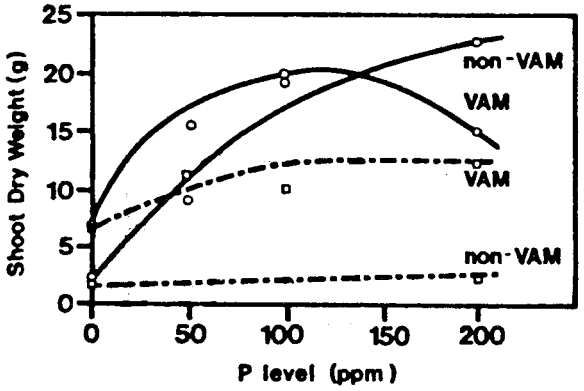


Figure C. Amount and type of fertilizer (soluble P--rock P---) affect both mycorrhizae and seedling growth. (Modified from Walker, 1992).

Root culture

Cultural practices that encourage proliferation of roots in the upper soil layers will result in seedlings whose root systems become mycorrhizal more rapidly and completely. Practices such as root wrenching and lateral pruning in bareroot nurseries will produce more roots that are suitable for colonization by mycorrhizal fungi. Container nurseries can encourage fibrous root development by using more porous growing media and containers treated to promote chemical root pruning.

Soil management

Physical and chemical characteristics of the soil or growing medium are important for the formation of mycorrhizae. Many mycorrhizal fungi prefer a mildly acidic environment with a high percentage of organic matter. Porosity affects mycorrhizae both directly and indirectly: porous, well-drained soils and growing media promote good fibrous root growth and provide more oxygen for both roots and fungi.

Pesticides

Some pesticides, especially soil sterilants and fumigants, inhibit or kill mycorrhizal fungi. In fact, soil fumigation with methyl bromide/ chloropicrin is used to eliminate competitors before inoculating with a desired mycorrhizal fungus. Most fungicides are designed to control specific fungi and so growers should consult the literature or mycorrhizae experts before use. Although recommended rates of most other pesticides are not damaging, high rates and frequent application are discouraged.

Conclusions and Recommendations

Well, have I confused you completely? The decision on whether to inoculate your seedlings is complicated and so if you are thinking about mycorrhizal inoculation, please consider the following:

1. Consult a specialist - Unless you have a good understanding of the various fungi/ host combinations and the inoculation process, please contact a mycorrhizal consultant before you get started.

2. Start with a small trial - The tendency is to immediately apply a new cultural treatment on an operational scale, but don't. Ralph Shugert relays a horror story of using a commercial inoculum on some cuttings to stimulate rooting. Luckily, he installed a small field trial because the treated cuttings became diseased with Rhizoctonia root rot and he ended up loosing all of them.

3. Be sure to include a control - As with any new cultural practice, remember to establish a control area so that you can make a valid comparison. The control must be of the same species, seed source, and receive all the same cultural treatments as the trial. I know this sounds obvious, but I have visited nurseries and seen trials without controls or the control seedlings were of a different seed source.

4. Monitor the trial frequently and document results - The tendency is to get excited about a new practice, establish some sort of trial, and then get busy with normal day-to-day operations and forget to check back on a regular basis. Without frequent observations, you may miss some critical event that affects the outcome of the trial. Even if everything goes smoothly and you get good results, remember to take some measurements and photographs to document the trial (Figure D).

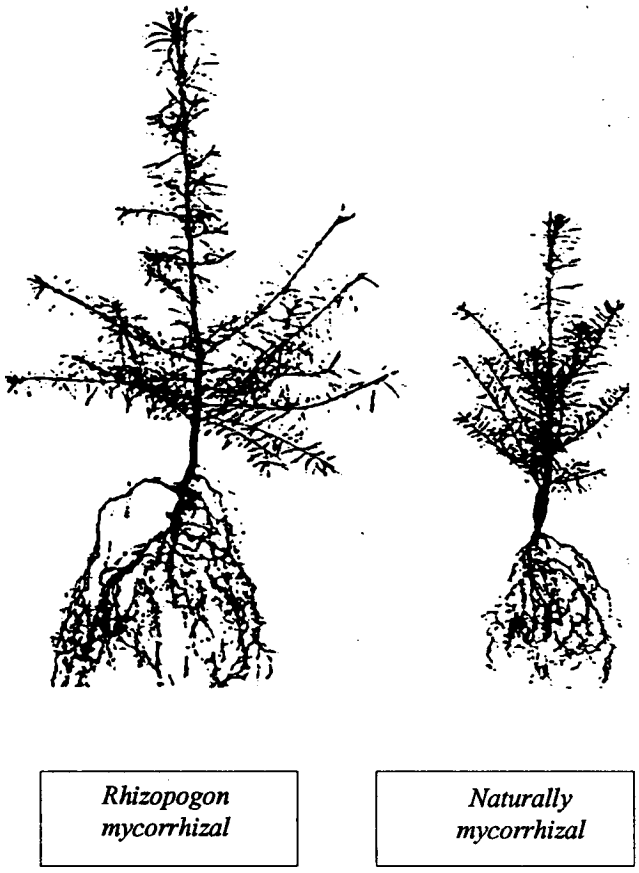


Figure D. Comparative photographs of seedlings from mycorrhizal inoculation trials provide effective documentation (Walker 1992).

Sources of mycorrhizal inocula:

Forest Mycorrhizal Application
P.O. Box 1181
Grants Pass, OR 97526 USA

PHONE/FAX: 503-476-3985

They offer specific strains of ECM spore inocula, including *Rhizopogon* spp., for commercial conifers at a cost of around $1.50 per M seedlings. Biogrow[R], a new VAM inoculum, is also being offered on a trial basis. They have worked with nurseries across the US and around the world, and offer consulting services.

Mikko-tek Labs
P. O. Box 2120
Timmins, ON P4N 7X8
CANADA

PHONE: 705-268-3536
FAX: 705-268- 7411

This firm produces commercial quantities of vegetative ECM mycorrhizal inoculum such as *Laccaria* spp. and *Paxillus* spp. for both conifer and hardwood stock, and also has lab facilities for evaluating the performance of inoculated seedlings.

MycorrTech InG
440 William Pitt Way
Pittsburg, PA 15231330 USA

PHONE: 412-826-5488
FAX.• 412-826-523

They sell vegetative inoculum of *Pisolithus tinctorius* and other ECM fungi, including *Hebeloma crustuliniforme* and *Laccaria laccata*, for conifers and hardwoods. They also provide consulting for anyone considering a mycorrhizal inoculation project.

Tree of Life Nursery
P.O. Box 736
San Juan Capistrano, CA 92693
PHONE: 714-728-0628
FAX: 714-728-0509

They can provide generic and site-specific VAM inoculum made from calcined clay, which can be incorporated into seedbeds or growing medium. Applications include forestry, restoration, and agriculture—contact Ted St. John for details.

Sources of inoculated growing media:

Premier Enterprises Ltd
326 Main St Red Hill, PA
18076 USA PHONE: 800
424-2554 FAX: 21S
679-4119

They sell a growing medium called "Mycori-Mix", which is a mixture of sphagnum peat moss, vermiculite, and perlite that has been inoculated with the VAM fungi *Glomus intraradix.*

Sources of inoculated seedlings:

Carino Nurseries
P.O. Bax 538
Indiana PA 15701
PHONE: 412-463-3350
FAX.• 412-463-3050

They have been working with vegetative ECM inoculum from Mycorr-Tech for the past several years, and will be offering a limited supply of Mycorr-ized[R] conifer seedlings for sale starting this fall.

Western Forest Systems, Inc.
1509 Ripon
Leiviston, ID 83501
PHONEIFAX.• 20&743-0147

They have been treating their conifer stock with spore inoculum from Forest Mycorrhizal Application for a couple of years, and are

References:

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

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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.*

SO. Proceedings of the Northeastern Area Nurserymen's Conference. 1992 July 27-29; Esbanaba, MI. Manistique, MI: Michigan Dept. of Natural Resources. 1993. This softbound publication contains 11 articles on a variety of different topics relating to nursery culture in the Northeastern US. If you are interested in a copy, please send a check payable to "Northeastern State, Federal and Provincial Nursery Association" to cover costs of printing and mailing.

COST: $8.00 ORDER FROM: Michigan Dept. of Natural Resources
Wyman State Forest Nursery
Route 2, Box 2004
Manistique, MI 49854

SO. Tree Planting in the United States-1992. Moulton, RJ.; Mangold, R.D.; Snellgrove, J.D. Washington, DC: USDA Forest Service, State and Private Forestry. 15 p. 1993. This pamphlet summarizes tree planting, timber stand improvement, and nursery production activities on all ownerships of forest land in the US. A national summary discussing historical trends and national statistics is followed by tables of specifics by state and ownership category.

COST: FREE ORDER FROM: USDA Forest Service
Cooperative Forestry
P.O. Box 96090
Washington, DC 20090-6090
PHONE: 202-205-1376
FAX: 202-205-1271

SO. Shelterbelt Varieties for Alberta. Casement, B.; Escott, R; Maryniak, L.; Hooke, G. Edmonton, AL: Alberta Agriculture, Alberta Tree Nursery and Horticulture Center. 68 p. 1993.

This handsome softbound publication contains valuable information on 32 species of trees and shrubs used for shelterbelt and other conservation plantings in central Canada. Each listing contains color photographs of growth habit, foliage, and fruits following by information on plant characteristics, site preference, hardiness, and pest problems.

COST: FREE

ORDER FROM:

Alberta Agriculture
Alberta Tree Nursery and Horticulture Centre
RR #6
Edmonton, AL TSB 4IC3
CANADA

PHONE: 403-422-1789
FAX: 403-472-6096

Container Tree Nursery Manual Update

As many of you know, I'm working on a publication called the *Container Tree Nursery Manual* (CI'NM). All seven volumes of the Manual are being serially published as Agricultural Handbook 674, but are being issued out of numerical sequence. Four volumes of the Manual have been printed so far. Volume Two, Volume Three, Volume Four, and Volume Five. Currently, we are working on Volume One: Container Nursery Planning, Development, and Management and hope to have it published by late this year. The current publication schedule and availability of the published volumes is outlined in the following table:

Volume	***Title***	***Date***	***Publication Stock Number and Price***
Volume One	Container Nursery Planning, Development, and Management	(12/93)*	-------
Volume Two	Containers and Growing Media **(Free Copies Still Available)**	1990	001-001-00644-1 $ 9.50 (US) $11.88 (Foreign)
Volume Three	Atmospheric Environment **(Free Copies Still Available)**	1992	001-001-00648-3 $16.00 (US) $20.00 (Foreign)
Volume Four	Seedling Nutrition and Irrigation **(* Out of free copies *)**	1989	001-001-00635-1 $15.00 each $18.75 (Foreign)
Volume Five	Biological Influences: Nursery Pests and Mycorrhizae **(* Out of free copies *)**	1990	001-001-00633-5 $30.00 (US) $37.50 (Foreign)
Volume Six	Seedling Propagation	(1994)*	------
Volume Seven	Seedling Processing, Storage and Outplanting	(1995)	------

* = Estimated Date

I still have a limited supply of free copies of *Volume Two: Containers and Growing Media* and *Volume Three: Atmospheric Environment,* and will send one to you if you don't have one already. You can also purchase copies of any of the published C)'NM volumes from the US Government Printing Office here in Portland. Several are in limited supply and, although we are working to get them reprinted, they may run out of copies until the new ones become available. When ordering, use the stock numbers and prices listed in the Publication Table. Note that prices include shipping and handling, and that foreign orders have a 25% surcharge. You can order by mail, phone, or FAX and all orders must be prepaid in cash, check payable to "Superintendent of Documents", or charged to Visa or MasterCard.

U.S. Government Printing Office
1305 S.W. First Avenue
Portland, OR 97201-5801
USA

PHONE: 503-221-6217
FAX: 503-225-05 63

Help Wanted: Slides for CTNM Volume One

We could use some good quality color slides that are suitable for publication. Specific needs for each chapter are as follows:

Chapter 1- Initial Planning and Feasibility Assessment Different species and container stock types, including comparisons with bareroot seedlings.

Chapter 2 - Site Selection Aerial views of container nurseries and other perspectives showing site characteristics.

Chapter 3 - Nursery Design and Site Layout Slides of growing structures, benches, and other structural features including construction photos.

Chapter 4 - Seedling Production and Environmental Control Equipment Any good slides of heating, cooling, and other control equipment and seedling production machinery.

Chapter 5 - Nursery Management
Anything appropriate.

I can't promise that we will use your slides but I will duplicate those that are selected and will return all originals. Of course, for those that are chosen, full professional credit will be given in the publication.

Health and Safety

Skin Problems

Nursery workers can develop a variety of different skin ailments, including rashes and minor swelling. Pesticides are often blamed for these symptoms, but plants themselves and exposure to the sun are often contributing factors. In medical terminology, these skin problems are called dermatitis, of which there are three kinds:

1. Primary irritant dermatitis (PID)

This is caused by chemicals that directly irritate the skin. The symptoms can range from redness or itching, to blisters or peeling; the areas of direct contact are usually the most affected. A number of different agronomic crops and weeds, including tomatoes and milkweed, can cause P)D, as well as some commonly-used nursery pesticides such as: captan, benomyl, chlorothalonil, and glyphosate. Treatment consists of washing the affected area and preventing further contact with the irritant by wearing gloves and long-sleeve clothing.

2. Allergic Contact Dermatitis (ACD)

In this disorder, the skin becomes sensitized to the chemical over time and then an allergic reaction occurs. Characteristic ACD symptoms include rashes, itching and blisters and the most wellknown allergenic plants are poison ivy and poison oak. Other plants including cedar, pine, and liverworts can also cause ACD in sensitive individuals as can nursery pesticides including captan, benomyl, malathion and thiram. Treatment consists of thorough washing to remove the allergen, followed by topical skin creams to reduce the symptoms.

3. Photosensitive Dermatitis

This condition occurs when a plant chemicalgets on the skin and then exposure to the sun causes a local irritation. Symptoms include redness, blisters, and hyperpigmentation of the affected area. Horticultural crops such as figs, limes, mustard, and Klamath weeds have been associated with this disorder.

All these skin conditions are easier to prevent than to cure. Gloves and long sleeves prohibit the chemical from contacting the skin, and so should be warned when working with pesticides or problem plants. Some people are more sensitive than others, and treatment is much more effective when skin problems are identified early. So be sure to inform nursery workers, especially new employees, of the symptoms and preventative measures.

It would be interesting to know more about forest and conservation species that can cause skin problems. Hal Wells of the California Dept. of Forestry Ben Lomond Nursery reports that some of his workers are affected by Scotch pine and I have observed sensitivity to spruce seedlings. If you'll share your experiences, I'll pass them along in the next issue of FNN.

Source:

Craigmill, A. Plants, pesticides and other toxic chemicals: cutaneous toxicity (toxic effects on skin). PAPA (Pesticide Applicators Professional Association) Applicators News 8(1): 6-7, January, 1993.

Cultural Perspectives

Soil Organic Matter Supplements

I'm sure that many of you are concerned about the increased cost and decreased availability of good organic matter sources for amending your nursery soils. Here in the Pacific Northwest, sawdust has always been the traditional soil amendment but the price has recently risen to around $8 per cubic yard because of competition for wood products. You have to be careful in the search for alternative sources, however, because some organic wastes can do more harm than good. For example, mint straw is the waste material that remains after the oils are squeezed out of peppermint plants. While this has been used as an economical source of organic matter for supplementing nursery soils, recent tests revealed pH values in the 7.0 to 8.0 range - and they appear to increase during decomposition! Obviously, we need to take another look at potential sources of organic matter.

One of the focus topics at our Combined Nursery Meeting in St. Louis, MO on August 2-5, 1993 will be *Management of Soil Organic Matter.* Following a general overview of organic matter used in bareroot nurseries, we will be discussing types of green manure and cover crops and how they can affect soil pathogens. Nursery managers will also be reporting on their organic matter programs including the use of municipal organic wastes.

Of course, these presentations will be captured in the *Proceedings,* but we are also working on another omnibus publication on organic matter use in forest and conservation nurseries. *Organic Amendments in Forest Nursery Management in the Pacific Northwest* was published back in 1973, and has been out of print for years. I consider it to be one of the true classics on the subject, so we will be updating and expanding this publication to cover the entire country.

We Need Your Help!!

In an attempt to determine current operational use of organic matter and unpublished nursery trials, we have included a survey question in this issue of FNN. If you have organic matter information that you would like to share, please check the box on the Literature Order Form on the back page of this issue and return it to me. We will be contacting respondents over the next few months to get the details. Thanks.

New Deer Repellent

I am going to have an entire section concerning Chemical Animal Repellents in the October, 1993 issue of FNN, but I wanted you to be aware of this new product immediately. A company called Plant Pro-Tec has developed a new deer repellent which they are trying to have registered with the Environmental Protection Agency (EPA). The product currently has a "conditional" pesticide registration which allows it to be used in field trials. The garlic-based repellent is contained in a special dispenser stake that can be placed near individual seedlings on the planting site or used to form a perimeter barrier around nursery seedbeds. The EPA has no problem with the environmental aspects of this product because everything, including the plastic dispenser stakes, are biodegradable. But, and this is where you come in, Plant Pro-Tec needs some more data on the effectiveness of their product. If you would like to field-test this new deer repellent in your nursery or plantation, then please contact Jerry Waiters at:

Plant Pro-Tec, Inc.
P.O. Box 902
Palo Cedro, CA 96073

PHONE/FAX: 916-547-5450

New Fungicide for Diplodia Has Potential for Botrytis

Phyton 27R is a fungicide/bactericide that is an organo-metallic polymer of copper. It can be applied as a spray, fog, dip, or drench, and is fully systemic. For nursery and ornamental crops, Phyton 27R is currently only registered for Diplodia tip blight on pines, and for fireblight on woody ornamentals in the Rose Family. It reportedly is very effective on Botryis blight, but is only registered on some flower crops. The company is interested in obtaining efficacy data for forest and conservation nursery crops, so contact Andy Petersen if you would like more information:

Source Technology Biologicals, Inc.
3355 Hiawatha Ave
Minneapolis, MN 55406

PHONE: 612-724-7102
FAX:612-724-1642

Limiting Factors --Mineral Nutrients

As we have been discussing in the last few issues of FNN, plants need six different "limiting" factors for good growth and development. Four are found in the ambient environment (light, temperature, humidity, and carbon dioxide) and two are supplied from the soil or growing medium (mineral nutrients and water). In this issue, we will take a look at the different mineral nutrients that seedlings need for normal growth and development.

Throughout history, humans have been adding "mineral" substances such as wood ash or lime to the soil to improve the growth of their crops. It was not until the 19th century, however, that Justus von Liebig proposed the mineral element theory which stated that elements such as nitrogen, phosphorus, and sulfur were essential for plant growth. But, it was only in the past 60 years that plant physiologists identified the 16 different chemical elements that were essential for plant growth and development (Table 1). Carbon, hydrogen, and oxygen are obtained from the air and water, and together comprise 96% of the oven-dry weight of an average plant. The remaining 13 mineral elements are absorbed through the root system from the soil or growing medium.

Chlorine is needed in such minute amounts, and is so ubiquitous, that scientists have to go to extreme measures to create a deficiency. That leaves an even dozen mineral nutrients that have to be supplied in nursery culture.

Biophysics of mineral nutrition

Tree seedlings obtain most mineral nutrients from the soil solution as ions, although some can also be taken up as molecules or organic complexes. Being electrically charged, nutrient ions become adsorbed on exchange sites in the soil or growing medium where they serve as a nutrient reserve (Figure A).

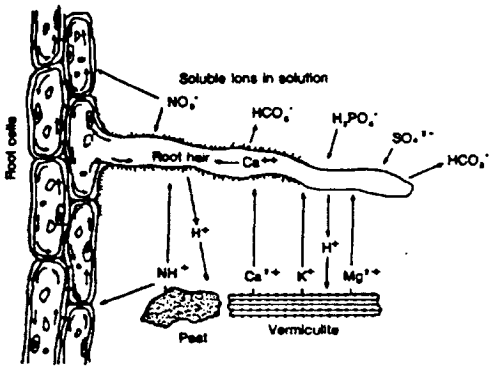

Figure A. Mineral nutrient ions are absorbed directly from the growing medium solution surrounding the root, which is replenished through ion exchange with growing medium particles (adapted from Donahue and others 1977).

Table 1 - The 16 essential chemical elements required for plant growth, types of fertilizers, and fertilization methods

Concentration in Plant Dry Matter					Type of Fertilizer and Fertilization Method	
Element	*Symbol*	*(%)*	*ppm*	*Source for Plants*	*Bareroot Nurseries*	*Container Nurseries*
Carbon	C	45	----	Carbon Dioxide	------	------
Oxygen	O	45	----	Carbon Dioxide/Water	------	------
Hydrogen	H	6	----	Water	------	------
Macronutrients						
Nitrogen	N	1.5	----	Soil/Growing Media	Granular Top-dressing	Liquid Fertigation or Slow-release Incorporation
Potassium	K	1.0	----	Soil/Growing Media	Granular Top-dressing	Liquid Fertigation or Slow-release Incorporation
Calcium	Ca	0.5	----	Soil/Growing Media	Granular Incorporation	Liquid Fertigation or Slow-release Incorporation
Magnesium	Mg	0.2	----	Soil/Growing Media	Granular Incorporation	Liquid Fertigation or Slow-release Incorporation
Phosphorus	P	0.2	----	Soil/Growing Media	Granular Incorporation	Liquid Fertigation or Slow-release Incorporation
Sulfur	S	0.1	----	Soil/Growing Media	Granular Incorporation	Liquid Fertigation or Slow-release Incorporation
Micronutrients						
Iron	Fe	----	100	Soil/Growing Media	Rarely Needed	Liquid Fertigation or Slow-release Incorporation
Chlorine	Cl	----	100	Soil/Growing Media	Never Needed	Never Needed
Manganese	Mn	----	50	Soil/Growing Media	Rarely Needed	Liquid Fertigation or Slow-release Incorporation
Zinc	Zn	----	20	Soil/Growing Media	Rarely Needed	Liquid Fertigation or Slow-release Incorporation
Boron	B	----	20	Soil/Growing Media	Rarely Needed	Liquid Fertigation or Slow-release Incorporation
Copper	Cu	----	6	Soil/Growing Media	Rarely Needed	Liquid Fertigation or Slow-release Incorporation
Molybdenum	Mo	----	0.1	Soil/Growing Media	Rarely Needed	Liquid Fertigation or Slow-release Incorporation

Nutrient uptake can be divided into active and passive absorption. Passive absorption means than ions are carried into the plant root along with the transpirational water stream. Factors controlling passive absorption include the volume of water being absorbed and the ion concentration in the growing medium solution surrounding the roots. Active absorption occurs when nutrient ions are selectively taken up against the osmotic gradient that normally exists between the root cells and the growing medium solution.

In the soil or growing medium, mineral nutrient availability is affected by the movement of ions with the soil solution, by diffusion, and by the growth of plant roots. Note that nutrient absorption and water uptake are closely linked, especially considering the large volumes of water that move towards the roots and into the plant during transpiration. Growers must keep soil water near optimum levels in order to realize the full benefits of fertilization. For example, the growth stimulation of N fertilizer decreases as soil moisture stress increases until it is completely negated (Figure B).

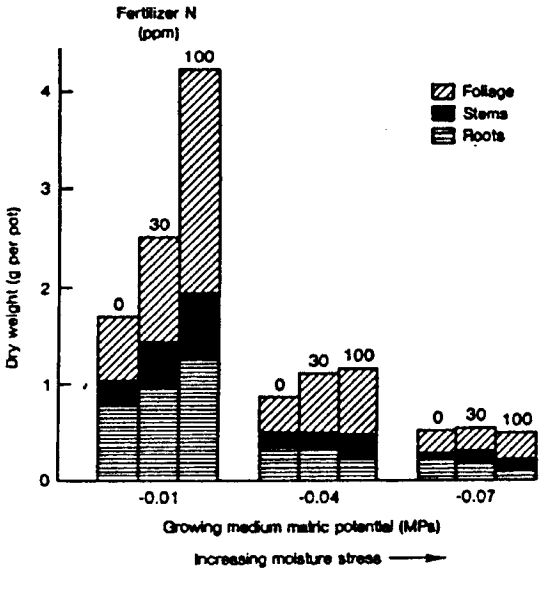

Figure B. The beneficial effect of nitrogen (N) fertilizer decreases with increasing moisture stress in the growing medium (from Squire and others 1987).

Effects of mineral nutrients on seedling growth

There is a characteristic relationship between the concentration of a nutrient ion in seedling tissue and its growth (Figure C). When a nutrient is present in low concentrations in seedling tissue and limiting to growth, it is said to be "deficient". At the lower end of the deficiency range,

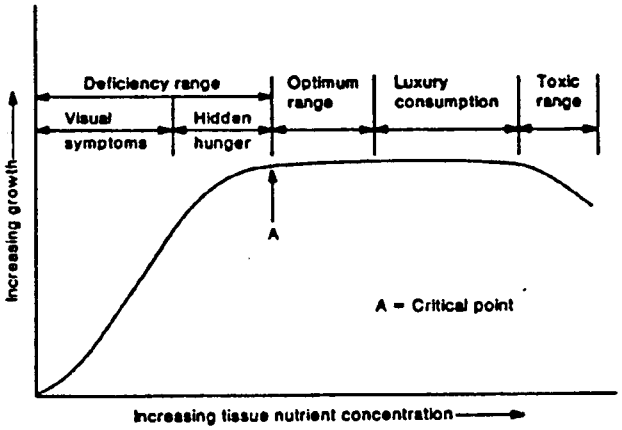

Figure C. The relationship between seedling growth and seedling tissue nutrient levels follows a characteristic pattern. Growth increases with increasing nutrient levels up to a critical point (A). Beyond this point, increasing nutrient levels do not result in more growth, but lead to luxury consumption or even toxicity.

plants often exhibit certain visible abnormalities called "deficiency symptoms", which include stunting and foliar discoloration. At slightly higher concentrations, the nutrient is still deficient enough to limit seedling growth and "hidden hunger" results. This condition is so named because there are no visible symptoms, so growers must diagnose it with chemical analysis. When the mineral nutrient supply is no longer limiting, seedling growth reaches a plateau termed the "optimum" range (Figure C). The limits of the optimum range are different for each of the 13 mineral nutrients, and growers must keep them all in balance to achieve maximum seedling performance. When they are present in surplus quantities, seedlings may continue to take

up mineral nutrients with no measurable increase in growth (Figure C). This "luxury consumption" is common in forest and conservation nurseries where fertilizers are readily applied Many growers keep nutrient levels in the luxury consumption range because fertilizers are cheap, and there are no obvious drawbacks. However, if nutrient concentrations in seedling tissue reach extreme levels, nutrient toxicity will cause a decrease in growth. Fertilizer "bum" is a typical symptom of nutrient toxicity that occurs because fertilizer salts cause a physiological drought in plant tissue.

Monitoring mineral nutrient levels

Determining the proper nutrient levels for growing plants is not easy and is as much an art as a science. This art cannot be taught, but must be learned through many years of practical experience and patient observation.

Deficiency symptoms

Visual nutrient deficiency symptoms are often the first sign that something is wrong, but it is difficult to diagnose their exact cause. For example, foliar yellowing (chlorosis) can be caused by a deficiency of several nutrients including N, S, Fe, and Mn. Besides, growers should never wait until symptoms develop to begin treatment; by the time a nutrient deficiency is visible, a significant amount of growth will have already been lost (see hidden hunger—Figure C).

Soil or growing media

Because all nutrients are absorbed through the roots, it makes sense to try and monitor the levels in the soil or growing medium. Most nurseries do some soil testing. Bareroot nurseries usually have soil tests done prior to sowing so that they can amend any deficiencies before the crop is sown. For multiple year crops, additional samples are taken at the end of the growing season. Analysis of soil samples for "available" nutrients is difficult, however, because of the many chemical interactions that can occur. So, most nurseries have their samples analyzed by professional testing laboratories who also provide fertilizer recommendations. Sampling growing media in small containers is much more difficult, so container growers must analyze growing medium extracts that are obtained by vacuum or a pourthrough sampling.

Fertilizer solutions

Container nursery managers who fertilize through the irrigation system ("fertigation") have another option for monitoring mineral nutrient levels. Collecting samples of the applied fertilizer solution as it comes out of the irrigation nozzle is an excellent way to directly keep track of the nutrients being applied to the crop. Sampling the leachate from the bottom of the container can also indicate mineral nutrient problems.

Seedling nutrient analysis

One of the best ways to monitor mineral nutrient levels in nurseries is to chemically analyze seedling tissue and determine its nutrient status. Growers can sample the entire shoot of small seedlings or the green foliage of larger ones and have it analyzed by a testing laboratory. Because nutrient levels change so rapidly during periods of shoot growth, most nurseries only sample when seedlings are resting or dormant. General ranges for all mineral nutrients for both bareroot and container seedlings are available (Table 2). Foliar nutrient values are typically higher for container seedlings because they are given more frequent and complete fertilization (Table 1). However, because the response of each species will vary, growers should analyze tissue from healthy seedlings and make their own standards (Figure D). And, when suspected nutritional problems occur, samples of symptomatic and normal seedlings should be collected and analyzed for comparison.

Modifying mineral nutrition in nurseries: Fertilization

Nurseries apply fertilizers to keep mineral nutrients at their optimum level for seedling growth. In fact, fertilization is one of the primary reasons for the rapid seedling growth rates that can be achieved in nursery culture. Fertilizer use differs considerably between bareroot and container nurseries in type and amount, as well as in the application method. Bareroot nurseries supply only a few of the essential mineral nutrients as fertilizer, whereas container nurseries typically provide them all (Table 1).

Table 2 - ***Standard values for mineral nutrient concentrations in conifer needle tissue***

		Adequate Range	
Mineral Nutrient	Units (% Dry Wt.)	Bareroot Seedlings	Container Seedlings
N	%	1.20 to 2.00	1.30 to 3.50
P	%	0.10 to 0.20	0.20 to 0.60
K	%	0.30 to 0.80	0.70 to 2.50
Ca	%	0.20 to 0.50	0.30 to 1.00
Mg	%	0.10 to 0.15	0.10 to 0.30
S	%	0.10 to 0.20	0.10 to 0.20
Fe	ppm	50 to 100	60 to 200
Mn	ppm	100 to 5000	100 to 250
Zn	ppm	10 to 125	30 to 150
Cu	ppm	4 to 12	4 to 20
Mo	ppm	0.05 to 0.25	0.25 to 5.00
B	ppm	10 to 100	20 to 100

Bareroot nurseries

Good agricultural soil contains a base level of all mineral nutrients, so growers usually fertilize based on pre-sowing soil tests. Depending on the type of soil and initial pH, nurseries add dolomitic lime (Ca, Mg) to raise the pH, or sulfur (S) to lower the pH, and incorporate it before the crop is sown (Table 1). Most forest and conservation nurseries normally supply only large amounts of the 3 major "fertilizer elements" - N, P, and K. N is by far the most important of the three, and is used on all soil types and in the largest quantities. Because it is very soluble in water, N is applied as a "top-dressing" in a series of small applications starting before, and continuing through, the active shoot growth period. In contrast, P is immobile in the soil, and is always incorporated into the seedbed before sowing. K is moderately soluble, and is applied either as a pre-sow incorporation or as a top-dressing during the growing season. Some nurseries also apply an additional application of N in the fall to recharge seedling nutrient reserves prior to harvesting.

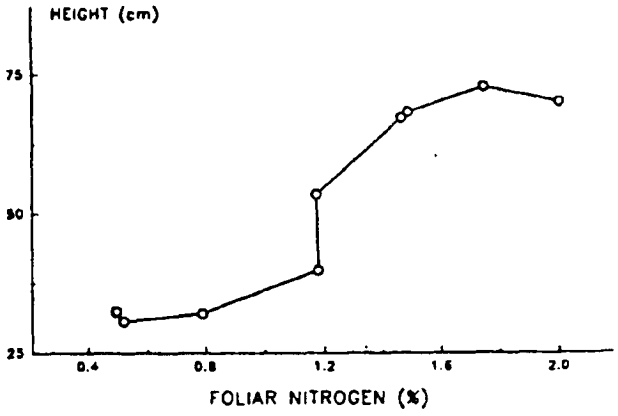

Figure D. Growers should develop their own tissue nutrient standards and growth response curves, such as this one for Juniperus virginiana (Henry and others 1992).

Container nurseries

The artificial growing medium that most container nurseries use is essentially infertile, so growers must add all 12 mineral nutrients through the irrigation system, or as a pre-sowing incorporation (Table 1). Because the growing medium is already slightly acidic, dolomite or sulfur is not needed to adjust the pH. Instead, most nurseries inject a mild acid to control the pH of the medium; many use phosphoric acid which also supplies P to the fertilizer mix. Some growers incorporate slow-release fertilizers into the growing medium to provide a starter charge of nutrients. Almost all nurseries have a fertigation program and fertilization frequency ranges from every day to once or twice a week. Different fertigation solutions are based on N concentration: starter solutions contain a moderate amount of N (75 ppm), rapid growth formulations have much higher levels (150 ppm), and hardening solutions have relatively low N levels (50 ppm). Some growers apply foliar fertigation solutions during the hardening period to maintain seedling color and nutrient reserves.

Problems with overfertilization

Most growers would rather overfertilize than risk a nutrient deficiency, with its resultant loss in growth rate. Although maintaining seedling nutrient levels at luxury consumption levels (see Figure C) is not generally considered harmful, overfertilization can cause other problems. In particular, high N fertilization has been shown to promote shoot growth at the expense of root development, and inhibit the formation of mycorrhizae. Perhaps the most worrisome effect is on outplanting performance (Figure E). In addition to their poor shoot: root ratio, seedlings with high foliar N levels are less cold hardy and suffer more animal browsing.

In recent years, concerns about agricultural pollution of surface and groundwater have made growers reevaluate their fertilization practices. High nitrates in drinking water can adversely affect human health and all nutrients, and phosphates in particular, can lead to eutrophication of surface waters. Today, most nurseries are using less fertilizer, and are looking for more efficient types of fertilizers and fertilization methods. Slow-release fertilizers have obvious benefits, and incorporation of granular fertilizers can lessen the chance for surface runoff. Container nurseries are particularly suspect, so growers are converting to better fertigation systems, such as boom sprinklers, which significantly reduce runoff. Political concerns about agricultural pollution are so acute that fertilization may soon be regulated just like pesticide use.

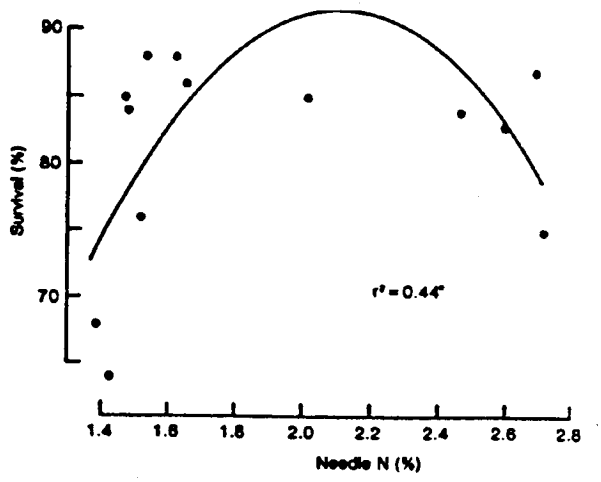

Figure E. Outplanting survival of 2 conifer seedlings decreased with higher foliar nitrogen (N) levels (van den Driessche 1988).

Whew! That takes us through all of the limiting factors except water, and we will take a look at that most important factor in the next issue.

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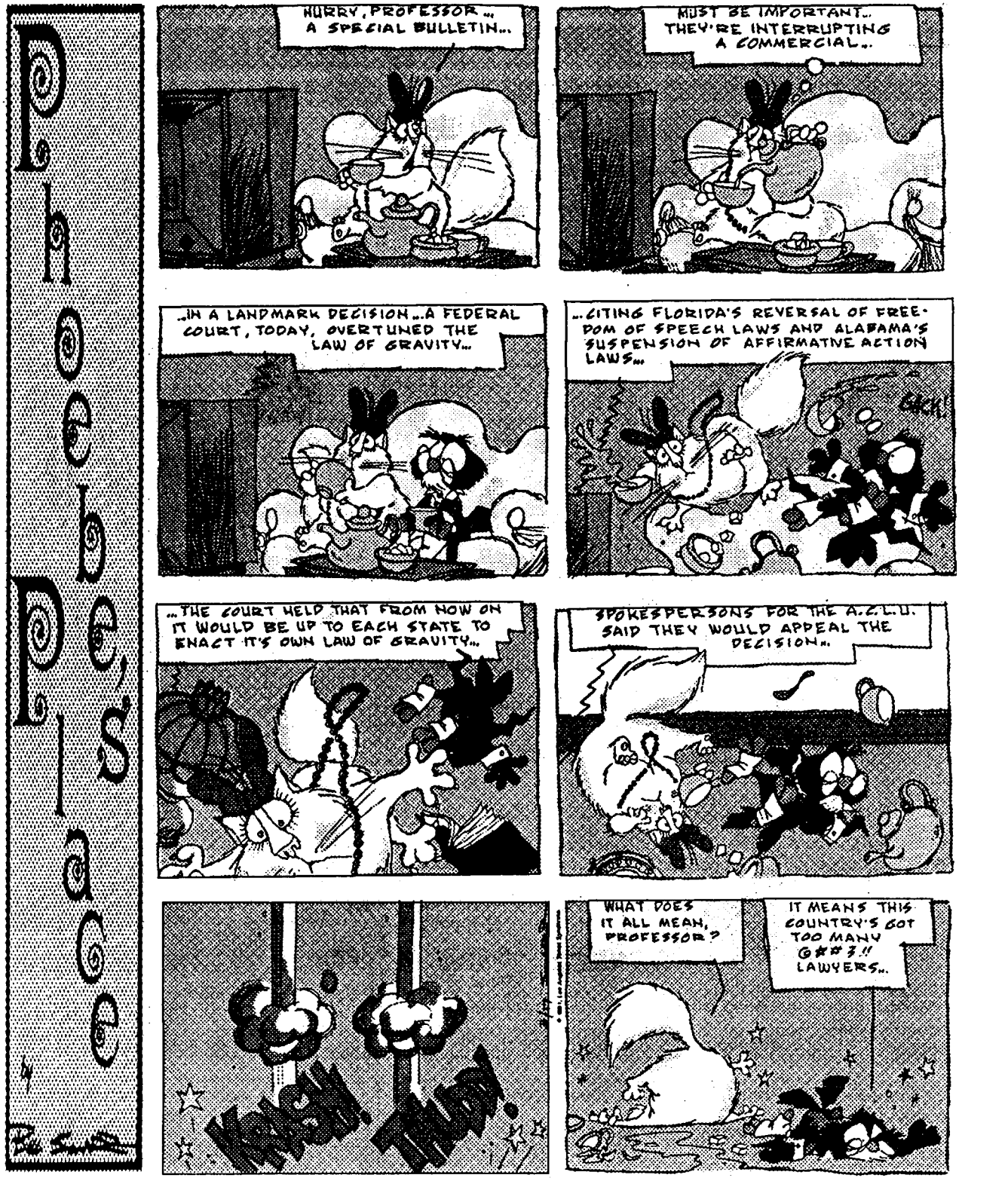

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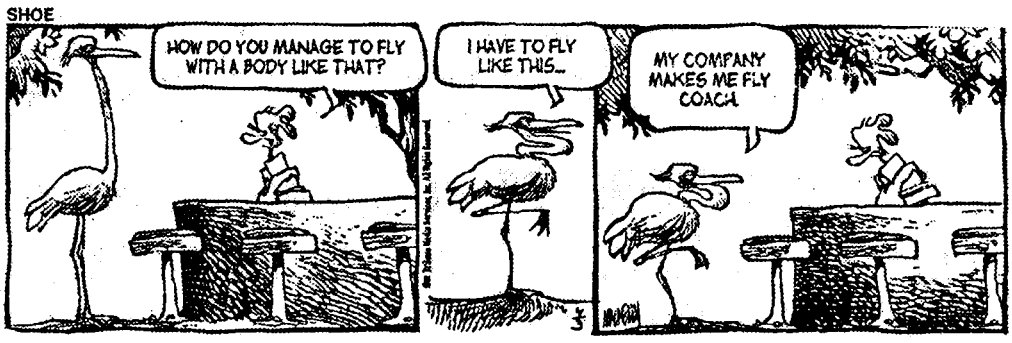

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