United States
Department of
Agriculture

Forest Service

**Pacific
Northwest
Region**

State and Private
Forestry

**Cooperative
Programs**

R6-CP-TP-25-97

FOREST NURSERY NOTES

July 1997

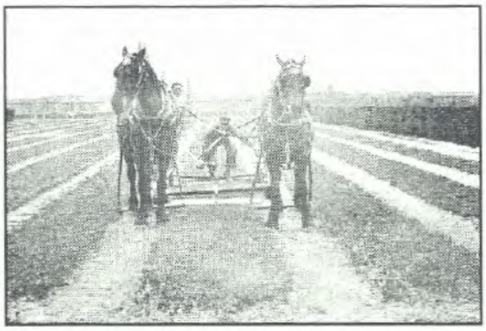
Health and Safety

Helping Hands

Cultural Perspectives

Native Plant Network

Editorial



The Role of Government Nurseries

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This technology transfer service is funded by:
USDA Forest Service, State and Private Forestry

Contents

Please Update Your Address

Our Forest Nursery Notes (FNN) mailing list is several years out of date and we would like to make sure that we have your latest address. So, please take the time to check the mailing label and note any additions or corrections on the Literature Order Form at the back of this issue. In particular, give your full telephone number as many area codes have changed recently. Note that you can also list your E-mail address and World Wide Web URL if you have them. Thanks!

New Phone and FAX Numbers

Speaking of which, the government just changed our telephone and FAX machine numbers so note the new 808 numbers for Tom and Aleta on the inside cover.

Notas Sobre Viveros Forestales

En coordinación con la Secretaría del Medio Ambiente, Recursos Naturales y Pesca (SEMARNAP) del Gobierno Mexicano, estamos trabajando para la traducción y edición en español la publicación "Forest Nursery Notes". Estamos muy entusiasmados con este proyecto y actualmente buscamos los fondos de financiamiento necesarios. Cuando tengamos más información la haremos del conocimiento a los suscriptores que actualmente reciben la version en inglés, y que puedan beneficiarse con la version al español.

Update of Directory of Forest & Conservation Nurseries

We are updating the national nursery directory—Directory *of Forest and Conservation Tree Nurseries in the United States* which was published back in 1994. In fact, the production statistics are for the 1992-1993 season due to the time that it took to do the survey and process the information. Because of the high cost of conducting surveys and publishing, we've decided to establish an electronic version of this directory on our World Wide Web (WWW) home page. We hope to republish the hard copy of the directory in a couple of years but, in the meantime, we'll have to rely on the version on our home page. This format also will allow potential customers to contact nurseries by E-mail as E-mail and Home Page addresses will be listed for those nurseries that have them. So, if you'd like to list your nursery in the Directory of Forest and Conservation Nurseries, update your listing, or add an E-mail or WWW home page link, write, FAX, or send an E-mail message to Aleta or Tom at the addresses on the inside cover of this issue (see "SNTI Homepage" in the Nursery Networks section for our WWW home page URL and more details on the electronic directory).

Nursery Meetings and Workshops

An **Integrated Pest Management (IPM) Course for Forest Nurseries** that was tentatively scheduled for July 22 **to 24, 1997** in Surrey, BC, CANADA is being postponed. It will be scheduled for either later this Fall or next Spring. For the latest information, contact:

Eileen Harvey
BioForest Technologies Inc.
105 Bruce Street
Sault Ste Marie, Ontario
CANADA P6A 2X6
Tel: 705/ 942-5824
Fax: 705/942-8829
E-Mail: eharvey@soonet.ca

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Green Timbers Reforestation Centre
14275 96th Ave
Surrey, B.C. V3V 7Z2
CANADA
Tel: 604/930-3302
Fax: 604/775-1288
E-mail: dtrotter@mforOl.for.gov.bc.ca

The **1997 Northeastern Forest Nursery Conference and Workshop** is scheduled for **August 11-14, 1997** at the Northern Inn in Bemidji, MN. The theme of this year's meeting will be "Plant Propagation Systems in North Central Minnesota: Where Recreation, Agriculture and Forestry Collide", and the agenda will consist of morning sessions and afternoon field trips. We will be visitin g the Badoura Nursery which is operated by the Minnesota Department of Natural Resources the first day, and then will have the choice of tours of other nurseries and other related forestry and recreation tours for the other afternoons. It sounds like a great meeting, and I hope to see you there. If you would like more information, contact:

Mike Carroll
Badoura State Nursery
RR 2, Box 210
Akeley, MN 56433 USA
Tel: 218-652-2385
Fax: 218-652-2383

The **Western Forest and Conservation Nursery Association** meeting will held on **August 19-21, 1997** at the Doubletree Riverside Motor Inn in Boise, ID. As is our tradition, the meeting will consist of indoor presentations each morning with afternoon field trips. The focus topics this year will include two sessions on Propagating Native Plants, Seed Considerations with Native Plant Propagation, New Nursery Equipment, Nursery Updates, and Nursery Projects from Around the World. On the field trips, we will be visiting our hosts at the USDA Forest Service Lucky Peak Nursery as well as touring a fire restoration site on the Boise National Forest. Motel reservations in Boise are extremely limited, so make your plans early. If you want the latest information on the meeting, contact me or:

Dick Thatcher
Lucky Peak Nursery
HC 33, Box 1085
Boise, ID 83706 USA
Tel: 208-343-1977
Fax: 208-389-1416
E-mail: /s.r.thatcher/oul=RO4F02A @mhs-fswa.attmail.com

The 17th annual meeting of the **Forest Nursery Association of British Columbia (FNABC)** will be held at the Silver Star Mountain Resort in Vernon, BC on **Sept. 8 to 11, 1997.** The theme will be Culture and Regeneration of High Elevation Interior Spruce and Subalpine Fir, and the meeting will consist of morning technical sessions followed by afternoon field trips. Contact Clare Kooistra for the latest information on the details of the agenda:

Clare Kooistra
BC Ministry of Forests
106-1340 Kalamalka Lake Road
Vernon, BC V I T 6V4 CANADA
Tel: 250/549-5655
Fax: 250/549-5540

The **Western Region of the International Plant Propagators' Society** will be meeting at the Delta Pacific Resort and Conference Center in Richmond. BC, CANADA on Sept. 10-13, 1997. The meeting theme will be Plants for Our Future, and the technical sessions always cover a wide range of basic plant propagation concepts and techniques. Richmond is located just across the Fraser River from Vancouver, BC and the area and 2 half-day nursery tours are scheduled. These IPPS meetings are an excellent opportunity to expand your horticultural horizons . Additional information can be obtained from:

IPPS Membership	Program Chairman
Wilbur Bluhm	Beverley Greenwell
IPPS, Western Region	Happy Hollow Nursery
743 Linda Avenue NE	36988 Dawson Road
Salem, OR 97303 USA	Abbotsford. BC V3G 2L1
Tel: 503/393-2934	CANADA
Fax: 503/393-2030	Tel/Fax: 604/852-4108
E-mail: wlbluhm@aol.com	

The Nursery Technology Cooperative at Oregon State University will be hosting a symposium on **Forest Seedling Nutrition from the Nursery to the Field** on **Oct. 28-29, 1997** in Corvallis, OR. The two day agenda will include sessions on Principles of Seedling Nutrition and Fertilizer Technology, Seedling Nutrition in the Nursery, Monitoring. Seedling Nutrition, and Seedling Nutrition in the Field. If you would like more information, contact Diane or check out their World Wide Web home page:

Diane Haase
Nursery Technology Cooperative
Oregon State University
Forest Science Lab. 020
Corvallis, OR 97331 USA
Tel: 541/737-6576
Fax: 541/737-5814
E-mail: haased@ccmail.orst.edu
WWW: http://www.fsl.orst.edu/coops/ntc/ntc.htm

The Annual International Research Conference on Methyl Bromide Alternatives and Emissions Reductions will be held on **Nov. 3-5, 1997** at the Double Tree Hotel Inn in San Diego, CA. The meeting planners are soliciting papers and posters on research and technology development for alternatives to methyl bromide fumigation such as biological control, cultural methods, solarization, steam heat, as well as other chemicals. If you would like to present a paper or poster, note that the deadline is August 1, 1997. More information on all aspects of the meeting can be obtained from Anna at:

Methyl Bromide Alternatives Outreach
144 W. Peace River Drive
Fresno, CA 93711 USA
Tel: 209/447-2127
Fax: 209/436-0692

The **International Conference of the Society for Ecological Restoration** (SER) will be held in Ft. Lauderdale, FL on **Nov. 12-15, 1997.** This year's theme is Ecological Restoration and Regional Conservation Strategies , and the symposium will consist of invited and submitted papers on a wide range of restoration topics from around the world. Native plant nurseries should find this conference of particular interest. Registration materials can be obtained from:

Society for Ecological Restoration
1207 Seminole Highway
Madison, WI 53711 USA
Tel: 608/262-9547
Fax: 608/265-8557
E-mail: ser@vms2.macc.wisc.edu

The International Union of Forest Research Organizations (IUFRO) is organizing an international symposium on **Innovations in Forest Tree Seed Science and Nursery Technology** in Raipur, INDIA on Nov. 22-25, **1997.** The symposium will consist of keynote and plenary lectures, contributed papers and posters on a wide range of topics in seed biology and nursery technology. For more information, contact the organizing secretary:

S.C. Naithani
IUFRO Symposium - 1997
SOS in Life Sciences
Pt. Ravishankar Shukla University
Raipur - 492 010
INDIA
Tel: 91-0771-26031
Fax: 91-0771-534283
E-mail: rsinf@shakti.ncst.ernet.in

The location and date of the **1998 Western Forest and Conservation Nursery Association (WFCNA)** meeting had to be decided by ballot. Both the Hawaii Division of Forestry and the **Forest Nursery Association of British Columbia (FNABC)** volunteered to host the meeting, and the members also wanted to see if the meeting date could be changed. A mail-in ballot was sent out in October and the voting was very close. The WFCNA and FNABC will schedule a joint meeting for either Victoria or Nelson, BC, and although the exact dates and location are still being decided, the meetings are traditionally held from mid-August to mid-September. For the latest information, contact me or Ev Van Eerden:

Ev Van Eerden

Pacific Regeneration Tech.. Inc.

#4 - 1028 Fort Street

Victoria, BC V8V 3K4

CANADA

Tel: 250/381-1404

Fax: 250/381-0252

We have just begun planning for a **Native Plant Propagation** conference at the LaSells Stewart Center in Corvallis. OR on **Dec. 9-10, 1998.** The conference will be jointly sponsored by the Nursery Technology Cooperative at Oregon State University and the USDA Forest Service. Other than the dates and location, we won't have any more information until the January, 1998 issue of FNN, but we thought that you'd like to get it down on your calendar. Feel free to contact me in the meantime if you have any comments or suggestions.

Seedling Storage, Part 3: Packaging, Monitoring and Handling

The first part of this series in the January, 1996 issue examined the different types of storage and how they must be designed to fit the needs of the outplanting season. In January, 1997, we looked at storage terminology and how to schedule harvestin g. In this final installment in the series, we'll discuss pre-storage treatments, types of packaging, the physiological effects of storage, and post-storage handling.

Pre-storage treatments

Just prior to packing the seedlings, some nurseries treat the foliage with fungicides to retard mold development, or dip the roots to protect against molds or desiccation. Foliar fungicides were commonly applied in the past but this practice is under review because of concerns about worker safety. Both nursery workers and tree planters have complained about skin rashes and other allergic symptoms after handling fungicide-treated stock. Also, the very need for pre-storage fungicide treatments of bareroot seedlings is coming under scrutiny because if the stock is clean and diseased seedlings are rigorously culled during packing, then storage molds are much less of a concern. The situation is slightly different for container seedlings because *Botrytis* spp. often can be found on the lower senescent foliage of conifers. These minor infections do not justify culling the seedlings because the fungus will not survive after outplanting. However, *Botrytis* can turn into a serious storage mold if conditions warrant, and so growers often use foliar fungicides to stop the spread of the fungus during storage.

Root dips of bareroot seedlings have been a common pre-storage treatment for the past 50 years. In the Southern States, pine seedlings traditionally were dipped in a kaolinite clay slurry during packing to protect the roots, but these treatments have been replaced by hydrophilic gels in recent years. Root dips are thought to prevent fine root desiccation during handling and storage and therefore increase outplanting performance. However, a recent review of the literature does not support this concept. Research studies found that root dips of conifer seedlings often are detrimental during storage and provide no consistent benefit after outplanting. Nevertheless, many nurseries and tree planters still consider them a necessary pre-planting treatment.

Packaging

The type of storage package and when the seedlings are packaged depends on the type of stock. Conifer seedlings need some sort of protective packaging to retard moisture loss and prevent injury durin g the storage period, and so typically are packaged immediately after harvesting and grading. On the other hand. some nurseries prefer not to package hardwood seedlings before storage because of concern about molding. The traditional storage method is to store bareroot hardwood seedlings on open racks in coolers or in heeling-in beds in the field **(Figure 1),** and then package them just prior to shipment. However, research has shown that bagged hardwood seedlings or those with just their roots enclosed in bags suffer much less stress.

Figure 1. Some nurseries still store bareroot hardwood seedlings in traditional "heeling-out" beds because of concerns over storage molds.

Enclosing seedlings in some sort of packaging protects them from several different stresses during the storage and handling period **(Table 1).** A good storage container should have the following attributes:

- *Lightweight—Packages* must be handled several times from the nursery to the outplantin g site and so must be light enough for workers to handle them without injury.

- *Moisture* proof—Seedlings must be protected against desiccation during storage and handling, yet be permeable enough to allow enough oxygen exchange for respiration.

Table 1. Seedlings can be injured by several **types of stresses during storage and shipping**

Type of Damage	High Risk Conditions	Preventative Measures
Drought injury	Plant moisture stress > 0.5 Mpa	Hardy, fully-turgid seedlings; proper packaging
Drought injury (Winter desiccation)	Exposure to weather, or freezer storage	Proper packaging: refrigerated storage, but no bales in freezers
Cold injury	Temperatures below seedling cold hardiness level roots are much more susceptible than shoots.	Hardy seedlings; refrigerated storage
Heat injury	Temperatures above 5 °C (40 cF); consider exposure time vs. temperature	Hardy seedlings: refrigerated storage
Loss of dormancy	Warm temperatures: consider exposure time vs. temperature	Hardy seedlings: refrigerated storage
Mechanical injury	Compression; physical shock	Hardy seedlings; use boxes for containers: proper handling

- Durable—Packages are stored under high humidity and so must be physically strong. Also, some bareroot hardwood seedlings have very rigid roots which can easily puncture the walls of storage containers.

- *Conducive to bulk handling—Storage* containers should fit easily on racks or pallets for handling with forklifts or other equipment.

Depending on the species and the type of storage, seedlings are packaged in bales, bags, or boxes. The standard storage container should weigh no more than 40 to 50 lbs and will hold from 500 to 2,000 seedlings, depending on the species and stock type.

Bales/Crates — Bareroot seedlings are sometimes packaged in open-ended bales or wrap-around crates when seedlings will be stored for only a few months. Because seedlings continue to lose moisture during storage, baled stock must be kept moist by misting or periodic light irrigation. Bales are popular in the South and in the Midwest, some nurseries prefer bales for their hardwood stock. In the West, bales are only used when the seedlings will be stored in snow caches. However, they are not suitable for freezer storage because seedling foliage is exposed to freeze drying.

The haling process consists of orienting the seedlings with their roots in the middle and then alternating with layers of wet sphagnum moss or other moisture-retentive material like shingletow. One or two slats are included to provide rigidity and then the entire bundle is baled with a waterproof wrapper.

Bags — Specially-constructed kraft paper/polyethylene ("K-P" or "Poly") packing bags feature gusset construction and a waxed and sown bottom. The typical poly bag consists of three layers with a 50 lb (110 kg) wet strength. and the inner ply is coated with a thin layer of plastic on the inside to retard moisture loss. Poly bags are most commonly-used for bareroot seedlings although they have occasionally been used for container stock. Bundles of seedlings are oriented on their sides with their roots overlapping in the middle and mixed with layers of sphagnum moss or singletow to prevent desiccation. Some nurseries sew the tops of their polybags whereas others just fold them over and then strap them with a banding machine. During storage and shipping, bags must be stored on shelves or pallet racks to allow good circulation.

Boxes — The typical storage box is made of corrugated cardboard that has been treated with plastic or wax to make it waterproof. Some nurseries use corrugated plastic boxes that, although they are more expensive, are reusable. Container nurseries who ship their stock to the outplanting site in the growth container often put

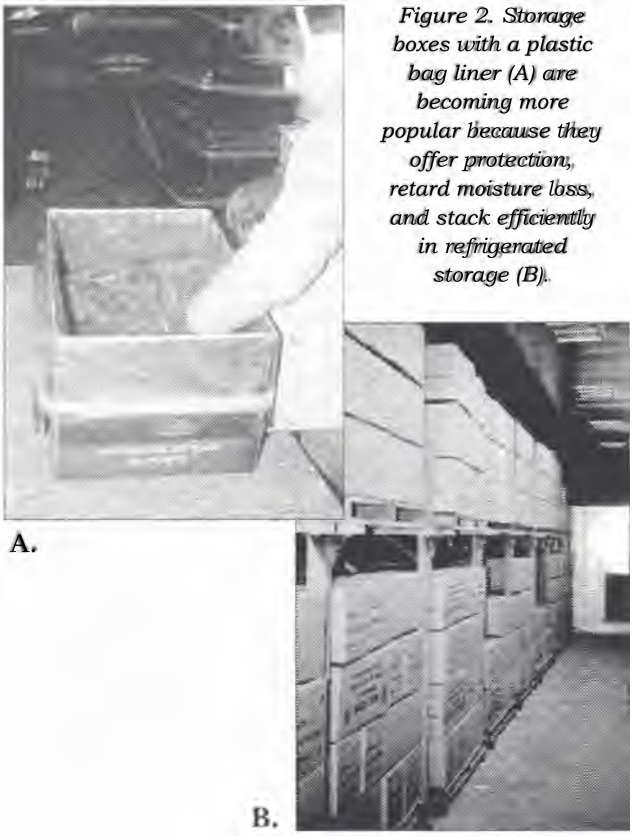


Figure 2. Storage boxes with a plastic bag liner (A) are becoming more popular because they offer protection, retard moisture loss, and stack efficiently in refrigerated storage (B).

them in boxes for additional protection against mechanical injury. Boxes are the standard for freezer storage of pull-and-wrap container stock but, because they are not moisture-proof, a thin (1-2 mil) plastic bag liner is needed **(Figure 2a).** Because of their square shape, boxes can be stacked more easily and safely than bags or bales, but should still be placed on pallet racks or shelves during long-term storage to allow good movement of the refrigerated air (Figure 2b).

Monitoring stock quality in storage

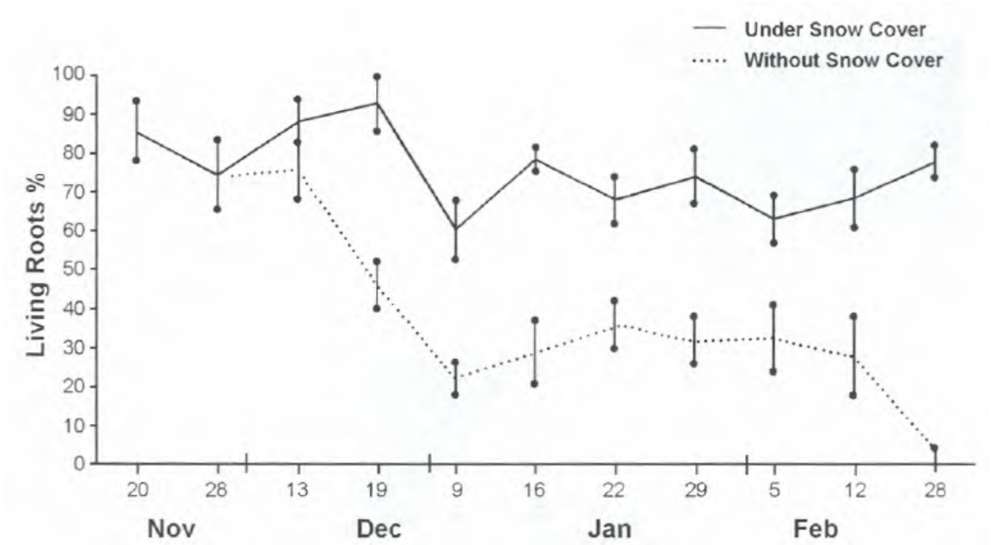
The physiology of dormant seedlings during storage can best be visualized as "suspended animation" - the seedlings are alive but their physiological functions have slowed to a minimum. The critical limiting factor that maintains dormancy during storage is temperature **(Table 1).** Therefore, temperature should be rigorously monitored throughout storage and shipping operations. It is important to measure temperature within the containers as well as in the storage building because the two locations tell you different things. Because stored seedlings are still respiring, they generate a small amount of heat which means that the in-bag or in-box temperature will always be a couple of degrees warmer than the ambient environment **(Figure 3).** For this reason, the setpoint temperature for the storage environment should always be 1 to 2 degrees cooler that the desired temperature in the container. For example, you may have to operate with a setpoint of 28 °F (-2 °C) to obtain a temperature of 30 °F (-1 °C) in-box temperature. The temperature in the storage facility should be monitored as well because it tells you whether the compressors are working properly and whether you arc getting good distribution of the cold air.

With hardy, dormant seedlings, desiccation has been shown to be serious concern during long-term storage. Container seedlings stored outside overwinter can suffer unacceptable root injury even when covered with a protective snow cover (**Figure** 4). To miminize desiccation in seedlings stored under refrigeration, high humidity be maintained around the seedlings and they should not be subjected to excessive air movement. This best method of accomplishing this objective depends on the type of packaging. For baled conifers and open-stored hardwood seedlings, the floors of the storage building are wet down periodically with a hose so that the ambient relative humidity is always near 100%. When seedling arc packed in poly bags or in boxes with plastic bag liners, the humidity in cold storage facilities is less of a concern because essentially no moisture is lost after the seedlings are packed. Still, well-designed cold storage rooms are equipped with mist jets and humidity sensors that maintain high humidity. With freezer storage, humidity control is strictly an in-package concern because all free moisture in the storage room turns to ice crystals.

Several pieces of equipment can be used to monitor seedling condition during storage. In-bag thermometers have already been mentioned but the advent of data loggers have revolutionized the technology. Data loggers are self-contained recording devices that monitor temperature, humidity and other weather

Figure 3. Although ambient temperature readings indicate how the refrigeration equipment is functioning, the true indication of storage temperature can only be obtained with in-bag monitoring.

Figure 4. Roots are always less hardy than shoots, and roots of these container Scots pine were seriously damaged when exposed during outside storage. Snow cover provided some protection but significant damage still occurred (Sutinen and others 1996).



variables that contribute to seedling stress. New models are small enough to place in storage packages where they detect both incidence and duration of exposure. Many nurseries measure plant moisture stress with a pressure chamber prior to and during harvesting, and this equipment also affords a quick and accurate way of monitoring the degree of seedling desiccation during storage.

Handling During Storage Period

Seedlings must necessarily be handled many times during harvesting, packing, storage, shipping, and outplanting.

Defrosting frozen stock — Frozen seedlings should be defrosted before excessive handling or exposure to sunlight or drying winds. Cell membranes may be ruptured by intercellular ice crystals, and conifer seedlings can develop damaging moisture stress while their roots are still frozen. The current operational practice has been to thaw frozen seedlings slowly at ambient temperatures in dark rooms or under shade, but this can take several days or even weeks. Recent research, however, has shown that frozen seedlin gs can be fully thawed in as little as 3 to 4 hours at room temperature.

Minimizing exposure — Obviously, seedlings should be handled with care and exposed as little as possible but research has shown that desiccation is more of a concern than warm temperatures. A comprehensive evaluation of the various types of stresses affecting seedlings during storage, handling, and outplanting revealed that desiccation of the root system was the most damaging factor and that direct sunlight and high temperatures were significant only as they increased moisture stress. The true impact of careless exposure i5 not immediately apparent, however, because it causes a degree of sublethal injury that only will be reflected in suboptimal performance after outplanting.

Physical shock — Several studies have shown that seedlings are relatively tolerant to vibration and dropping. Although research has shown that rough handling and shocks during have relatively minor effects on seedling quality. they are accumulative and so should be avoided **(Figure 5a).** This is one of those cases where common sense should prevail over the need for validation through research.

A.

Figure 5. Although research studies have shown that physical shocks and mishandling do not cause major injury (A), all types of abuse are cumulative and can only decrease seedling quality (B—see figure on following page).

Conclusions and Recommendations—Accumulated Stresses

Storage must be viewed as a holding action which strives to maintain stock quality until the seedlings can be outplanted. Harvesting itself is a tremendous stress, especially with bareroot stock, and then the seedlings are subjected to a series of additional stresses as they are graded, packed, stored, shipped. and outplanted. Because of the variability involved and our lack of sensitive monitoring equipment, it is difficult to quantify or predict the degree of these individual stresses. However, it is very important to emphasize that *stresses are cumulative, and that there is no way to increase quality after the seedlings are harvested.* A useful concept is to think of seedling quality as a checking account. Each seedling has a given quality "balance" when it is harvested, and each stress only subtracts from that initial quality just like writing a check **(Figure 5b).** Unfortunately, there is no way to make deposits to this account - there is nothing we can do to improve seedling quality after it leaves the nursery. So, nursery managers must pay close attention to details during the storage period so that their seedlings reach their customers at their peak of quality.

Sources:

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Lavender. D.P.; Parish, R.; Johnson, C.M.: Montgomery, G.; Vyse, A.; Willis, R.A.; Winston, D. 1990. Regenerating British Columbia's Forests. Vancouver: University of British Columbia Press. 372 p.

B. Bank of Seedling Quality

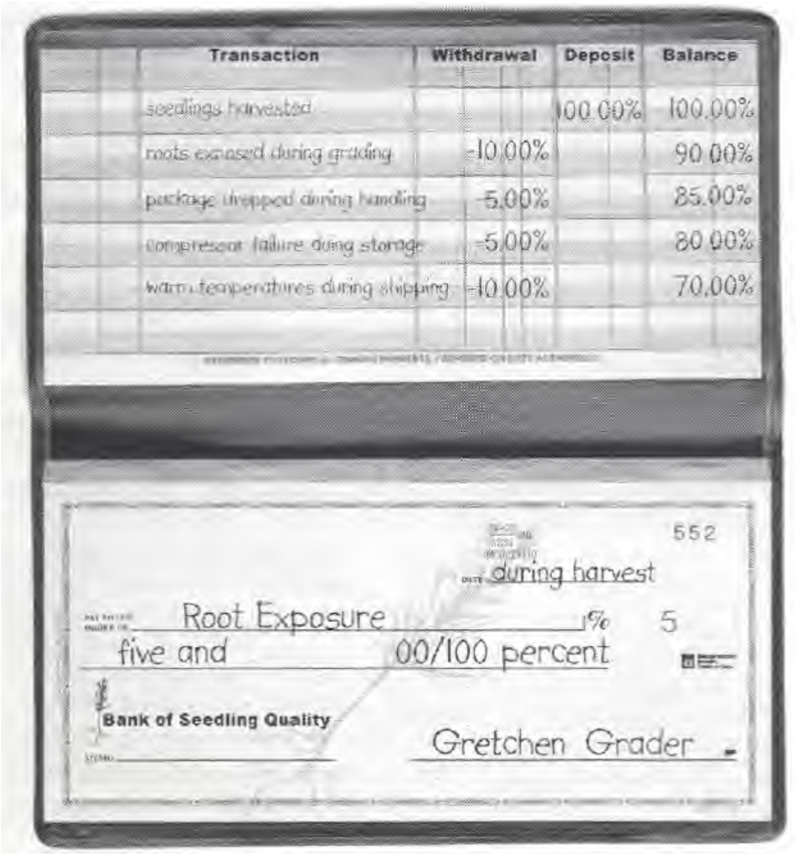

Figure 5h. Each abuse to seedlings is like a check drawn on a bank account of seedling quality.

May, J.T. 1985. Chapter 10: Packing, storage and shipping. IN: Lantz, C.W. ed. Southern pine nursery handbook. Atlanta, GA: USDA Forest Service, Southern Region 12 p.

McKay, H.M. 1997. A review of the effect of stresses between lifting and planting on nursery stock quality and performance. IN: Colombo, S.J.; Noland, T.L. 1997. Making the Grade. New Forests 13:1-3 (Special Issue). Dordrecht: Kluwer Academic Publishers:369-399.

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Sutinen, M. Makitalo, K.; Sutinen, R. 1996. Freezing dehydration damages roots of containerized Scots pine *(Pinus sylvestris) seedlings* overwintering under subarctic conditions. Can. *J.* For. Res. 26: 1602-1609.

Micronutrients—Iron

In the January 1997 issue, we completed our discussion of secondary nutrients, so with this issue we will start with the seven micronutrients (Table 2). Eric van Steenis of the British Columbia Ministry of Forests assisted with the writing of this article, and his help is gratefully acknowledged.

Iron (Fe) is one of the most common metallic elements on earth but its content and availability in soils is extremely variable. In good agricultural soils, adequate amounts of iron are released by the weathering of minerals and so supplemental fertilization is not needed. Many iron deficiency problems that require treatment can be found on alkaline or calcareous soils which are most common in semi-arid and arid climates. However, problems also have occurred on calcareous chalk soils which are found even in humid climates like England. Container growers need to be more aware of the availability of iron because levels are naturally low in artificial growing media, like those composed of peat moss and vermiculite.

Role in Plant Nutrition

In historical terminology, the "Iron Age" began about 1000 years B.C. but our understanding of the roles of iron in plant growth are relatively recent, dating back to the late 19th century. Plants are the ultimate energy transducers, converting light energy to chemical energy, and iron is absolutely critical in both the manufacture of the chlorophyll molecule and the physiological functioning of the photosynthetic process. Thus, even though iron is thought of as a micro-nutrient (Table 2), its role is of macro-importance in seedling nutrition.

A fascinating aspect of the energy transfer system in plants are ring structures known as porphyrins, which can be found in several molecules that are critically important to life as we know it. Porphyrins form metal chelates with a variety of metal ions; in chlorophyll, the center atom is magnesium, whereas in plant cytochrome and mammalian blood hemoglobin the center atom is iron **(Figure 6).**

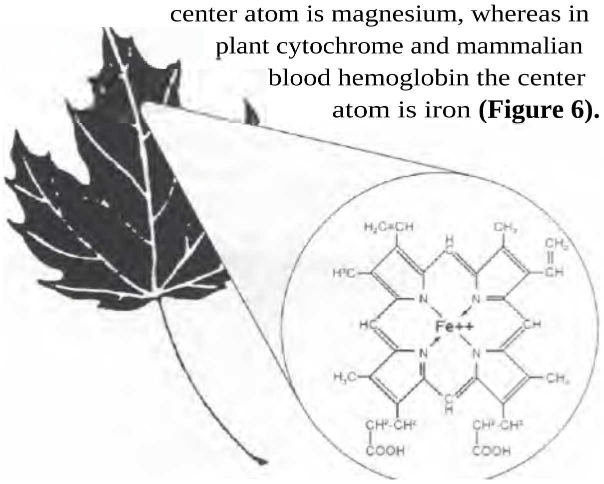


Figure 6. Iron can be found in the "heme" structure of cytochrome molecules, which are critical for formation and function of chlorophyll in leaves.

Table 2. The seven essential micronutrients and their typical concentrations in seedling tissue.

Element	Symbol	Average Concentration in Plant Tissue (%)	Adequate Range in Seedling Tissue (ppm)	
			Bareroot	Container
Iron	Fe	0.01	50 to 100	40 to 200
Manganese	Mn	0.005	100 to 5.000	100 to 250
Zinc	Zn	0.002	10 to 125	30 to 150
Copper	Cu	0.0006	4 to 12	4 to 20
Molybdenum	Mo	0.00001	0.05 to 0.25	0.25 to 5.0
Boron	B	0.002	10 to 100	20 to 100
Chloride	Cl	0.01	10 to 3,000	

Of course, you already knew that because you remembered the similarity between the structure of chlorophyll (see "Secondary Nutrients—Magnesium" in the July, 1996 issue of FNN) and hemoglobin (see "Carbon Monoxide—the Silent Killer" in the January, 1997 issue). This presence of iron explains why blood can be used for iron fertilizer and why poisons that destroy the energy/oxygen carrying capacity of the cytochrome system are so deadly, *e.g.* cyanide and carbon monoxide.

The porphyrin structure is known as "heme" when iron is the central metal ion. Heme serves as a catalyst in various enzymes systems, directly influencing the synthesis of certain compounds, one of which is chlorophyll. Without iron, even if other building blocks are present, chlorophyll synthesis is seriously impaired or just will not occur. Combine this with the fact that iron is highly immobile in plants and you begin to understand why iron deficiency decreases the level of chlorophyll in newly forming tissues. In fact, "iron chlorosis" is the universal symptom for iron deficiency in plants.

Iron is also intimately involved in the energy transfer and capturing process. Note that this is *after* chlorophyll has been synthesized so iron actually has a hand in determining the efficiency of photosynthesis as well. As a constituent of cytochrome molecules, iron helps facilitate the transfer/elevation of electrons to "excited" states and is part of the final receiving protein molecule, ferredoxin, which plays an important role in nitrate and sulphate metabolism within plants. And, as a carrier of oxygen, iron is also an activator of respiration and aids in symbiotic nitrogen fixation.

From the above discussion, it's easy to see why the internal iron status of plants determines their level of photosynthetic efficiency.

Availability and Uptake

Like all the mineral nutrients, plants take iron up from the soil where it occurs in two ionic forms: ferrous (Fe^{2+}) and ferric (Fe^{3+}). Although both ions can be absorbed by roots, the Fe^{2+} form is the most physiologically important. Compounds containing Fe^{3+} are usually of low solubility which limits their availability and, when Fe^{3+} ions are taken up by the plant, they have to be reduced to Fe^{2+} ions before they can be used. Iron availability and uptake are greatly influenced by the presence of other ions both in the root zone and in the plant. Iron and manganese together form a redox system, meaning they react with each other to induce valence changes in each other *(ie.* $Mn^{3+} + Fe^{2+}$ <<==>> + Fe^{3+}). Since Fe^{3+} is generally unavailable for plant use, excess manganese in the soil can induce iron deficiency. In horticulture, therefore, the Fe/Mn ratio in the fertilizer solution and in foliar analysis are important factors to consider when diagnosing a deficiency and prescribing a remedy. As mentioned earlier, excess calcium ions also can reduce the availability of iron for plant uptake. In fact, the most common soil condition associated with iron deficiency is the presence of calcium carbonate.

The pH of the soil is critical to iron availability since under alkaline conditions iron combines readily with phosphates, carbonates and hydroxyl ions. Phosphates can actually combine with iron inside the plant as well to form insoluble precipitates, rendering both elements unavailable. Another concept to keep in mind is that of ionic balance in general. This is critical when considering competition from calcium, magnesium, potassium, copper, and zinc for uptake by the roots. Ion competition can continue within the plant as both copper and zinc can interfere with iron function. This has particular application when copper-treated containers are used. The rate of iron application should be increased by several ppm to offset the copper competition effect and reduce the possibility of copper-induced iron deficiency. In bareroot nurseries with alkaline or calcareous soils or water, iron chelates should be used. (See Iron Management section for more specifics).

New, fine roots are the most efficient at taking up iron hence it is imperative that the plant has a healthy, actively growing root system. Anything that impairs root growth and function will impair iron uptake including extremes in temperature, moisture content, and salinity as well as low root zone oxygen levels and root disease. For example, under conditions of waterlogging, redox values are reduced along with pH and oxygen levels which favor the ferrous form of iron. However, the low oxygen availability is most critical because it virtually disables the root system, preventing it from taking up any available iron. A classic case of starvation in the midst of plenty. In this case, although iron deficiency is the symptom, applying iron fertilizer will not solve the problem. The real cure is proper irrigation and climate management to encourage transpiration and promote active root growth.

The form of nitrogen fertilizer also warrants attention. When nitrate (NO_3-) ions are taken up by the roots, hydroxyl (OH-) ions are released to balance the internal charge. This not only raises soil pH but the hydroxyl ions can tie up iron in the rhizosphere. On the other hand, when ammonium (NH_4^+) ions are absorbed, a hydrogen (H+) is released which acidifies the soil in the root zone and thereby increases the availability of the desirable ferrous form of iron. Nitrate fertilizers are often preferred in container nurseries during cloudy weather and with winter crops, especially with sensitive species or ecotypes *e.g.* coastal Douglas-fir. However, excessive use -of nitrate-nitrogen causes a slow increase in pH in the rhizosphere ultimately leading to an induced iron deficiency.

Diagnosis of Deficiencies and Toxicities

Because of its importance in the manufacture of chlorophyll and its functioning, the first symptom of iron deficiency is chlorosis. Remember that this symptom is the same for many other nutrient deficiencies, however, including nitrogen, magnesium, and sulfur. The diagnostic characteristic of iron deficiency is that it typically shows first in new foliage because iron is immobile in the plant. Note that this is different from a mobile nutrient, such as nitrogen, where the chlorosis shows first in older foliage. The possibility of iron deficiency can also be deduced from climatic and soil conditions. Iron chlorosis is a common disorder in arid or semi-arid climates, which often have alkaline soils and water, and in calcareous soils.

Deficiency symptoms — In young conifer seedlings, chlorosis of actively growing tops is the first evidence of iron deficiency. In severe cases, the affected foliage will turn white and may eventually die. If newly flushed shoots display the symptoms, the grower should be alerted to a change in conditions in the root zone. The primary symptom of iron deficiency in broadleaved seedlings is interveinal chlorosis of young leaves which can progress into marginal necrosis in severe cases.

Iron deficiencies can be difficult to diagnose with foliar symptoms, however, because the symptoms are often the result of an imbalance between several different micronutrients. One of the simplest tests for iron deficiency is to apply a dilute solution of ferrous sulfate (0.5 to 1.0 %) to the chlorotic foliage, which will turn green within a couple of weeks if iron is the problem.

Toxicity symptoms — Iron toxicity is rare under natural conditions but can occur with excessive foliar fertilizer applications. Be aware that moss control chemicals containing iron sulfate may result in iron toxicity, especially on young succulent tissue. The principal symptom is severe stunting, with some species showing chlorosis, browning, or necrotic spots.

Monitoring

The available iron status of nursery soils or growing media can be monitored by soil tests, irrigation water tests, or seedling nutrient analysis.

Chemical analyses of soils or growing media are relatively useless for determining iron availability. Many laboratories report total iron but active iron is more important, because total iron includes unavailable ferric iron. Measure root zone pH on a weekly basis and watch for any trends. An upward pH drift mayb be indicative of a developing problem. Rising root zone pH is often thought to be the cause of iron deficiency when it may actually be the symptom, rising concentrations of ions such as calcium and bicarbonate being the actual culprits.

Iron quickly becomes unavailable when alkaline water is used for irrigation. The water sources of good nursery sites typically is around neutral or slightly acidic, but it may exceed ph 7.0 when other dissolved salts are present, especially bicarbonate ions. Weakly buffered alkaline water may not need to be treated if the pH of the soil or growing medium is maintained in the proper range. It is relatively easy to lower water pH with acid injection because the excess hydrogen ions bond with the hydroxyl ions to form water. The need for acid injection and the amount of acid to use per volume of water must be determined with a laboratory titration.

Seedling nutrient analysis can be used to diagnose iron deficiency but interpretation can be difficult. Because of the variability that can exist, paired samples of normal and healthy plants should always be taken. Seedlings with iron chlorosis keep trying to take up more iron but cannot metabolize it, and so foliar analysis often shows that symptomatic seedlings have higher concentrations than healthy ones.

Iron Management

When iron chlorosis is diagnosed, growers need to remedy it in the short term, determine its cause, and adjust long term culture to prevent a future occurrence. Foliar fertilization will provide a quick remedy for an acute deficiency, but this will not solve the real problem and so some detective work is needed. Check the supply of iron first. If it is adequate, then check water and soil pH and complexing/competing ion concentrations of the fertilizer solution. Often, instead of requiring the addition of more iron fertilizer, one actually needs to make that iron which is present more available by reducing something else or just shifting the balances. Once active iron is available and the plant's root system has been encouraged to take it up, iron problems will disappear. Granted, this type of diagnosis and correction may be challenging but that's why growers make the big bucks!

There are basically two options for managing iron in nurseries: • *maintain slightly acid pH,* and *fertilize properly.*

pH maintenance — Hopefully, this should not be a problem if the nursery site was properly selected but there are still several nurseries with problems of high pH. In bareroot nurseries, either alkaline soil or irrigation water can be the culprit. Water is much easier to treat and acid injection is commonly recommended for container nurseries, but treating the water has not solved the problem in bareroot nurseries with alkaline or calcareous soils. In particular, calcareous soils are highly buffered and the excess calcium ions can still cause problems after the pH has been lowered. The pH of alkaline soils can be lowered with sulfur applications although this can take many years with calcareous soils. Leaching must be done at the same time to remove the excess ions from the acidification.

Fertilization — Iron can be supplied from inorganic fertilizer salts or organic compounds known as chelates, and both single nutrient and micronutrient mixes are available **(Table 3).** The most comprehensive list of the types of iron fertilizers and their US suppliers can be found in the Farm Chemicals Handbook. In Canada, Plant Products Co. Ltd. offers a wide variety of chelated iron fertilizers.

The effectiveness of iron fertilizers can be rated by solubility and resistance to chemical tic-up by other ions in the soil or water. The most soluble inorganic Fertilizer is ferrous sulfate which is ineffective as a soil application because it is rapidly oxidized to insoluble Ferric sulfate. Ferrous sulfate may be acceptable as a Foliar spray depending on water quality. Although they pan be attractive because of their low price, inorganic ron fertilizers cannot be widely recommended considering all the possible problems with availability.

Chelates are the most popular type of iron fertilizers and consist of organic compounds which contain a nega-:ively charged "cavity" which holds a positively charged cation such as Fe++ **(Figure 7a).** In this enveloping structure. the iron is protected from other ions which normally render it unavailable to plant uptake. Not only does chelation keep iron available to plants under adverse soil conditions, it also protects against overfertilization because the iron is slowly released From the organic complex.

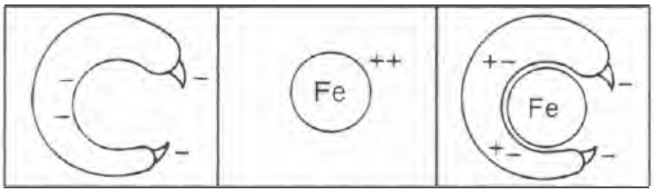
There are several types of chelates, which vary in the strength with which they hold the ferrous ion at different pH values and against competing ions in the soil or growing medium. Fe-EDTA is primarily used in more acidic conditions because the chelate is weak above pH 7 **(Figure 7c),** and it has a high affinity for calcium

Table 3. Some common fertilizers containing iron.

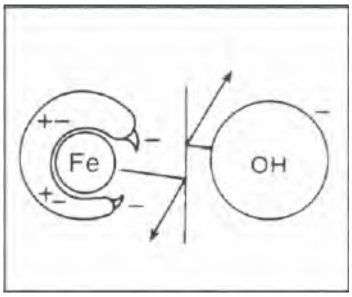
Fertilizer	*Chemical Notation*	*Iron (%)*	*Use in Nurseries*
	Single Nutrient Fertilizers		
Ferrous sulfate	$FeSO_4 \cdot 7H_2O$	19	Only for foliar applications
Iron Chelate	NaFeEDTA	5 to 14	Foliar or soil applications*
Iron Chelate	NaFeDTPA	7	Foliar or soil applications*
Iron Chelate	NaFeHEDTA	6	Foliar or soil applications*
Iron Chelate	NaFeEDDHA	10	Foliar or soil applications*
	Multinutrient Fertilizers		
STEP®	Iron as $FeSO_4$	7.5	Incorporation in growing media
Micromax®	Iron as $FeSO_4$	12	Incorporation in growing media
Chelated Micronutrient Mix®	Iron as EDTA and DTPA	7	Foliar or soil applications*

*Availability of iron chelates depends on pH—see Figure 7c.

A. What is a chelate?



B. How a chelate works.



C.

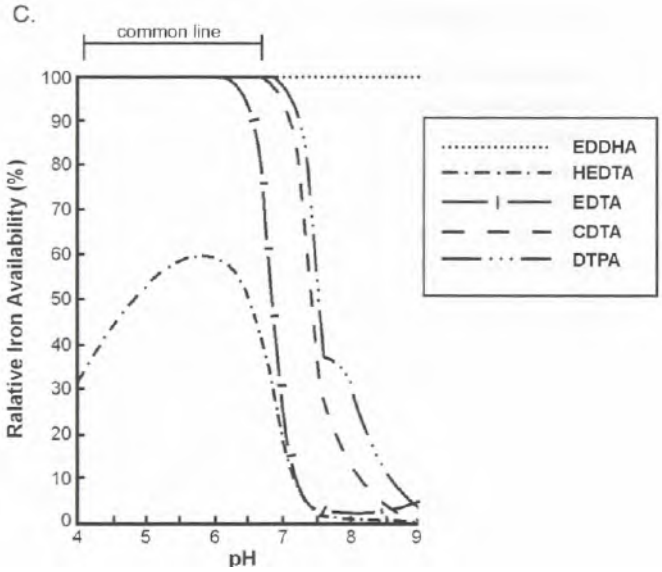


Figure 7. Chelates are composed of a negatively charged organic complex and a positively charged cation such as ferrous iron (A). Chelate fertilizers remain active under adverse conditions because they resist inactivation by ions such as hydroxyl (B). There are several types of chelate fertilizers available, but EDDHA chelates are the only ones that remain active across the full range of pH (A,B from Stoller chemical company; (C) modified from Norvell 1972).

ions which can displace the iron. Therefore, Fe-EDTA is often used for foliar applications but should not be used with high alkalinity/calcium water sources. FeDTPA is not as susceptible to calcium replacement hence is recommended for nutrient solutions. Above pH 7 the recommended chelate is FeEDDHA although this fertilizer is by far the most expensive. Iron chelates can be applied to the soil or to the foliage but bed width spray applications are a combination of both. Severe cases of chlorosis may require application every couple of weeks during the early part of the growing season. Even with the proper iron chelate fertilizer, treatment must begin in the early stages of the chlorosis or the seedlings may not respond.

In conclusion, iron is a critical micronutrient which must be carefully managed to make certain that it is supplied in a readily available form. This is usually not a problem in container nurseries or in bareroot nurseries with good quality soil and irrigation water. Iron chelates are recommended instead of ferrous sulfate because they are more available and there is little chance of overfertilization. The best chelate to use is a function of soil and water pH. The most serious availability problems occur in alkaline or calcareous soil and these will require special chelates and cultural procedures.

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Propagating Native Plants

Forest and conservation nurseries are being asked to propagate an increasing variety of native plants from noncommercial trees, to woody shrubs, to wetland plants **(Figure 8a-c).** This trend shows no signs of decreasing anytime soon, and I feel that native plant propagation will be one of the defining issues of the next decade.

Finding Propagation Information

Learning how to propagate these new plants can be a challenge, however. Research is the traditional source of new technology but I'm not aware of any scientists working on new native plant propagation techniques in the US. This problem can be traced to the recent personnel downsizing as well as a lack of priority by research administrators.

So, most of new propagation techniques are being developed on-the-job by operational nurseries but, unfortunately, this information is not being shared. There are several reasons for this. Obviously, private nurseries have a economic reason for not wanting to share their trade secrets and so the burden falls on the government (see Editorial section in this issue). This is a traditional role for USDA Forest Service nurseries and a team headed by Frank Bonner is currently gathering propagation information on trees and woody shrubs. The new edition of *Seeds of Woody Plants in the United States* should be available by later next year. State nurseries and universities are also responding to the demand. The Nursery Technology Cooperative at Oregon State University in Corvallis has been gathering propagation information in a 3-volume series called *Propagation of Pacific Northwest Native Plants: a Manual.* These publications currently are available only to Co-op members although this information will be published as a single book which will be available for general sales in 1998. The State of Illinois has one of the best native plant propagation programs in the US and is currently producing over 130 species: 35 trees, 18 shrubs, 47 forbs, 7 grasses, and 20 herbs in their two nurseries. Government nurseries have been documenting their propagation techniques in production manuals; for example, the *Greenhouse and Shadehouse Production Manual* from the Mason State Nursery in Illinois covers grasses, forbs, wildflowers, riparian and wetland plants, woody shrubs, and trees for the Great Plains. Again, there is a problem with how to get this information published and distributed because state nurseries are not funded for this purpose.

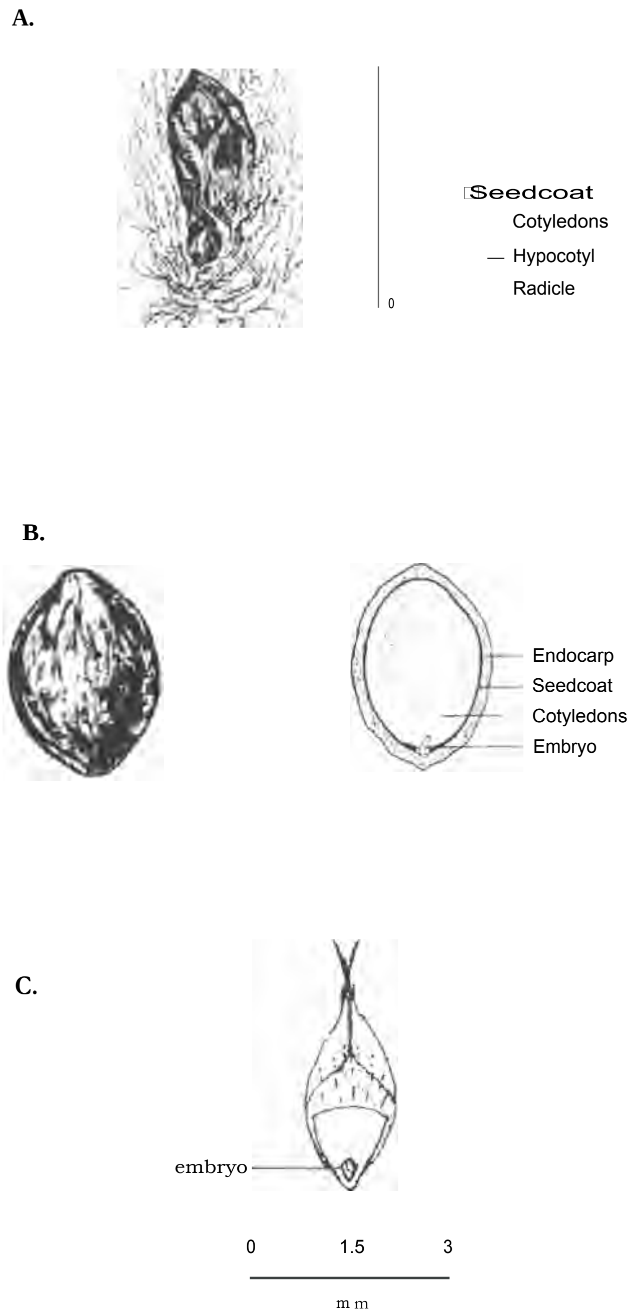

Figure 8. Propagating native plants is a particular challenge because of the wide variety of seed sizes and shapes, and type and degree of dormancy: A=Populus tremuloides, B=Prunus americana; C=Carex spp. (A, B from Schopmeyer; C from Hurd and Shaw).

Okay, so what are you supposed to do if a customer asks you grow a new species of plant? The first step is to decide whether you should use seed or vegetative propagation. This decision will depend on several other propagation considerations **(Figure 9).** Some plants are more easily propagated by one technique than another. You should also discuss the amount of genetic variability that they want. Seed propagation preserves the most variation but vegetative propagation may be needed if your customer want to produce plants for some specific reason such as to maintain a valuable clone. Sometimes, propagule availability or delivery date will be the determining factor. If your customer wants their plants in a short time then if may be impossible to find seed and you will have to use vegetative propagation. Some species only produce seed crops at long intervals or the seed may have complex dormancy requirements and so vegetative propagation may be more practical. Finally, economics must be considered because plants propagated from seed will, almost always, be less expensive than those produced vegetatively.

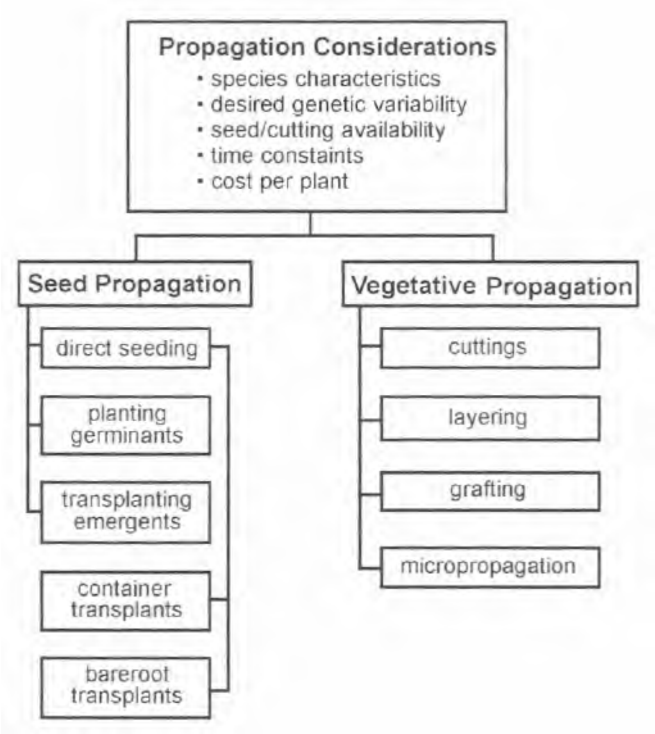

Figure 9. Many factors must be considered before deciding how best to propagate native plants.

Some other possible sources of propagation information include:

1. Systematically search the published literature. Someone may have propagated your species before, and so you may want to conduct a literature search. I know that most of you don't have the means to do this, and as already mentioned, most of the best propagation information never gets published. I try to include as many new propagation articles as I can find in the "Diverse Species" category in the New Nursery Literature section of each issue of FNN. General horticultural texts may contain some specific information but you will have more luck with technical journals. In particular, the *Combined Proceedings of the International Plant Propagators' Society* is a wealth of information and trade journals such as *American Nurseryman* have featured articles on propagating natives which can be used for landscaping purposes. Regional and special publications from Botanic Gardens and Native Plant Societies can also be helpful.

2. Compare propagation methods for related species. If you can find no information for your specific plant. then consider how they propagate close relatives within the genus or family. Some plants have relatives that are being grown as ornamentals and so the propagation information is available. Be aware that there is considerable variation even with a genus. For example, the seed treatments for two shrubby *Acer* species vary considerably. *Acer circinatum* seeds must be stratified under warm, moist conditions for 1 to 2 months followed by cold, moist stratification for another 3 to 6 months. The seeds of *Acer spicatum,* on the other hand, only require the cold stratification treatment.

3. Study the native environment and natural growth habit of the plant. Environmental factors such as total precipitation, distribution of precipitation through the year, and maximum/minimum temperatures affect seed germination. Many other clues can be gained by studying how plants grow in nature. For example, ecological information such as growth habit, type of fruit, and how the seeds are disseminated in nature may provide helpful clues. Most forest and conservation species from the temperature zone require some exposure to cold temperatures and moist conditions that naturally occur during winter. Species from this climate therefore would logically require a cold, moist stratification treatment before the seeds would germinate. Species that are adapted to fire-dominated ecosystems, such as many of the chaparral species, often have seeds that need hot water or acid scarification **(Figure 10).** Species that grow in low thickets, such as rose and wild berries, root quite easily and so can be vegetatively propagated by cuttings or by layering.

While these techniques may occasionally provide propagation hints, the truth is that we still have a lot to learn about propagating natives. With the rising interest in native plants, nurseries are developing innovative new techniques and I think that the best solution is to share what we know. Since I already don't have enough to do, I am proposing that we start a network of people who are interested in the propagation of native plants.

Native Plant Network

We have established a place on our World Wide Web home page (See "Nursery Networks" section in this issue) where we can accumulate propagation protocols and share them with each other. What is a propagation protocol? It's a comprehensive and systematic documentation of all the steps necessary to propagate a plant, starting with collection of seeds or cuttings and ending with harvest, storage, and shipping. I have developed a tentative format (see following example) and am using bur oak as an example. This format is just a suggestion and I would be most interested in any improvements that you can provide. Even if you don't have an entire protocol worked out yet, we also would be interested in any type of information such as seed treatments. By accumulating these bits of propagation information and listing them by species, we will eventually gain a more complete picture. Photographs, slides, or any other illustrations that you want to include are also welcome. Be assured that you will get full credit for your work - note that I have included a listing for personal information at the end of the form.

Figure 10. Seeds of native plants like this Rhus trilobata *have hard and impermeable seed coats and will not germinate readily without special pre-treatments, such as acid scarification (courtesy of Nancy Shaw, USDA Forest Service).*

We have included a blank protocol form in the back of this issue and will also post one on our World Wide Web home page— see page 32. Send or FAX the completed forms back to me, and we'll see about getting them posted. I may also be able to use some of this new propagation information in Volume Six: Seedling Propagation of the Container Tree Nursery Manual which will have an entire chapter dedicated to propagation protocols for natives. Thanks in advance for your help!

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Example of a Typical Propagation Protocol

Species: Bur oak, *Quercus macrophylla*

Ecotype: North Dakota

Outplanting Site: Northern Great Plains

Outplanting Date: April to May

TARGET SEEDLING INFORMATION

Height: 10 to 18 inches

Caliper: 4 to 6 mm

Root System: Firm root plug

PROPAGATION AND CROP SCHEDULING

Propagation Environment: Fully-controlled greenhouse

Propagation Method: Seeds. Sowing germinants.

Source of Propagules: Collected by hand from Turtle Mountains. ND.

Pretreatments: Float test acorns in water and use only sinkers. Dip acorns in a fungicide solution (Captan) to reduce mold during stratification. Place wet acorns in a plastic bag in a refrigerator for 180 days of cold, moist stratification at 0 to 2 °C (32 to 36 °F). Remove acorns from refrigerator 4 to 5 days before sowing and rinse to remove fungicide. Place acorns in tubs and cover with plastic sheeting to retain humidity. Fill tubs 1/4 to 1/3 full and place in a warm environment [60 to 60 °F (16 to 19 ^{c}C) to stimulate rapid germination.

Container Type and Volume: Bur oak requires big containers with large cavities to accommodate the large acorn and they also need to be widely spaced to permit good caliper development. The Spencer-Lemaire Tinus Rootrainer® has a top opening of 3.8 x 5.1 cm (1.5 x 2.0 in.) and is 18.5 cm (7.2 in.) deep. The cavities are 350 cm' (21.5 in') in volume with a cell density of 516 cells/m^2 (48/ft^2). Another good container for this species is the Colorado Styroblock which has a top opening of 5 x5 cm (2 x 2 in.) and is 20 cm (8 in.) deep. These cavities are 492 cm^3 (30 in^3) in volume with a cell density of 270/m^3 (25 ft2).

Growing Media: 50% *Sphagnum* peat moss and 50% #2 grade vermiculite. Fill cavities and tamp lightly to remove air pockets. Use a large pointed dibble board to make room for the germinating seeds.

Total Time to Harvest: 12 months. including freezer storage.

Sowing Date: March 1

Sowing/Planting Technique: Irrigate filled containers to saturate growing media. Remove germinating acorns and place one germinant in each container. Sow at 1 cm (1/2 in) depth and be sure to orient the radicle downwards to prevent abnormal stem crooking. Cover germinants with a shallow layer of perlite.

Establishment Phase: Keep the greenhouse warm and humid both day and night (see following schedule). Frequent misting is all that is needed to keep the media "moist. but not wet" until the primary leaves have developed. Fertigate with a low nitrogen (100 ppm) but well-balanced fertilizer solution twice per week. Keep leaves dry to avoid fungal pathogens. Bur oak seedlings can tolerate full sunlight so shading is not necessary. Photoperiodic lighting is required to keep the seedlings actively growing. Turn on the carbon dioxide generators as soon as the primary leaves develop and set it to come on about 4 hours before sunrise.

Rapid Growth Phase: After the seedlings are well established in the container. the day temperature range can be increased to 24 °C (75 °F) to 32 °C (90 °F) to promote multiple flushing. Bur oak grows in a series of up to 4 flushes of similar height. The relative humidity should also be kept high to minimize moisture stress. As the leaves increase in size. irrigation will become more difficult because a high percentage of the applied water is intercepted and never makes it into the growing medium. Therefore. the duration of each irrigation and the number of irrigations per week must be increased accordingly. Although it is simplest to wait to irrigate until the foliage begins to wilt, monitoring the weight of the containers is the easiest way to keep the growing medium in the ideal moisture range. Fertigate with a high nitrogen (200 ppm) but well-balanced fertilizer solution twice per week to keep all essential mineral nutrients at optimum levels.

Hardening Phase: As the individual containers of seedlings reach their target height, they are moved to the shadehouse in late summer. Removing these larger plants also opens up the canopy and makes irrigation easier. All seedlings will have been moved by mid-August to begin hardening under ambient conditions. The seedlings should be placed on raised benches to continue encouraging air pruning of the roots. The change to lower humidity and natural photoperiod will help trigger the hardening process but you also should switch to a hardening fertilizer formula with a reduced nitrogen level of around 50 ppm. This should be applied as long as day temperatures are above freezing and the root plugs remain unfrozen.

Harvest Date: Late October

Storage Conditions: Seedling are extracted from the containers and grouped with the rootballs wrapped in cellophane. The bunches of seedlings are placed in a cardboard box with a polyethylene **bag** liner, and the boxes moved to freezer storage at -4 to -6 oC (20 to 25 F).

Storage Duration. The oak seedlings will remain in freezer storage until shipment the following Spring. One week prior to shipping. the temperature in the freezer should be raised to 2 to 5 °C (35 to 40 °F). Individual boxes can be removed from the freezer and thawed at ambient temperatures for quick shipping orders.

Propagator:

Roy Laframboise
Towner State Nursery
HC 2. Box 13
Towner, ND 58788

History Plots as an IPM Tool

One of the basic requirements of a successful integrated pest management (IPM) program is monitoring your crops so that you can detect potential pests before they can become a serious problem. In the July, 1996 issue of FNN we discussed scouting techniques and in this issue I'd like to introduce history plots, which I feel can be an excellent IPM tool.

History plots are permanent monitoring plots that are established in sections of seedbed or in a group of containers at the time of sowing. Although history plots can serve many purposes in a nursery, one of their best uses is to detect and diagnose the causes of poor seedling growth and mortality. The design of a history plot is unique in that it features a paired-plot design which permits destructive sampling **(Figure 11).** Non-destructive, repetitive measurements such as live seedling counts and shoot measurement can be made throughout the crop cycle in Subplot A, whereas one-time destructive measurements involving seed and seedling excavation are done in Subplot B. In bareroot nurseries, history plots should be laid-out with the subplots side-by-side in the same seedbed with a narrow buffer zone between them. The subplots should extend across the full width of the seedbed to eliminate any possible variation between seed rows. The same concept can be applied to container nurseries; for example, one half of a styroblock could be designated as for destructive sampling and the other used for long-term monitoring.

The ability to excavate sown seeds is an essential feature of the concept. Although the approximate number of seeds that are sown per area of seedbed or container cavity can be estimated from sowing calculations, the only way to really know if to count them directly. Small seed can be difficult to locate and separate from the soil in bareroot beds, but coloring the seed coat has made this job much easier. Fluorescent powders are easy to apply to seeds and, because they are organic, do not interfere with germination (If you are interested, the address for the Day-Glo company is listed in Sources at the end of this article). Once the sown seeds are counted, they can be replanted in the container or seedbed. If they are carefully sown at the same depth, they will germinate and emerge normally. Container nurseries have a real advantage in that the sown seed can more easily be extracted and resown in the destructive sampling subplot.

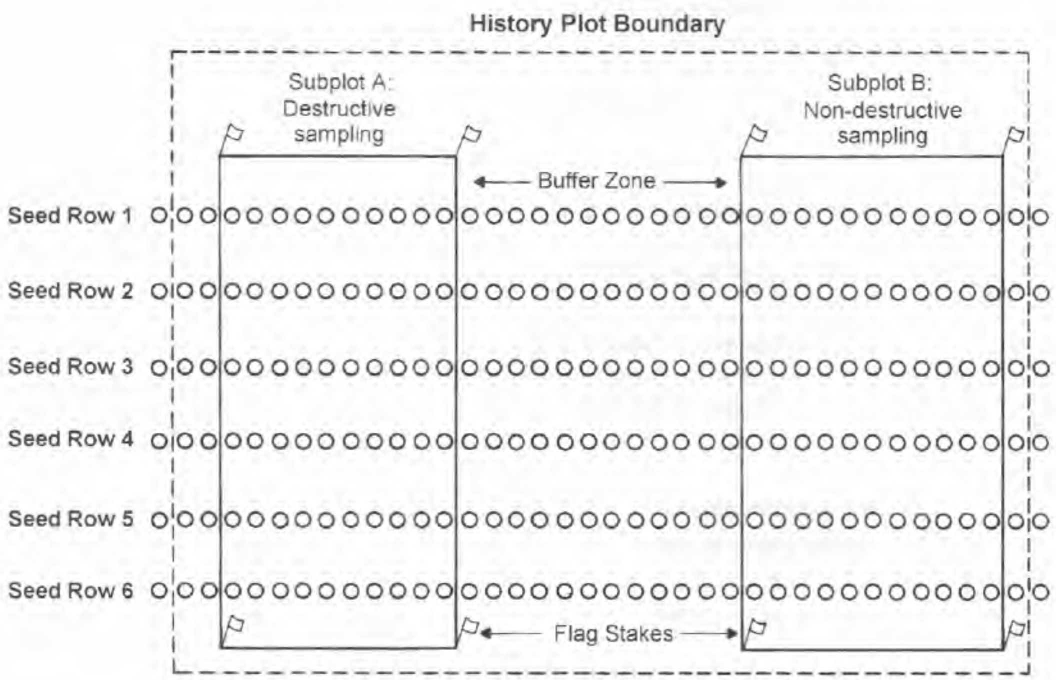


Figure 11. History plots feature a paired-plot sampling design so that destructive sampling can occur immediately adjacent to, but not disturb, the non-destructive long-term monitoring plot.

Table 4. Types of Integrated Pest Management (IPM) monitoring information that can be obtained with history plots

When to Monitor	***Type of Monitoring***	***Use in IPM***
	Subplot A: Destructive Sampling	
Post-sowing	Actual seed sowing density	True measure of potential seedling population
	Examination of ungerminated seed	Dormant or dead seed Pre-emergence damping-off
During growing season	Examination of root systems	Root rot: mycorrhizal inoculation
	Destructive seedling sampling	Development of growth curves, including root system; Seedling nutrient analysis
Prior to harvest	Destructive seedling sampling	Actual shippable seedling yield
	Subplot B: Non-destructive sampling	
Post-emergence	Seedling establishment	Actual causes of early seedling loss such as post. emergence damping-off
During growing season	Seedling growth data	Normal seedling growth rate curves; evidence of stunting
	Seedling injury and mortality during growing season	Actual causes of loss
	Entire History Plot	
During growing season	Weather station	Documented incidents of climatic damage
	Soil pathogen analysis	Diagnosis of root diseases; Effectiveness of fumigation or other pesticide treatments

History plots should be monitored at regular intervals beginning immediately after sowing and continuing until harvest **(Table 4).** The fate of the sown seed and emerged seedlings can be determined during each visit. After emergence is complete, the destructive plot can be sampled for ungerminated seed which can be bisected to determine if the seed is dormant or diseased (Figure 12). Decayed seed gives a direct and accurate measurement of pre-emergence damping-off, a statistic which could only be estimated by normal monitoring. Dead seedlings should be recorded and then removed during each visit to avoid possible confusion as to when the loss occurred. Damaged seedlings can be marked with colored toothpicks to see if they die between the monitoring visits. Close-up photographs during each visit will great aid in the diagnosis and, when viewed in sequence at the end of the growing season, present an excellent visual chronology of crop development. The history plot area can also be equipped with weather recording data which can be most useful in determining microsite conditions and cause of weather injury. Soil samples can be collected at the history plot locations during the growing season and analyzed for pathogen populations. This information can prove most useful in determining the efficacy of soil fumigation and other subsequent soil fungicide treatments later in the growing season **(Table 4).**

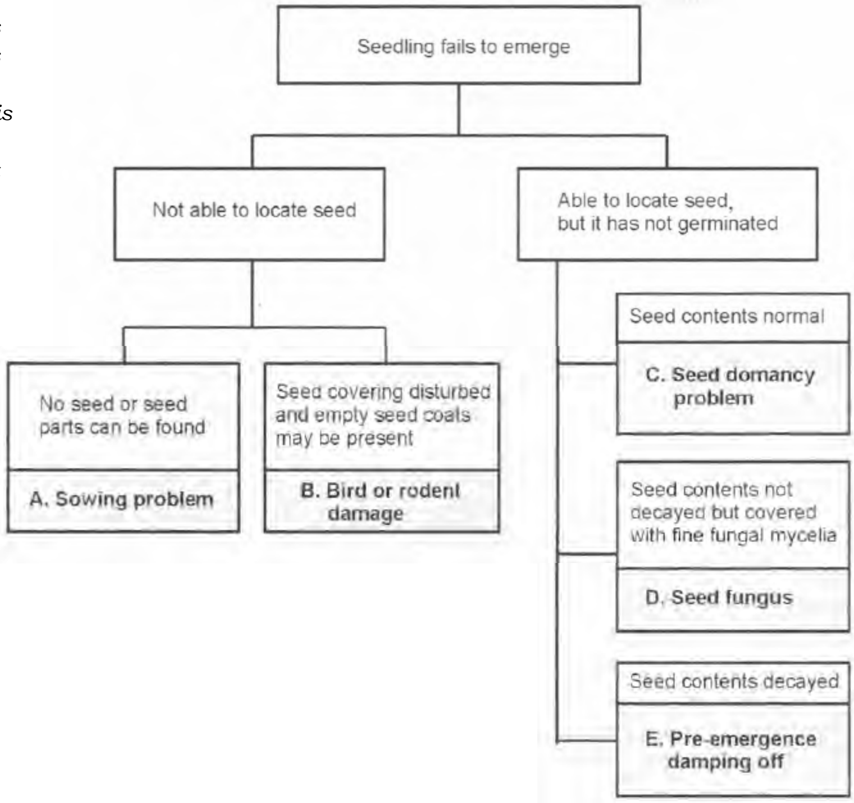


Figure 12. Excavating seed from the destructive subplots allows diagnosis of problems that occur prior to seedling emergence; for example, this is one of the only ways to distinguish between dormant seed and pre-emergence damping-off

One of my very first assignments after starting to work in nurseries was to determine what was causing severe seedling losses at a bareroot nursery. The nursery manager was complaining of irregular seedbed densities and high cull rates, but was unable to determine the exact cause and timing of these losses. So, we established a series of history plots in the seedbeds and monitored them throughout the growing season. Careful observations showed that the vast majority of the loss was occurring during the first few weeks of the growing season **(Figure 13a).** These close-up evaluations also revealed that bird predation was a major factor. The smaller-seeded *Engelmann spruce* was entirely consumed and so the true extent of this predation would not have been documented without the knowledge of the actual seed density from the destructive subplot sampling. Damage to the larger seeds of ponderosa pine were easier to diagnose because the germinants were clipped as soon as they emerged from the soil (Figure 13b). These terminally injured seedlings quickly dried-up and were not evident after a week or so.

Soil tests were also collected within the history plots and analyzed for the presence and population trends of the pathogenic fungi *Fusarium* spp. and *Pythium* spp. High levels of these pathogens along with the examination of the excavated seed showed that both pre-emergence and post-emergence damping-off were also common. Without the information from the history plots, the true cause of the seed and seedling losses would never have been known. In this nursery. the first seedling counts are not made until the first year inventory and, by that time, it was impossible to determine what happened to any missing seedlings.

Another useful application of history plots is for nurser) problem solving. Installing history plots in particularly troublesome areas of the nursery or in species or seedlots of unknown quality can be quite revealing. Without the focused perspective provided by history plots, nursery managers are often unable to determine the specific causes of seed and seedling losses.

So, I think that you can see that the history plot technique has many applications in forest and conservation nurseries and provides an excellent way to monitor seedlin g development and diagnose the true cause of injury and mortality. Although it is usually too late to do any corrective treatment during the first season, this information can show what types of controls are needed and when is the best time to apply them.

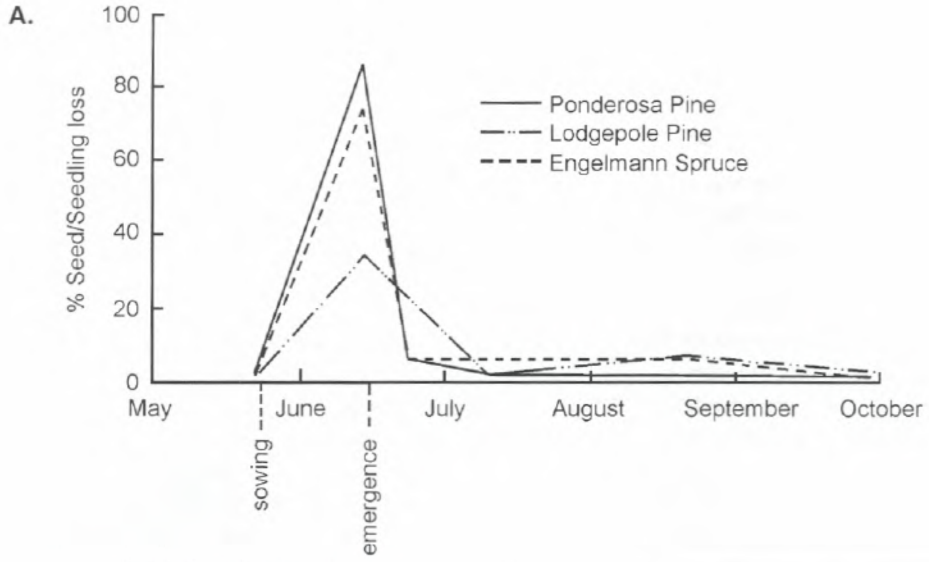


Figure 13. Careful monitoring of history plots revealed that the vast majority of seed and seedling losses were occurring within the first few weeks of the growing season (A), and that the cause was damping-off and bird predation (B).

Sources:

Belcher, E.W. Jr. 1964. The use of history plots in the nursery. Tree Planters' Notes 64: 27-31.

Day-Glo Color Corporation - Tel: 216/391-7070; Fax: 216/391-7751. WWW: www.dayglo.com. E-mail: dayglo@dayglo.com

Landis, T.D. 1976. An analysis of seed and seedling losses at Mt. Sopris Tree Nursery. Biological Evaluation R2-76-18. Lakewood, CO: USDA Forest Service, State and Private Forestry. 7 p.

Landis, T.D.; Karrfalt, R.P. 1987. Improving seed-use efficiency and seedling quality through the use of history plots. Tree Planters' Notes 38(3): 9-15.

Landis, T.D.; Tinus, R.W.; McDonald, S.E.; Barnett, J.P. 1989. The biological component: nursery pests and mycorrhizae, Volume Five, The Container Tree Nursery Manual. Agric. Handbk. 674. Washington. DC: USDA Forest Service, 171 p.

Health and Safety

Preventing Heat Stress

It's that time of the year when nursery workers are exposed to long hours in the sun. and are therefore at risk to a number of heat-related illnesses **(Table 5).** Heat stress is a function of environmental conditions and personal condition. There are four environmental factors that contribute to heat stress: air temperature, humidity, wind velocity, and radiant heat. People vary in susceptibility to heat with age, gender, weight. physical condition, medical history, and degree of acclimation.

Controlling heat stress is the common responsibility of the nursery manager and the workers. A comprehensive heat safety program should consist of eight steps:

1. **Assign responsibility—Make** sure that someone takes the lead in the program. Ideally, one field worker should be appointed a safety coordinator and receive special training, but everyone should he taught to look out for each other.

2. **Hold seasonal** training—All new workers, and especially supervisors, should be trained in the recognition, prevention, and treatment of heat-related problems. Refresher courses should be given at the beginning of each season and work crews should be reminded with periodic tail-gate sessions and posters.

3. **Acclimatize workers—** The human body need time to adapt to working in the sun and heat, and this is particularly important for new hires. Acclimatization is a physiological process where the body adapts to the type of work and ambient heat levels, improving the circulation system and salt balance. It usually takes about two weeks, although individuals acclimatize at different rates. Everyone, regardless of their age or physical condition needs time to acclimate to heat, so don't assume that someone in good physical shape will naturally he more heat tolerant.

4. **Adjust for weather conditions and type of** work—Work assignments should take into account weather, workload. the physical condition of the worker, and if special protective clothing will be worn. Watch weather forecasts and monitor conditions at the work site. and then adjust the job accordingly. Assign tasks based on ability, acclimatization, and general health. Adjust work times to cooler hours and postpone strenuous jobs during unseasonably hot weather. Schedule or modify pesticide application methods to account for high temperatures. Schedule frequent water and rest breaks and provide shade.

5. **Establish a drinking water program—** Dehydration is the primary cause of heat-related illnesses, so replacing water loss through sweating in the single most important factor of a heat safety program. Water is physiologically important for two reasons. We all know that sweating is an evaporative process which cools the skin, but dehydration also strains the circulation system. The human body contains about 5 quarts (4.7 1) of blood (mostly water), which helps cool the body by conducting heat produced by the muscles to the skin surface. The amount of water that is needed to prevent dehydration varies between individuals, and is affected by temperature, humidity, and the type of work. An average person requires 6 to 10 quarts of water on a hot summer day. Thirst is not a good indication of when or how much to drink because the sensation of thirst always lags behind the physiological demand for water. Workers should he trained to drink some extra water before starting the job and then drink "by the clock"—at least one cup of water every 30 minutes under average conditions **(Figure 14).** Water temperature should be cool but not cold, and plain water is generally preferable to other types of liquid, including sports drinks.

6. **Make proper clothing a condition of employment—**Encourage workers to wear light-colored. loose weave cotton garments and especially to wear hats or visors. Provide special cooling clothing if necessary. Special cooling vests and sweat bands are now available and are particularly effective when chemical resistant suits must be worn. The Cool Clothes ™ company manufactures a line of clothing that contains water-absorbing copolymer gels that help keep you cool through evaporation **(Figure 15).** If the garments are soaked in water for 10 to 30 minutes, they will provide cooling relief for hours or even days (For more information. contact the company at Tel: 757/496-9050; Fax: 757/496-9061).

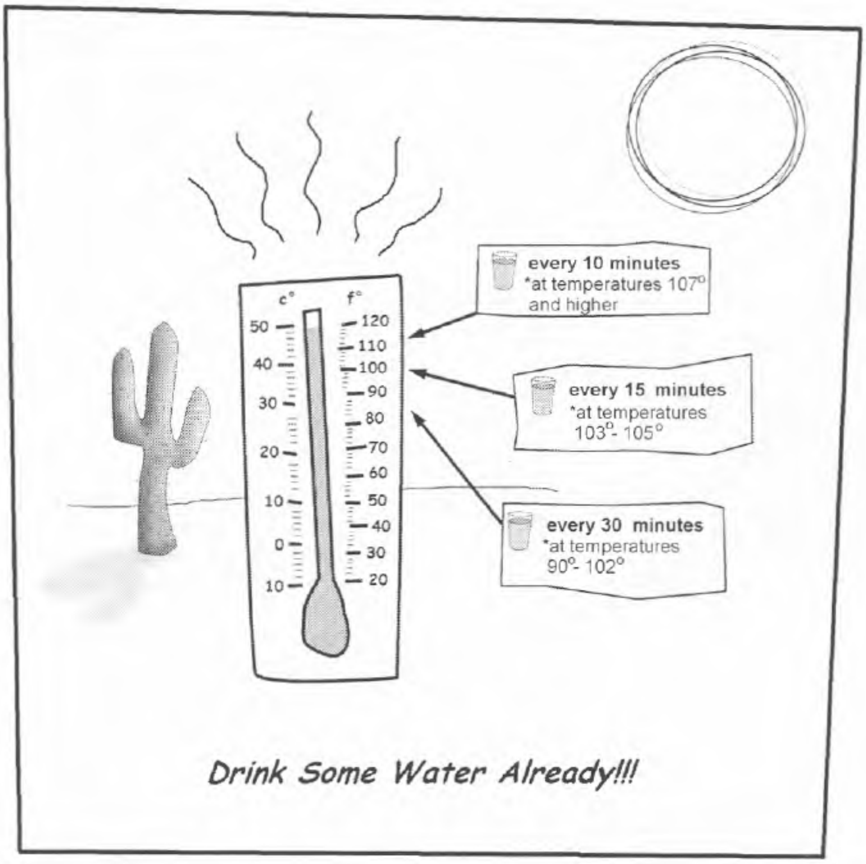


Figure 14. Humans cannot be acclimatized to need less water when working under hot conditions, and the average worker requires 6 to 10 quarts of water on a hot summer day. The rate of water consumption should increase with temperature.

7. **Give first aid quickly—All** workers should be trained to recognize the first symptoms of heat stress in themselves and their fellow employees **(Table 5).** Under hazardous conditions, nobody should work alone and employees should utilize a buddy system to look out for each other. Supervisors or safety officers must take quick action whenever symptoms are noticed and document all incidents, however minor, in writing. Workers must understand that asking for aid is encouraged and that they will not be penalized.

Safety Posters—The US Environmental Protection Agency has developed an informative poster called "Controlling Heat Stress Made Simple" that provides basic instructions for prevention as well as signs, symptoms, and treatments for heat-related illnesses. They can be purchased through the Government Printing Office for only $1.25. Contact them at Tel: 202/512-1800 or Fax: 202/512-2250, and request document #055-000-00544-3.

The "Horticultural Health—Heat Stress" poster contains much of the same information but is printed on tear-resistant, water-repellent Tyvek paper that will hold-up well around the nursery. They are available for $9.95 + 4.95 (S&H) through Blue Crab Press (Tel: 757/496-9050; Fax: 757/496-9061)

Figure 15. New types of clothing, such as these head bands, are now available to help keep you cool when working under hot conditions (courtesy of Cool Clothes, Inc.)

Source:

Appleton, B.L. 1996. Dealing with heat stress in the nursery industry. Nursery Management & Production 12(7):59-60, 63-65.

OSHA. 1993. A guide to heat stress in agriculture. Pub. No. EPA-750-b-92-001. Washington, DC: U.S. Environmental Protection Agency. 44 p.

Table 5. Types of heat-related illnesses, their diagnosis and treatment.

Type of Illness	Signs and Symptoms	Cause and Problem	Treatment
Mild Heat Stress	+Dizziness, fatigue, or irritability with decreased concentration and impaired judgement	Reduced blood flow to the brain	* Loosen clothing * Rest in shade * Drink water
Heat Rash ("prickly heat")	+Tiny, blister-like red spots on the skin with prickling or itching. +Common on clothed areas.	Plugged sweat glands become inflamed	" Wash skin and apply lotion or corn starch A See physician if rash persists.
Heat Cramps	+Heavy sweating; painful spasms of legs, arms, or abdominal muscles; can occur after strenuous work	Loss of electrolytes during heavy perspiration	* Loosen clothing * Drink lightly salted liquids or sports drinks * Massage affected muscles
Heat Exhaustion	+Profuse sweating, fatigue, headache, dizziness, nausea, chills, fainting +Pale, cool skin; excessive thirst, dry mouth; dark yellow urine. +Fast pulse, with body temperature from 99.5 to 101.3 °F (38 to 39 °C)	Dehydration, especially without proper acclimatization. Reduced blood flow to brain. *May lead to heat stroke*	Move patient to shade and make them recline and rest * Loosen and moisten clothing, and fan to cool body * Encourage patient to drink water, *but do not give salt* *A If patient becomes unconscious, treat for heat stroke*
Heat Stroke ** Life-threatening Emergency "*	+Often develops suddenly. +Headache, dizziness, confusion, incoherent speech, irrational or aggressive behavior. +Sweating may decrease or even stop. +Body temperature of over 104 °F (40 "C)	Sustained exertion in heat, especially without proper acclimatization. Temperature-regulation system of body fails. Risk of permanent damage to internal organs	" Move patient to shade and wrap body with wet cloth and fan to cool. * Treat for shock by elevating legs * Transport immediately to medical treatment facility * Encourage patient to drink water, *but do not give salt*

Helping Hands

Nursery work means hand labor. The hands of you or your crew are in frequent contact with soil, growing media, fertilizers and other chemicals that suck the moisture right out the skin. Long hours in the sun and wind accelerate the problem as does the need to frequently wash your hands after exposure to fertilizers and pesticides or before breaks and lunch. Our skin contains natural oils that keep it moist and pliable but this natural protection is quickly lost during routine nursery tasks. The result is a condition called eczema with symptoms of inflamed skin which itches and often develops small spits and cracks, especially around the nails. These cracks only get worse with time and can become very painful and annoying; in extreme cases, your hands can become infected.

Many people think that rough, dry hands are an unavoidable hazard of working in a nursery but that's not true. A few simple precautions and treatments can protect the skin on your hands and make nursery work even more enjoyable:

* ***Wear gloves—the*** best treatment is prevention, so get in the habit of wearing gloves whenever you do hand labor. Yeah, I know—you don't like wearing gloves because you lose dexterity and the "feel" that makes many tasks quicker and easier. Good habits must be learned and so, as the commercial goes —"just do it". There are several types of gloves available so select the most appropriate kind. Cotton gloves are cheap and good for general purpose work, and special gloves without fingertips aid dexterity for sensitive tasks. Many workers prefer leather gloves when operating equipment or during repetitive use of hand tools because they offer greater protection and last longer. And, of course, use the recommended rubber or plastic gloves whenever handling chemicals, especially pesticides.

* *Use moisturizers—You* need to rehydrate your skin frequently when working in the nursery, especially after you wash them. Hand creams or ointments are better than lighter weight lotions and oils. Moisturizers containing petrolatum, glycerin, or lanolin are best and some brands are specially formulated with humectants that give maximum protection against drying. Be sure to work moisturizers into the area around the nails. If your hands are already badly damaged, soak your hands in warm water and apply petroleum jelly or bag balm and cover with light cotton gloves before going to bed.

Figure 16. Dry skin splits and small cuts heal quickly and do not become infected when fused together with a small amount of epoxy (courtesy of NM Pro Magazine and Bonnie Appleton).

* *Repair skin cracks—Those* annoying small splits that develop around your nails or any small cut can be easily and quickly healed by fusing them together with epoxy glue **(Figure 16).** Clean the area first and remove any rough areas with an emory board. Apply a small amount of epoxy and hold the two sides together for a few minutes until they are joined. A little final buffing with the emory board and even the most stubborn skin cracks will be healed within a few days.

Source:

Selden. S.; Appleton, B. 1997. Hand and foot care for nurserymen. Nursery Management and Protection 13(3):36-38, 40-41.

LUSTR Co-operative, Inc.

Mission

To determine and execute research priorities and provide technical guidance, scientific liaison and support services for those involved in container seedling production and plantation establishment.

Brief Historical Background and Current Programs

In the late 1980's, Ontario tree seedling growers received regional funding from the provincial government for the provision of technical services. The Thunder Bay Tree Seedling Growers Association used this money in 1988 to create a technical services operation. under the direction of James Reid, of Inno-Tec. In 1991, this service was teamed with the research efforts of Dr. Ladislav Malek, at Lakehead University, to form the "Lakehead University Seedling Technology, Research and Extension Co-operative" (LUSTRE Co-op).

By 1992, the "E" had been dropped from the Co-op's name and, when the growers' money had been fully used, they met to discuss the formation of a new and broader based co-operative, encompassing the needs of both growers and stock users. The organization would be registered, non-profit, self-funded and would provide research and extension services to its members. As of September 17, 1993, the Co-op was legally incorporated under the name "LUSTR Co-op Inc" **(Figure 17).** This name is not an acronym, as the head office is no longer located at Lakehead University. We continue, however, to maintain strong contacts within the university and access many of their services. Although the head office is located in Thunder Bay, Ontario, LUSTR Co-op is a national organization. Currently, LUSTR Co-op members include tree seedling growers, timber companies, tree plant contractors, associated supply companies and researchers from across Canada. LUSTR Co-op is privately funded, but government and university representatives sit on the Board of Directors.

Staff

LUSTR Co-op has contractual agreements with two consultants, Dr. Irwin Smith and Karen Watt, MSc. to carry out the aims and objectives of the Co-op. Irwin serves as the Administrative and Research Director, while Karen is the Research Scientist.

Figure 17. The LUSTR Co-op is a nursery cooperative that provides applied research and technology transfer services to container seedling growers across Canada.

Co-operators

LUSTR Co-op has nineteen members, consisting of 11 tree seedling growers in Ontario and Manitoba, 3 timber companies, 1 tree plant contractor, and 4 allied supply companies. Membership is open to anyone involved in seedling production or plantation establishment anywhere in the world, and includes Active, Associate, and Honorary Memberships. Seven members serve on the Board of Directors, for one year terms, as elected by the members-at-large.

Research

LUSTR Co-op has an active research program, which is designed to involve the membership as much as possible. Rather than focusing on "in-house" research at the LUSTR Co-op office, our approach is to run trials at members' nurseries and in members' forest management areas. Projects are undertaken which are of interest to the larger membership, however, individuals may fund proprietary trials, provided that the results are made available to the entire Co-op. Work completed thus far has explored seed priming, root egress of seedlings in different soil types, chlorophyll fluorescence, HPLC analysis of pigments, ebb and flow production of containerized tree seedlings, stock quality assessments, wetting agents, chlorine as an algicide, copper root pruning, slow release fertilizers, calcium nutrition and mycorrhizal inoculation of black spruce seedlings.

Technology transfer

Technology transfer is almost as important as research to LUSTR Co-op members. Due to the enormous geographical distances between members, the Co-op's office acts as a distribution center for information. All research is compiled in reports, available upon request to the membership. A bi-monthly newsletter is published which summarizes current research results, LUSTR Co-op business, conference proceedings and upcoming meetings. Advertising space and subscriptions are available through the LUSTR Co-op office. A January conference, held in conjunction with our Annual General Meeting (AGM), and a summer workshop are held annually to allow open interaction between the members, industry, government and scientists. Visits arc made to the members periodically by Irwin and/or Karen to better address their needs.

Program Development

Research priorities are discussed every year at the AGM and are under the direction of the Research Committee. In order to expand the knowledge base, expertise and funds of LUSTR Co-op, increased membership is one of the Co-op's main goals. Irwin and Karen are encouraged to attend international and national meetings in order to increase awareness of LUSTR Co-op and its work and to pass along information to the members.

For more information on LUSTR Co-op, contact:

Irwin Smith or Karen Watt

LUSTR Co-op

640 Balmoral Street

Thunder Bay, Ontario P7C 5G9

CANADA

Tel: 807/623-1397

Fax: 807/623-4271

E-mail: lustr @baynet.net

WWW: http://www.baynet.net/–lust

SNTI Home Page:

"willow.ncfes.umn.edu/snti/snti.htm"

We continue to work on the Seedlings, Nurseries, and Tree Improvement (SNTI) home page, adding information and improving the content. In fact, it will have changed again by the time you read this. If you haven't visited us yet, I thought that I would give you a brief overview of what you will find when you reach our home page. The first panel that you will see **(Figure 18)** lists the 6 major sections, each with it own "button" represented by a tree seed. Click your mouse on these buttons and you will go to the following:

The Seedling, Nursery and Tree Improvement (SNTI) Program

This section lists our objectives in creating the home page, tells who we are, what geographic areas we serve, and what services we provide **(Table 6).** You will see that some of us have our E-mail addresses highlighted in blue, which means that you can send us a self-addressed memo by just clicking on the address.

Forest Nursery Notes—News and Information Service

This section lists the last several issues of FNN and a link called "Search the Forest Nursery Reference Database". Click on the January, 1997 issue and you'll go to the cover page (which looks just the same as the hard copy) and, when you click on "Table of Contents", you can go anywhere in the issue. We're also going to include a Literature Order Form so that you can order articles from any of the recent issues. We hope to publish the July, 1997 issue in a few weeks, and eventually to have all past FNN issues on-line.

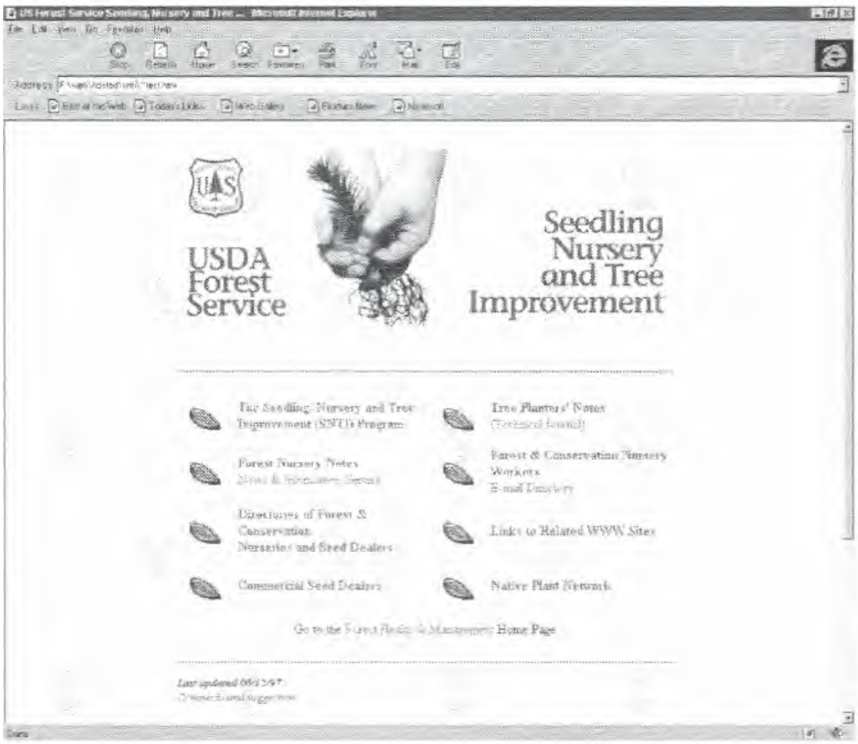


Figure 18. The Seedlings, Nursery, and Tree Improvement home page contains a listing of technical services, including Forest Nursery Notes.

If you choose "Search the Forest Nursery Reference Database", you can do a literature search of the FNN database which currently contains almost 8.000 articles that have been listed in past issues. Instructions for ordering articles is also included.

Directory of Forest & Conservation Nurseries

Our intent in this section is to maintain an up-to-date listing of all the nurseries in the US. We started by posting all the information that is currently in the national nursery directory - "Directory of Forest and Conservation Tree Nurseries in the United States - 1994 edition". We've arranged the statistics by State or Territory, so you can either click on the postal abbreviation for your State or on the State itself on the US map **(Figure 19).** The information is presented in a table that includes Nursery Name and Address, Ownership Type, Stock Type, and Current and Potential Seedling Distribution. For those nurseries with E-mail addresses and Home Pages, these also will be listed so that customers can contact them on-line. Write, FAX, or send an E-mail message to Aleta or Tom if you would like to list your nursery, update your listing, or add an E-mail or Home Page link - our addresses are provided on the inside cover.

Commercial Seed Dealers

When it is finished, this section will contain the same information that is in the national seed dealers' directory - "Commercial Suppliers of Tree and Shrub Seed in the United States" (1995). Seed dealers are listed alphabetically along with reference codes that will allow the user to check which species of seeds that they carry. As with the nursery directory, customers will be able to link directly with those dealers who have E-mail addresses and Home Pages. Contact us if you would like to be added.

Tree Planters' Notes—Technical Journal

This section will eventually contain the latest issues, but currently features a form for ordering TPN.

Forest & Conservation Nursery Workers—E-mail Directory

The intent of this section is to allow browsers to contact people working in forest and conservation nurseries or research facilities. To add your name, send your E-mail address to us by FAX, snail mail, or you just click on "Send the URL (address) to us" if you want to send us the information to us on-line. Eventually, we hope that this directory will serve as a central reference point to facilitate E-mail communication.

Figure 19. Addresses and production information about forest and conservation nurseries can be accessed on the Seedlings, Nurseries, and Tree Improvement home page by clicking on the State postal code on the US map.

Links to Related WWW Sites

This section contains listings of forestry-related World Wide Web (WWW) home pages. For now, we've just listed them in alphabetical order but will eventually work out some more rational organization. If you would like to list your nursery or company web page, click on "Send the URL (address) to us" link or mail or FAX the information to us.

Native Plant Network

The Native Plant Network is a new service through which we hope to encourage growers to share information about how to propagate native plants. We have designed a Propagation Protocol form which contains information on the entire propagation process. An example is given for bur oak *(Quercus macrocarpa),* and we encourage you to download the blank form and submit it with information on any natives that you are growing. Note that you can also include graphics, so if you have good photos or slides of your seedlings, send them and we'll try to scan them. We will review the information and then post it to this location, giving credit to you. If you would like to correct or add propagation information about any of the listed species, send that to us also. (See the "Propagating Native Plants' section in this issue for more discussion).

Table 6. Contact list from Seedlings, Nurseries and Tree Improvement (SNTI) Home Page

Technology Transfer Services	Region of Responsibility	Who To Contact
Technical Assistance about Forest and Conservation Nurseries Forest Nursery Notes Container Tree Nursery Manual Proceedings of Nursery Meetings	US and International	**Tom D. Landis** USDA Forest Service Cooperative Programs PO Box 3623 Portland. OR 97208-3623 Tel: 503-808-2344 Fax: 503-808-2339 E-mail: *nurseries@aol.com*
Technical Assistance about Tree Improvement and Genetic Resources Technical Assistance about Forest and Conservation Nurseries	US and International Southeastern US	**Clark Lantz** USDA Forest Service, Cooperative Forestry 1720 Peachtree Road NW, Suite 811N Atlanta, GA 30367 Tel: 404-347-3554 Fax: 404-347-2776
Technical Assistance about Forest and Conservation Nurseries Technical Assistance about Tree Improvement and Genetic Resources	Northeastern US	**Ron Overton** USDA Forest Service. S&PF Forest Resources Mgmt. 1992 Folwell Avenue St. Paul, MN 55108 Tel: 612-649-5241 Fax: 612-649-5238 E-mail: *overt002@maroon.tc.umn.edu*
Technical Assistance about Tree and Shrub Seed	US and International	**Bob Karrfalt** USDA Forest Service National Tree Seed Laboratory 5156 Riggins Mill Road Route 1, Box 182-B Dry Branch, GA 31020 Tel: 912-751-3552 Fax: 912-751-3554
Editor—Tree Planters' Notes	US and International	**Rebecca Nisley** USDA Forest Service 51 Mill Pond Road Hamden, CT 06514 Tel: 203-230-4304 Fax: 203-230-4315 E-mail: *misley@ct2.nai.nei*

Well, that completes the tour of the SNTI home page. Check us out the next time that you are surfing the Web and be sure and let us know of any improvements or additions.

Editorial

The Role of Government Nurseries

"The best government is that which governs least"

—John O'Sullivan

"Government, even in its best state, is but a necessary evil"

—Thomas Paine

Americans have always had a healthy suspicion of government, and that's one of the things that makes our country unique. Lately, however, I've been disturbed by a growing anti-government philosophy which has culminated in the terrorist bombing of the federal building in Oklahoma City. This radical anti-government sentiment also has hit closer to home. Last year, the Detroit Ranger Station of the USDA Forest Service was burned to the ground and other buildings and vehicles vandalized here in Oregon. We can all condemn such extremist measures but the fact is that many, if not most, Americans just do not trust their government.

One of the spinoffs of this anti-government sentiment is the privatization movement which believes that many, if not all, services of federal and state governments should be turned over to private industry. Their basic premise is that private industry can do anything cheaper and more efficiently. I don't agree. I think that there is a place for government in our lives and that federal and state nurseries have a role. The problem is: defining that role in our changing society.

A Proud History

Before we try to figure out where we are going, it's often helpful to look at where we have been. In the US, the first forest and conservation nurseries were established by the federal government almost 100 years ago. The USDA Forest Service started the Bessey nursery in 1902 to provide seedlings for the afforestation of the Nebraska Sand Hills **(Figure 20).** Out on the West Coast, the Wind River Nursery was started in Washington in 1906 and the Savenac Nursery in Montana in 1909 with the primary objective of growing seedlings to reforest after large wildfires and protect watersheds. The federal work programs of the 1930's, such as the Civilian Conservation Corps and the Shelterbelt Project, created the need for more government nurseries. In 1939, the output of Forest Service nurseries was over 136 million trees. As these programs were disbanded, many of these federal nurseries were turned over to the states with the mission of providing quality, low-cost seedlings for forest and conservation projects on state and private land.

Figure 20. Government nurseries have a long history of developing new cultural procedures and equipment (like this "high-tech" undercutting bar at Bessey Nursery) and then sharing this information through technical publications.

Table 7. Cultural techniques and equipment developed in government nurseries have provided the bulk **of the technical information used in forest and conservation nursery manuals in the United States.**

Title	Publication Date	Publisher
Seedling and Planting in the Practice of Forestry	1916	John Wiley and Sons, Inc.
Reforestation on the National Forests	1917	USDA Forest Service
Planting the Southern Pines	1954	USDA Forest Service
Forest Nursery Practice in the Lake States	1957	USDA Forest Service
Conifer Nursery Practice in the Prairie—Plains	1965	USDA Forest Service
Woody Plant Seed Manual	1948	USDA Forest Service
Seeds of Woody Plants in the United States	1974	USDA Forest Service
Hardwood Nursery Guide	1976	USDA Forest Service
Forest Nursery Manual: Production of Bareroot Seedlings	1984	Oregon State University/ USDA Forest Service
Southern Pine Nursery Handbook	1985	USDA Forest Service
Container Tree Nursery Manual	1989 to 1998	USDA Forest Service

Government nurseries also have a legacy of generating technical information about the propagation of forest and conservation plants, and sharing that knowledge through demonstrations, workshops and publications. In fact, the first US nursery manuals were federal government publications. The classic book *Seedling and Planting in the Practice of Forestry* was written by J.W. Toumey of Yale University School of Forestry in 1916. If you check the references and citations, you will find that almost all of the scientific knowledge used to write this book was developed by the US Forest Service or State forestry organizations. Another classic is *Reforestation on the National Forests* which was published as a USDA Bulletin No. 475 in 1917 and shares the accumulated experience from the early federal nurseries. This was followed by a series of USDA Agriculture Handbooks from across the country (**Table** 7). The classic *Woody Plant Seed Manual* (1948) has been republished as *Seeds of Woody Plants in the United States.* A team of Forest Service scientists are currently updating this invaluable reference and it should be ready next year. Since I don't have access to my own nursery, state nurseries arc a primary source of propagation information for the Container Tree Nursery Manual series.

It's easy to see that government has a strong tradition in the forest and conservation nursery business, but what are some of the roles of government nurseries today?

Provide inexpensive seedlings to encourage conservation plantings — Small, private landowners have a need for high quality, source-identified, locally-adapted seedlings and state forest nurseries are supplying this need as well as providing technical assistance after the sale.

* Most states forestry organizations have tree improvement programs and so customers receive seedlings of the highest genetic quality.

* Government specialists provide professional advice to customers on matching the species and seed source to their land, and then follow-through with site preparation services and outplanting advice.

Government nurseries have state-of-the-art storage facilities and a delivery network to assure that seedlings reach customers in top quality.

* Problem solving is provided in the case of poor performance. Government nurseries will guarantee their stock and provide free replacement if the problem is determined to be their fault.

A typical sale to a private landowner is small (as few as 25 seedlings) and most states will make up custom orders of many different species. There is no large profit margin in these sales and so most private nurseries are not interested in such small orders. State forestry organizations also offer a variety of technical services to small, private landowners which would be cost-prohibitive for most private nurseries.

Develop and share information — As discussed earlier, the government has always served as a source of information on how to propagate and plant forest and conservation seedlings. State and federal nurseries always are willing to share what they know. In fact, most consider technology transfer to be one of their primary missions. Many private growers got started with a visit to a government nursery, and others can see the latest technology during demonstration tours and workshops.

The continuing need for these services is becoming apparent with the recent interest in native plant propagation. New information is needed on how to collect seeds or cuttings, treat them to overcome complex dormancy requirements, and raise them in nurseries. Understandably, private nurseries have no incentive to share their propagation secrets and so I feel that the government must step in to provide this service. Sharing this technical knowledge actually helps stimulate competition in the private nursery sector by allowing new growers to get started (see the propagation protocol example in Propagating Native Plants section in this issue).

Working Together

The controversy about privatizing government nurseries has been going on for some time **(Figure 21).** It was the subject of a group discussion at the Intermountain Forest Nursery Association meeting in 1987. The groups discovered that the situation varies considerably across the nation and concluded that the issue needed to be resolved by promoting better cooperation and communication on a regional basis. Unfortunately, the negotiation process can take time and sometimes get politically complicated. For example, the Wisconsin Department of Natural Resources is working together with representatives of the Wisconsin Nursery Association and other interested parties to develop an agreement on the future role of their state nurseries. Based on these discussions, a memorandum of understanding (MOU) was developed, but the Wisconsin Department of Justice ruled that it potentially violated the Sherman Anti-Trust Act since it mentioned production quotas. Everyone is hopeful that the MOU can be modified so that everyone can support it. Similar negotiations have prevented conflict in other states which just proves that any obstacle can be overcome if everyone agrees to work together.

I realize that much of my justification for government nurseries is historical in nature, and I'm willing to admit that things are changing. However, I still think that federal and state government nurseries have a role to play in the management of our natural resources. I hope that this editorial will stimulate the dialogue to determine just what that role should be.

Sources:

Landis, T.D. 1987. Government vs. private nurseries: the competition issue. IN: Landis, T.D. tech. coord. Proceedings, Intermountain Forest Nursery Association. August 10-14, 1987: Oklahoma City, OK. Gen. Tech. Rep. RM-151. Ft. Collins. CO: USDA Forest Service, Rocky Mountain Forest and Range Experiment Station: 126-129.

Marty, T. 1997. Personal communication. Madison, WI: State of Wisconsin. Dept. of Natural Resources.

Tourney, J.W. 1916. Seed and planting in the practice of forestry. New York: John Wiley and Sons. 455 p.

Figure 21. This political cartoon from the Sacramento Bee newspaper on April 4, 1941 shows that the government-private nursery competition issue is nothing new.

How to Become a Better Bureaucrat

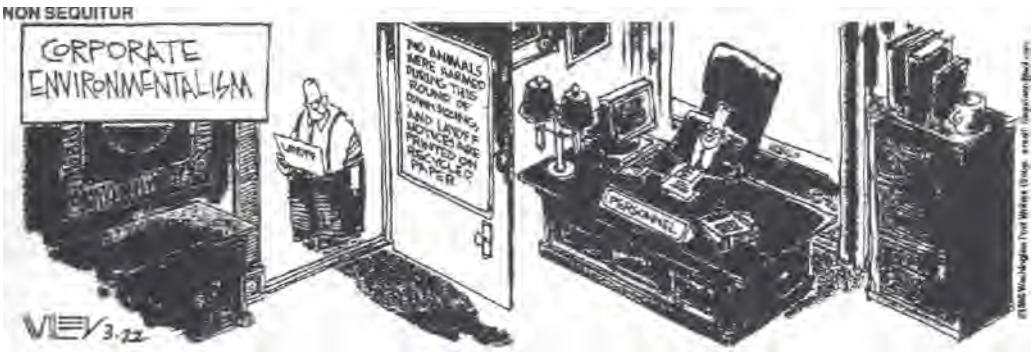
A "training guide" for new government staffers is circulating in Washington, DC, and contains the following helpful hints:

- An honest answer can get you in a lot of trouble
- The facts, although interesting, are irrelevant
- Truth is a variable
- "No" is only an interim answer
- You can't kill a bad idea
- If at first you don't succeed, destroy all evidence that you ever tried
- A porcupine with his quills down is just another fat rodent

Source:

Kamen, A. 1997. In the Loop. Washington, DC: Washington Post (May 26, 1997)

I know that it's mean to pick on bureaucrats so I'll let Dilbert do it for me:



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Special Orders

The following publications are either too long or too expensive for us to provide free copies, but prices and ordering instructions are given here and following the individual listings in the New Nursery Literature Section.

SO. Arnott, J.T.; Colombo, S.J.; D'Aoust, A.L..; McKay, 1-1.M.; Noland, T.L.; Odlum, K.D.; Parker, W.C. 1997. **Making the Grade.** New Forests 13:1-3 (Special Issue). Dordrecht: Kluwer Academic Publishers. 514 p. ISSN 0169-4286

This softbound book is the proceedings of an international symposium on planting stock performance and quality assessment that was held in Sault Ste. Marie, Ontario, CANADA on Sept. 11-15, 1994. It contains 28 articles organized in five categories: Plant quality assessment techniques; Improvements in nursery cultural practices; Measurement, Improvement, and prediction of field performance; Effects of handling on plant quality; and Operational plant quality assessment programs. This book contains a wealth of information on the many aspects of seedling quality and emphasizes the fact that quality requires continual feedback between nursery managers, seedling users, and researchers (Figure 22). It is an invaluable reference for both nurseries and reforestation specialists.

COST: $ 206.50

ORDER FROM: Kluwer Academic Publishers
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Fax: 617/871-6528
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WWW: http://www.wkap.nl

Figure 22. The summary paper of the Making the Grade symposium proceedings emphasizes the synergy between nurseries, customers, testing facilities, and research and development in improving seedling quality.

SO. Kachadoorian, R.; Cummings-Carlson, J.; McCullough, D.G.; Lantagne, D.O. 1995. **Pesticides for Use in Conifer Nursery Production in the North Central Region.** Extension Bulletin E-2593. East Lansing, MI: Michigan State University. 41 p.

COST: S2.00

ORDER FROM:
Bulletin Office
10 B Agricultural Hall
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SO. Garber, M.P.; Hudson, W.G.; Norcini, J.G.; Thomas, W.A.; Jones. R.K.; Bondari, K. 1996. **Biologic and Economic Assessment of Pest Management in the United States Greenhouse and Nursery Industry. NAPIAP** Report No. 1-CA-19. Athens. GA: University of Georgia, Cooperative Extension Service. 131 p.

This softbound book was developed as a special project of the USDA Agricultural Pesticide Impact Assessment Program (NAPIAP) and covers the period 1988-1993. The information was gathered by means of a national survey of the American Association of Nurserymen and Society of American Florists members. The data is presented in a series of tables with explanatory text. It would be of use to anyone who is interested in which pesticides are being used in ornamental nurseries, and how this use has changed in recent years.

COST: Free

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Tel: 912/386-3410
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E-mail: mgarber@uga.cc.uga.edu

SO. US Environmental Protection Agency.1993. A **Guide to Heat Stress in Agriculture.** Publication No. EPA-750-6-92-0001. Washington, DC: US Environmental Protection Agency. 44 p.

This handy pamphlet is discussed in detail in the "Health and Safety" section of this issue. Ask for Stock number 055-000-00474-9.

COST: $3.50	**ORDER FROM:**	US Government Printing Office 1305 SW First Avenue Portland, OR 97201-5801 USA Tel: 503/221-6217 Fax: 503/225-0563

SO. Reed, D.W. 1996. **Water, Media and Nutrition for Greenhouse Crops.** Batavia, IL: Ball Publishing. 314 p.

This softbound book contains 12 chapters by noted nursery experts including Paul Nelson and Conrad Skimina. Although oriented to ornamental crops, much of the information such as the chapter growing media will be useful for forest and conservation nursery managers.

COST: $55.00 S&H = $5 (US) $15 (Foreign)	**ORDER FROM:**	Ball Publishing PO Box 9, 335 N. River St. Batavia, IL 60510-0009 Tel: 630/208-9080 Fax: 630/208-9350

SO. Hilliker, D.B. Jr.; Hillier, J.M. 1992. **Growing conifer seedlings, transplants, and trees in an outdoor nursery. Book Two.** Elma, NY: Treehaven Evergreen Nursery. 210 p.

This handy, loose-leaf format book is the second in a series that was written for the novice nursery manager. The books are meant to be used as a set, so you should order both volumes if you don't have the first book already. They will be a good source of information for anyone who wants a good "down-to-earth" guide to growing bareroot seedlings.

COST: $20.00 (Foreign = $25.00)	**ORDER FROM:**	Donald Hilliker Treehaven Evergreen Nursery Hilltop Tree Farms 981 Jamison Road Elma, NY 14059 USA Tel: 716/652-4206 Fax: 716/652-0051

SO. Suszka, B.; Muller, C.; Bonnet-Masimbert, M. 1996. **Seeds of Forest Broadleaves from Harvest to Sowing.** Paris, Institut National de la Recherche Agronomique (INRA). 320 p.

This book was originally published in Polish and French but has recently been translated into English. It is based on research from two of the major tree seed laboratories in Europe, and consists of two sections. The first covers general collection, processing, storage, and testing and is followed by the second part which discusses specifics of fifteen common hardwood species. Although some of the species are European, they have closely-related counterparts in North America. Good black-and-white illustration add to its utility.

COST: $65.00
(340 French Francs)

ORDER FROM:
INRA Editions
Route de St. Cyr
78026 Versailles Cedex
FRANCE
Internet: http:/www.inra.fr

SO. Rolfe, C.; Currey, A. Atkinson, I. eds. 1994. **Managing water in plant nurseries.** NSW Agriculture. 163 p.

This softbound book is a comprehensive guide to the obtaining, pumping, treating, and recycling water in container nurseries. Each chapter begins with an explanation of basic concepts, discusses needed equipment, and then goes into how to use this information in your nursery. In addition, the book features color photographs and black-and-white illustrations as well as numerous tables and sample calculations **(Figure 23).**

COST: $60.00
+ $5 S&H

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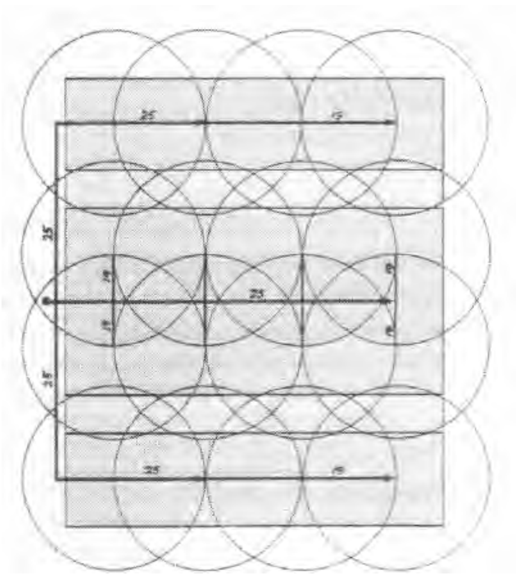

Figure 23. Managing Water in Plant Nuseries contains many useful appendices including schematics for designing sprinkler irrigation systems.

SO. Quarles, W. 1997. **Alternatives to methyl bromide in forest nurseries.** The IBM Practitioner 19(3): 1-14.

This article presents the most comprehensive look at the use of methyl bromide fumigation in forest and conservation nurseries that I have seen. It begins with a look at the nursery industry and the historical need for fumigants and then discusses the possible alternatives to fumigation including other pesticides, soil amendments, solarization and steam pasteurization. A list of suppliers of alternative treatments and materials also is given. This would be an excellent first reference for anyone who is considering fumigation or wants to change their fumigation practices.

COST: 86.50 **ORDER FROM:** Bio-Integral Resource Center
PO Box 7414
Berkeley, CA 94707 USA
Tel: 510/524-2567
Fax: 510/524-1758

SO. Longman, K.A. 1993. **Rooting Cuttings of Tropical Trees.** London: Commonwealth Secretariat Publications. 137 p.

This is the first volume in the series *Tropical Trees: Propagation and Planting Manuals* which is being written for the non-industrial grower. Chapters include genetic selection, stockplant management, collection of cuttings. propagation conditions, culture of cuttings, and record keeping. It is well organized and illustrated with high quality line drawings, and the propagation of over 100 species of tropical trees is referenced. This book will serve well as both a technical reference and training manual.

COST: £12.50
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ORDER FROM: Commonwealth Secretariat Publications
c/o Vale Packaging Ltd
420 Vale Road
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Tel: (44) 1732 359387
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SO. Secret Life of Tree Seeds. Carole Leadem and her co-workers from the British Columbia Ministry of Forests in Victoria have finished a handsome color poster (60 x 90 cm) that features illustrations and fascinating facts about tree seeds from the Pacific Northwest. In fact, it won top award for poster design at a recent Graphic Designers of Canada award on Vancouver Island. This poster will make a welcome addition to any nursery or seed processing facility and is also an excellent education tool for nursery visitors and tours.

COST: Free **ORDER FROM:** Tony Barron
BC Ministry of Forests
PO Box 9528
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Bareroot Production

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2. © *Sowing methods and mulch affect 1+0 northern red oak seedling quality.* Tomlinson, P. T.; Buchschacher, G. L.; Teclaw. R. M. New Forests 13(1-3):193-208. 1997.

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SO. *Growing conifer seedlings, transplants, and trees in an outdoor nursery, Book 2.* Hilliker, D. B., Jr.; Hilliker, J. M. Treehaven Evergreen Nursery, Elma, NY. 210 p. ORDER FROM: Donald Hilliker, Treehaven Evergreen Nursery, Hilltop Tree Farms, 981 Jamison Road, Elma, NY 14059. Phone (716) 652-4206. Fax (716) 652-7776. Price: $20.00 in U.S., $25.00 foreign.

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Example of a Typical Propagation Protocol

Species:

Ecotype:

Outplanting Site:

Outplanting Date:

TARGET SEEDLING INFORMATION

Height:

Caliper:

Root System:

PROPAGATION AND CROP SCHEDULING

Propagation Environment:

Propagation Method:

Source of Propagules:

Pretreatments:

Container Type and Volume:

Growing Media:

Total Time to Harvest:

Example of a Typical Propagation Protocol (continued)

Sowing Date:

Sowing/Planting Technique:

Establishment Phase:

Rapid Growth Phase:

Hardening Phase:

Harvest Date:

Storage Conditions:

Storage Duration.

Propagator:

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