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Pacific
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**Cooperative
Programs**

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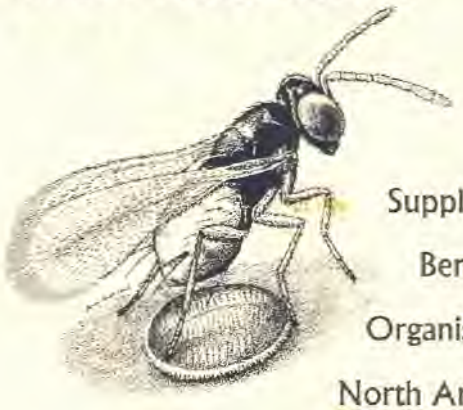
FOREST NURSERY NOTES

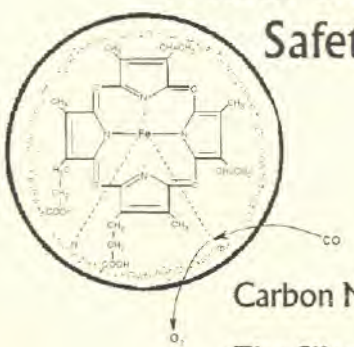
January 1997

New Literature



Suppliers of
Beneficial
Organisms of
North America

Health and
Safety



Carbon Monoxide—
The Silent Killer

Nursery Networks

Auburn Cooperative

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Contents

May the Wonders of Nature Please your Eyes,

and Enrich Your Lives

Well, another year has passed and we're all still here! The FNN staff wants to thank all of you who took the time to write and express your support for our services. The Comment Cards and letters that you mailed to our Washington, DC office really helped, and as evidence, our budget has already been approved for this year. This is a big improvement over the budgetary chaos that we went through last year at this time. FNN was even nominated for a National Technology Transfer award! So, the FNN staff would like to personally thank each and every one of you for your continued support, and wish you and yours the very best during this holiday season and throughout the coming year.

Nursery Meetings

The **Northern Container Nursery Association** will be meeting in St. Paul, MN on the University of Minnesota campus on **January 28-29, 1997.** The morning sessions will consist of a variety of nursery topics by both researchers and growers. The first afternoon will feature a workshop on Diagnosing Seedling Problems and the second will be a field trip to Bailey nurseries. Early registration is encouraged so contact Cindy Buschena immediately if you are thinking of attending. I'll see you there!

Cindy Buschena
University of Minnesota
Dept. of Forest Resources
1530 N. Cleveland Ave.
St. Paul, MN 55108 USA
Tel: 612-624-5327
Fax: 612-625-5212
E-Mail: cbuschen@forestry.umn.edu

The third meeting of the **Southwestern Container Growers' Meeting** will be held on **Feb. 12-13, 1997** at Colorado State University in Ft. Collins, CO. Randy Moench of the Colorado State Forest Nursery and his staff will be our hosts, and we will be touring their nursery during the meeting. John Harrington of the Mora Research Center is coordinating the technical agenda which will include focus topics on Diagnosing Nursery Pests and Cultural Problems, and Innovative Approaches to Propagating Native Plants. We also plan to have a Computer Networking session at the computer laboratory at CSU in which we will discuss ways to use the Internet and World Wide Web. Anyone interested in growing forest and conservation seedlings in containers is invited to attend. Call John for registration information, or give Randy a call for information on local accommodations:

John Harrington
New Mexico State University
Mora Research Nursery
PO Box 359
Mora, NM 87732 USA
Tel: 505-387-2319
Fax: 505-387-9012
E-mail: joharrin@nmsu.edu

Randy Moench
Colorado State Forest Service Nursery
Foothills Campus, Bldg. 1060
Ft. Collins, CO 80523 USA
Tel: 970-491-8429
Fax: 970-491-8645
E-mail: rmoench@lamar.colostate.edu

A half-day symposium on **Using Seeds of Native Species on Rangelands** will be part of the Society for Range Management meeting which will be held in Rapid City, SD on **Feb. 16-21, 1997.** The meeting agenda includes presentations on seed policy, collection and processing, genetics, rare and endangered species, and the seed symposium will be held on the afternoon of Feb. 18. If you are thinking of attending and need more information, contact:

Society for Range Management
1839 York Street
Denver, CO 80206 USA
Tel: 303-355-7070
Fax: 303-355-5059
E-mail: srmden@ix.netcom.com

The **Natural Resource Management Training Program** will be held from **April 7 to 11** and **April 14 to 18, 1997** in Phoenix, AZ. This program is a joint effort between the USDA Forest Service, the USDI Bureau of Land Management, the University of Arizona and other cooperators. The suite of 12 courses will be presented over the two-week period including one on Forest Health Management for Tree Nurseries. For more information, give a call, send an E-mail message, or visit their WWW site:

Training Coordinator
Resource Technologies Institute
2629 Redwing Road, Suite 320
Ft. Collins, CO 80526 USA
Tel: 970-204-1388
Fax: 970-204-1270
E-mail: rt-training@geomatics.com
WWW homepage: www.geomatics.com/rti

An **Integrated Pest Management (IPM) Course for Forest Nurseries** is tentatively scheduled for **July 22 to 24, 1997** in Surrey, BC, CANADA. This course will examine IPM within the context of the following nursery goals: producing high quality seedlings, achieving the desired quantity of seedlings, protecting human health and the environment, and doing all of this economically. In this course, the term "pest" will refer to insects as well as diseases and competing vegetation, and abiotic (such as winter desiccation and heat damage) and cultural problems (such as fertilizer damage) will also be discussed. For more details contact either:

Eileen Harvey
BioForest Technologies Inc.
105 Bruce Street
Sault Ste Marie, ON P6A 2X6
CANADA
Tel: 705/ 942-5824
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CANADA
Tel: 604/930-3302
Fax: 604/775-1288
E-mail: dtrotter@mfor01.for.gov.bc.ca

The **Northeastern State, Federal, and Provincial Nursery Association Conference** will be hosted by Mike Carroll and the Minnesota Dept. of Natural Resources Badoura Nursery during the week of **August 11-15, 1997.** The meeting will be held at the Northern Inn in Bemidji, MN, where the theme will be Plant Propagation Systems in North Central Minnesota: Where Recreation, Agriculture and Forestry Collide. The details of the agenda are still being developed but will feature nursery trials, research updates and field trips to the DNR Badoura Nursery, North Central Minnesota plant communities, and other local forestry attractions. For the latest information, contact:

Mike Carroll
Badoura State Nursery
Rt. 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 Red Lion Riverside Motor Inn in Boise, ID. Dick Thatcher and his staff at the USDA Forest Service Lucky Peak Nursery will be our hosts. The technical agenda is still being developed but will include Focus Sessions on Propagation of Native Plants and Fire Restoration. We will also schedule a General Nursery Topics session so please let us know if you would like to present a paper. A tour of the nursery and the 8 th Street fire rehabilitation area near Boise are also scheduled. For more information on the meeting, contact me or:

Dick Thatcher
Lucky Peak Nursery
HC 33, Box 1085
Boise, ID 83706 USA
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Fax: 208-389-1416
E-mail: /s=r.thatcher/ou 1 =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. The details of the agenda are still being developed but contact Clare Kooistra for the latest information:

Clare Kooistra
BC Ministry of Forests
106-1340 Kalamalka Lake Road
Vernon, BC V1T 6V4
CANADA
Tel: 604-549-5655
Fax: 604-549-5540

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 and I hope to see you there. Additional information can be obtained from:

Wilbur Bluhm
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Salem, OR 97303
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Beverley Greenwell
Program Chairman
Happy Hollow Nursery
36988 Dawson Road
Abbotsford, BC V3G 2L1
CANADA
Tel/Fax: 604-852-4108

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 Bareroot and Container Nurseries, Fertilization after Outplanting, and Monitoring Seedling Nutrition. If you would like to present a paper or just want more information, contact:

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 Conference on Methyl Bromide Alternatives and Emissions Reduction** has tentatively been scheduled for **Nov. 5** -7, **1997** at the Red Lion 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 or just want more information, contact either:

Gary Obenauf
Methyl Bromide Alternatives Outreach
PO Box 5377
Fresno, CA 93755
Tel: 209/244-4710
Fax: 209/224-2610

or

Stan Barras
USDA-Forest Service, FIDR
PO Box 96090
Washington. DC 20090-6090
Tel: 202/205-1532
Fax: 202/205-6207

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 althou gh 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
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Fax: 604/381-0252

Seedling Storage, Part II

In the January, 1996 issue we talked about the types of storage and how they must be tailored to the outplanting season. Now, let's take a look at how a knowledge of seedling physiology and some relatively simple measurements can be used to determine the proper time to harvest your seedlings.

Hardiness vs. Dormancy. Nursery managers must know how to harvest their crop at its peak of quality and how to maintain that quality until the seedlings can be outplanted. This means lifting seedlings when they are fully dormant and also resistant to stresses of harvesting, storage, shipping, and outplanting. In the forest nursery business we often use the terms "dormancy" and "hardiness" interchangeably, and yes, there is some overlap - both in physiology and in time. These conditions are NOT the same, however, and it is important that growers understand the differences.

In the temperate zone, seedlings go throu g h a seasonal pattern of active growth in the summer followed by a period of dormancy in the winter. Dormancy has a couple of common definitions:

"a state of minimal metabolic activity", or "any time that a plant tissue is predisposed to grow, but does not". Note that dormancy usually refers to a specific meristematic tissue. Hardiness, on the other hand, can be defined as "a condition of durability, or resistance to stress". Note that hardiness can apply to all types of plant tissues, but the term can also refer to a specific stress, such as cold hardiness. In operational use, however, we usually mean a hardy seedling is resistant to all the various types of stresses that will be encountered during lifting, handling, storage, and outplanting. Although there are some differences, seedlings that are cold hardy are also resistant to other types of stresses.

As we mentioned earlier, there is some temporal overlap between dormancy and hardiness and, in fact, dormancy is a prerequisite to deep levels of hardiness. Although non-dormant tissue can harden to some degree, seedlings cannot achieve full hardiness if they are still growing. In coastal Douglas-fir, the deepest levels of hardiness are reached after the plant has already passed the period of maximum dormancy and is actually coming out of it **(Figure 1).** Of course, in the tropics or semitropics where seedlings never really go dormant,

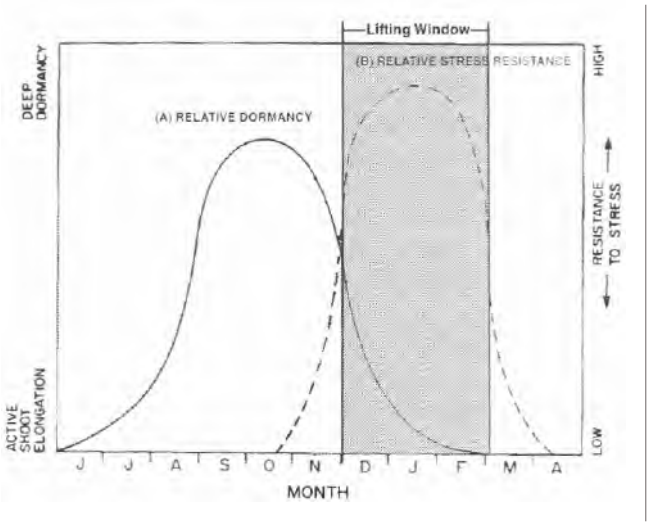

Figure 1. The period of maximum seedling resistance (hardiness) actually occurs after the period of maximum dormancy (Lavender 1985)

there is no lifting window as such but seedlings still can be cultured into a state of peak hardiness so that they can be harvested.

Scheduling the Lifting Window. Our objective then is to measure, or better yet predict, when seedlings are ready to harvest. In forest and conservation nurseries, three different methods of scheduling seedling harvesting have been used:

1. Calendar/experience—Scheduling the harvest according to the calendar is the most traditional technique, and when based on the combined experience of the nursery staff, can be quite effective. The procedure is simple - if it takes 4 weeks to harvest all the seedlings, then that amount of time is scheduled on the calendar based on past weather records and how well seedlings that were lifted on various dates have survived and grown after outplanting.

Unfortunately, the actual lifting window in bareroot nurseries is subject to the vagaries of weather and so will change from year to year. Container growers have easier, especially those with enclosed growing structures, because seedlings can be lifted irrespective of weather conditions. In tropical and semitropical nurseries where weather is not a factor, the seedlings can be harvested as soon as they are large enou g h and after they have been exposed to several weeks of hardening.

Experienced g rowers use several morphological indicators to help them determine when seedlings are becoming hardy:

- **Foliage characteristics:**

  Determining when deciduous species are ready to lift is easy, because the leaves change color and eventually fall off the seedlings. Even evergreen seedlings show signs when they are becoming dormant, however. For example, the cuticle of leaves or needles becomes thicker and waxier so that the seedling can tolerate desiccation during the winter. Experienced growers can feel when the seedlings are becoming hardy and the needles of some species even show a slight change in color. In spruces, the actively-growing foliage is bright green whereas the dormant foliage becomes bluer in color because of the waxy cuticle that develops on the surface.

- **Buds (presence, size, and number of primordia):**

  Even novice growers know that most seedlings form a bud at the end of the growing season. In the temperataure zone, most people look for large buds with firm scales as an indication of shoot dormancy. This is not the case for some Southern pines, however, where the presence of a bud is not considered necessary. Bud size and length has also been used as a good indicator of when seedlings are ready to harvest and counting the number of bud primordia is one of the ways that Ontario nurseries determine the timing of their harvests.

- **Presence of white root tips:**

  The root system is the last part of the seedling to go dormant and so growers often dig up bareroot stock or extract a few container seedlings to check for new root growth durin g the Hardening Phase. This technique is more useful in the Fall than in the Spring because the roots in postdormant seedlings will grow whenever the temperature allows.

Although it is not too scientific, the calendar/experience method of scheduling the lifting window is popular and widely used because it is simple and usually effective.

2. Time/Temperature—The technique of accumulating chilling hours, or degree-hardening-days (DHD) involves measuring the temperature each day and calculating the amount of time below some reference or threshold temperature **(Table 1).** Note that there can be both positive and negative degree days depending on your objectives. Positive degree days are used to determine insect development where the relative warmth is important, for example for insect development. For our purposes, we are interested in negative degree days (NDD) because we want to track the accumulated chilling below the base temperature. Soil temperatures have been used for base temperatures for bareroot seedlings in Ontario [<10 °C (50 °F) at 15 cm (8 in) depth] and air temperatures [< 5 °C (40 °F)] for container seedlings in Washington. The concept is logical enough - the cumulative exposure of seedlings to cold temperatures should help indicate when they are becoming dormant and hardy.

The chilling hours technique is relatively simple: record the daily temperatures, calculate the chilling hours, and then correlate this numerical index to some measure of seedling quality such as outplanting performance. Seedlings are harvested over the duration of the potential lifting season and outplanted to determine survival and growth. Because chilling hours will vary from year to year **(Figure** 2A), data should be gathered for at least 3 to 5 years. This seedling performance data is then plotted against the accumulated chilling hours, and the resulting graph shows when it is safe to begin lifting **(Figure 2B).** This example from Ontario shows how second year outplanting survival was correlated to DHD's for bareroot jack pine and white spruce, and how this information was used to predict the fall lifting date. Note that the different hardening patterns for the two species which shows that the white spruce seedlings could be lifted almost 3 weeks earlier than the jack pine.

Table 1. Calculating negative degree days with a 40 °F (4.5 °C) base temperature (NDD_{50})

NDD_{50} = 40 °F - [(Maximum daily temperature + Minimum daily temperature)/ 2]

Examples: Day One: 40 °F - (40 °F+ 20 °F)/2 = 40 - 30 = 10 Degree Days

Day Two: 40 °F - (45 °F+ 35 °F)/2 =40 - 40 = 0 Degree Days

Day Three: 40 °F - (50 °F + 40 °F)/2 =40 - 45 = 0 Degree Days*

"Note that average daily temperatures that are warmer than the base temperature still equal 0 negative degree days.

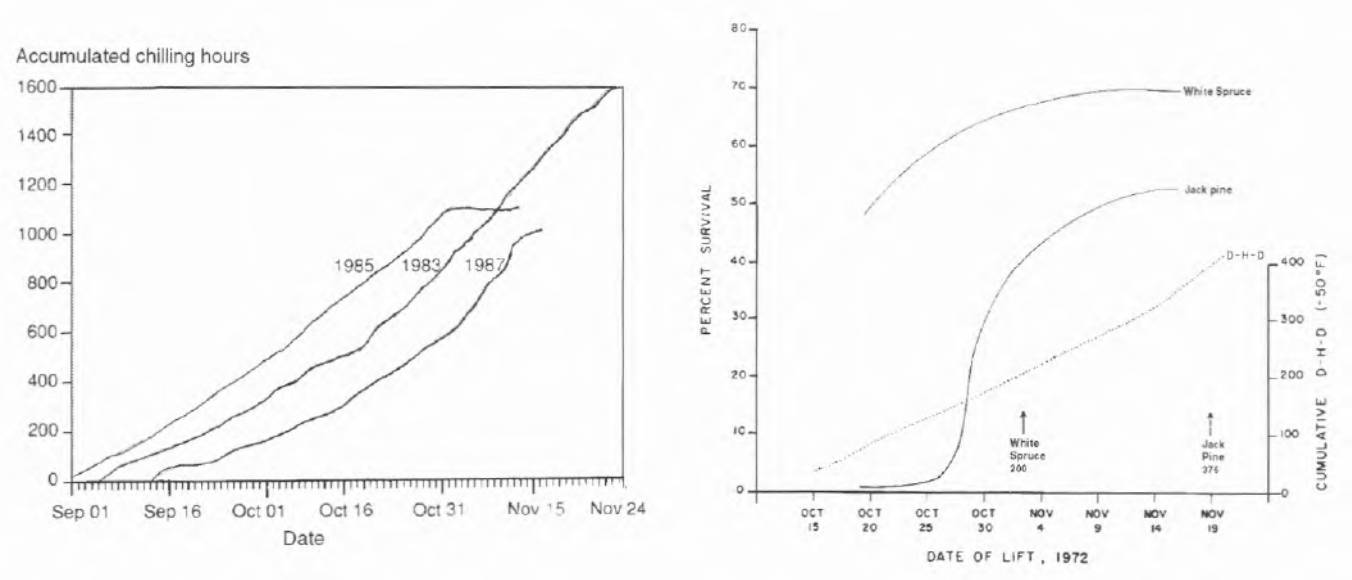

Figure 2 A/B. Accumulated chilling hours or Degree-Hardening-Days (DHD) can vary considerably from year to year as in this data from British Columbia (A), and when compared to seedling performance data, are an easy and practical way to schedule lifting dates: 200 DHD's for white spruce, and 375 DHD's for jack pine from Ontario (B). (A modified from Daniels and Simpson 1990; B from Mullin and Parker (1976).

3. Seedling quality tests—Other nurseries use some test of seedling quality as a index of when it is safe to harvest their stock. You hear so much about the various seedling quality tests that it is easy to forget that *you have to determine exactly what you are trying to measure before deciding on a specific test.* Seedling quality is very a complex subject, and some tests are more appropriate than others - it all depends on what you are trying to measure or predict. Since we are interested in determining lifting windows, then a short turn-around time is essential. You can't afford to wait 3 or 4 weeks for a test, especially for fall lifting in bareroot nurseries where the ground can freeze and put an abrupt stop to the entire season. Another important thing to remember is that many seedling quality tests only measure a certain tissue rather than the entire seedling. While a researcher may be primarily interested in a specific tissue or physiological function, we nursery folks have to deal with the entire seedling. For example, the entire root system of a container seedling could be killed by a unseasonable cold snap but the foliage will appear normal for days or even weeks. A seedling quality test that was run on the foliage buds may not indicate that they seedlings are critically damaged until it is too late.

Root growth potential (RGP), dormancy, and cold hardiness tests have all been used to try and predict lifting windows. RGP is the most famous (and, if you ask me, the most misused) seedling quality test. While it gives us an indication of vitality and relative vigor, RGP readings typically show too much variation to be a practical way of predicting when it is safe to lift.

Dormancy tests, such as the days to bud break and dormancy release index (DRI), are primarily concerned with the physiological status of the buds. While the DRI has been linked to lifting date, it is only being operationally used in a few nurseries. Because it is so closely related to overall seedling hardiness, I believe that cold hardiness tests are the best for the purpose of determining lifting windows.

There are several ways to measure cold hardiness: the whole plant freeze test (WPFT) and freeze-induced electrolyte leakage (FIEL) are the two that currently are in operational use to determine lifting windows. The WPFT consists of freezing seedlings over a range of temperatures, moving them to a greenhouse, and rating their cold tolerance by visible damage after a week. This test is being used operationally in British Columbia where conifer seedlings are considered ready to lift and cold store when they can tolerate freezing to - 18 °C (0 °F) with no more than 25% visible cold injury to the foliage. The FIEL test consists of immersing needle tissue samples in vials of distilled water which are then placed in a freezer where the temperature is gradually lowered. When the temperature reaches the killing point. the cell membranes rupture and the cell contents leak into the water which raises its electrical conductivity. An Index of Injury (I_{50}) is calculated by comparison to a relative scale in which the unfrozen control tissue reading rates 0 and heat-killed tissue rates 100. The USDA Forest Service is currently evaluating the FIEL test as a means to predict the lifting window in 8 different nurseries from across the US, and preliminary results appear very encouraging **(Figure 3).**

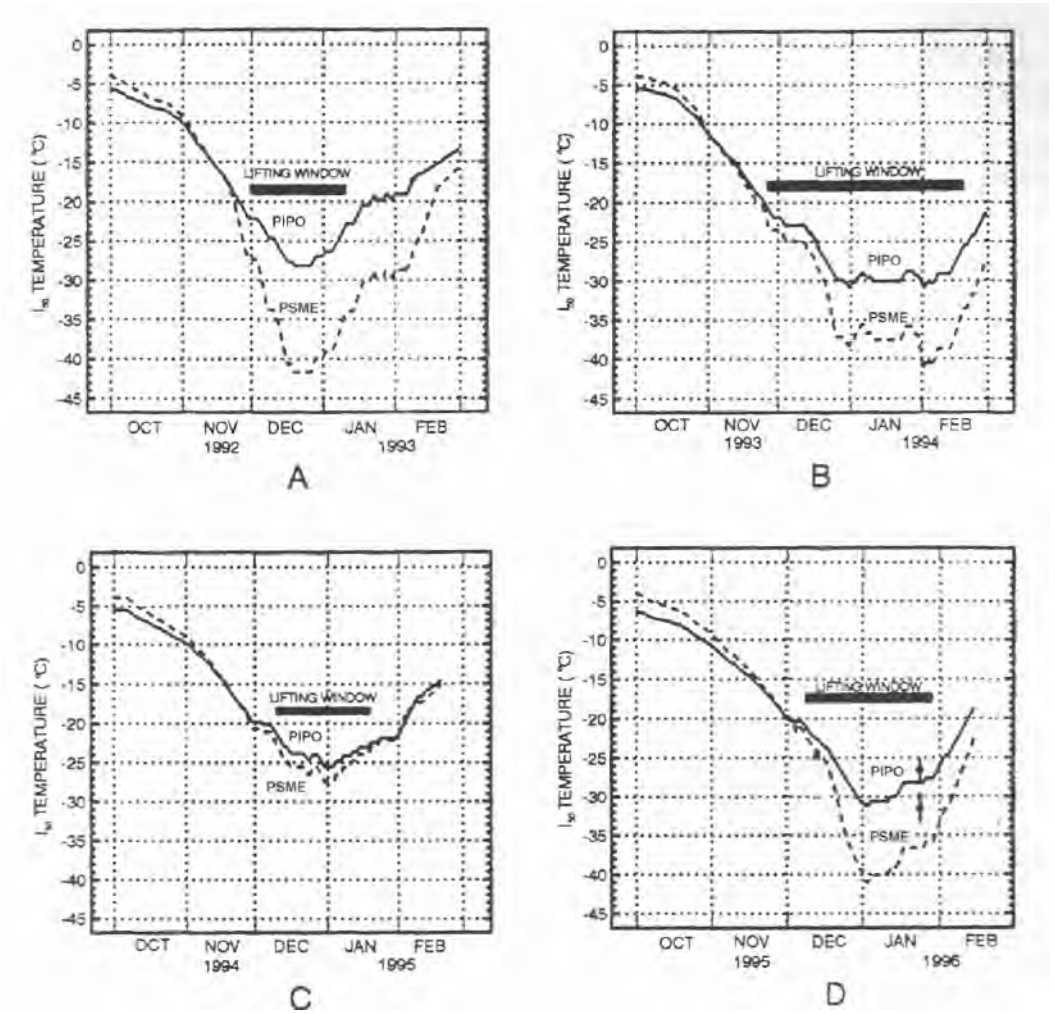

Figure 3. When the cold hardiness of Douglas-fir (PSME) and ponderosa pine (PIPO) seedlings were monitored over four consecutive winters using the Index of Injury (I_{50}) from the freeze-induced electrolyte leakage test, the lifting window was found to vary considerably (modified from Tinus 1996)

Chlorophyll fluorescence (Ch1F) is the newest seedling quality test which has shown promise in predicting the lifting window for some northern conifer species. The technique consists of exposing preconditioned seedlings to high li[g]ht intensity and measuring the amount of light that is re-emitted or "fluoresced". The beauty of the Ch1F test is that it is immediate, non-destructive, and the newest equipment is portable. The major drawbacks are that ChIF doesn't work on all species, and that interpretation requires a skilled technician. Operational testing in British Columbia appears very promising, however, and it remains to be seen whether Ch1F will be accepted as a practical way to schedule seedling harvest.

Conclusions and Recommendations

Determining when it is safe to harvest seedlings so that they will maintain a high level of quality throughout the storage period is one of the most challenging parts of nursery management. Scheduling the lifting window based on calendar date and personal experience will continue to be used in operational nurseries, but the quality of the stock will occasionally suffer due to the year-to-year variation in seedling hardening rate. Chilling sums are relatively simple and inexpensive to develop but remember that they will vary by species and ecotypes. As far as seedling quality tests go, I recommend cold hardiness tests as the best way to schedule your lifting window each year. Some exciting new research is currently underway which will make cold hardiness testing even easier and faster and Ch1F tests also show promise. Stay tuned, because I'll be reporting on them in future issues of FNN.

Well, now that we have discussed the types of seedling storage and know how to schedule seedling harvesting, we will conclude this series in the next issue of FNN with a look at packaging, monitoring storage conditions, physiological effects of storage, and post-storage handling.

Sources:

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The Nutrient Value of Irrigation Water

Most people don't consider water a source of nutrients and, if they are talking about animal nutrition, then they are correct. For plants, however, irrigation water can be a valuable source of secondary mineral nutrients. In fact, certain waters can contain all or a substantial portion of the calcium (Ca), magnesium (Mg) , and sulfur (S) needed for normal growth.

Before we go any further, let's have a quick review of mineral nutrition and water quality. Plants need 13 essential mineral nutrients: six macronutrients, which are needed in relatively greater quantities, and seven micronutrients which are required in minute amounts (Table 2). The quality of irrigation water is primarily determined by the type and concentration of dissolved salts. For our purposes here, a salt is defined as a chemical compound that dissolves into positively and negatively charged particles called ions in water. Too much of any salt can be harmful but, in the proper concentration, salts can be either beneficial or harmful depending on their chemical characteristics of the specific ions. As an example, ordinary table salt is composed of sodium chloride (NaCl) and, when mixed with water, dissolves into two ions (Na^+ and C1-) either of which is extremely toxic to plants. Young seedlings are only able to tolerate 50 parts per million (ppm) of sodium or 70 ppm of chloride.

Soluble fertilizers also are technically salts and supply essential plant nutrients. For example, potassium nitrate (KNO_3) is a soluble chemical which dissolves into two nutrient ions: potassium (K^+) and nitrate-nitrogen (NO_3-) **(Figure 4).** These dissolved ions are electrically-charged and so the total salt concentration of irrigation water can be determined by measuring its electrical conductivity (EC).

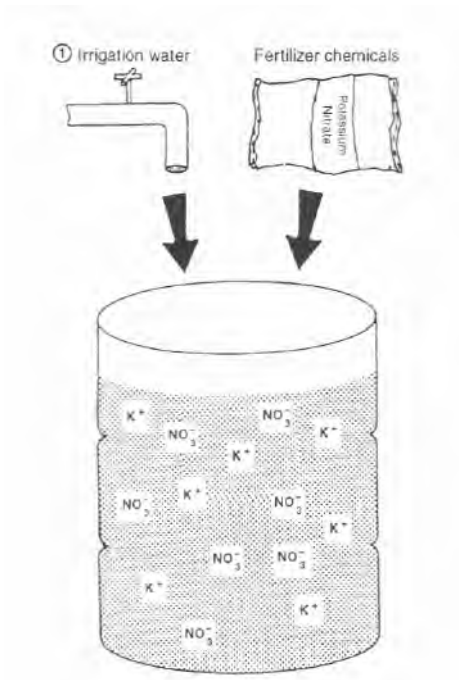

Figure 4. Fertilizers are salts which are used to supply mineral nutrients; for example, potassium nitrate (KNO_3) dissolves into charged nutrient ions (K^+ and NO_3-) which are taken up by plants.

The concentrations of soluble mineral nutrients in irrigation water vary considerably from nursery to nursery depending on the source of the water and the local geology. Because it has had less time to dissolve soluble minerals in the soil, irrigation water that is obtained from surface sources such as streams and ponds will usually have lower soluble salt levels than water from underground sources. Rain water is the purest natural source of irrigation water that is available to nurseries. When I was out in the Pacific Islands and far from any source of air pollution, I collected rain water from the roof and measured an EC of only 16 0/ cm - almost as pure as distilled water. For contrast, I also collected sea water and came up with a whopping EC reading of 50,000 µS/cm! Obviously, rain runoff would be a much better irrigation source than groundwater which can be contaminated with saltwater intrusion in maritime regions. Rain water is a poor source of mineral nutrients, however. In Hawaii, rain filters through young, pumice soils which do not contain many soluble minerals and so the irrigation water is very pure. The EC of irrigation water at a nursery in the hills of Hawaii was only 30 µS/cm **(Table** 2). This means that most if not all the calcium, magnesium, and sulfur must be supplied through fertilization. Actually, irrigation water can be too pure for good plant growth because it quickly leaches out the soluble nutrients from the soil or growing medium - this same thing happens in open growing compounds during periods of heavy rainfall.

Few forest and conservation nurseries rely on rainfall for irrigating, however, and so most irrigation water contains some dissolved salts. The water at many places in the semi-arid Western US is called "hard" because it contains a high levels of calcium and magnesium which cause scale to deposit on pipes and also leaves deposits

Table 2. Chemical analysis of irrigation water from forest and conservation nurseries compared to recommended mineral nutrient target concentrations

		Irrigation Water Analysis		
Essential Mineral Nutrients	**Target Levels**	**Hawaii Nursery**	**Colorado Nursery**	**California Nursery**
Macronutrients		***Parts per million***		
Total Nitrogen (N)	222	NT*	3	7
Nitrate-nitrogen (NO3)	156	NT*	3	5
Ammonium-nitrogen (NH4)	66	NT*	0	0
Phosphorus (P)	60	0	0	0
Potassium (K)	155	0	2	2
Calcium (Ca)	60	1	82	66
Magnesium (Mg)	40	1	14	113
Sulfate-sulfur (SO4)	63	NT*	43	315
Micronutrients		***Parts per million***		
Iron (Fe)	4.00	0.20	0	0
Manganese (Mn)	0.50	0	0	0.01
Zinc (Zn)	0.05	0	0	0.05
Copper (Cu)	0.02	0	0	0
Chloride (CI)	4.00	NT*	3.00	132.00
Molybdenum (Mo)	0.01	NT*	0	0
Boron (B)	0.50	0	0.06	1.00
Other Water Quality Factors Affecting Mineral Nutrient Uptake				
pH	5.5 to 6.5	5.7	6.9	8.1
Salinity (EC in mcmhos/cm)	1200 to 1800	30	470	1610

* = Not Tested

on other surfaces. Hard water inhibits the action of soap and so is softened for domestic purposes. Nurseries with moderately hard water are fortunate because it often supplies all or most of the calcium and magnesium requirement. On the other hand, soft water should never be used for irrigating plants because the added sodium and chloride ions are toxic.

Water from some irrigation wells can be too high in soluble salts as the analysis from the Sacramento Valley of California illustrates (Table 2). Although the calcium, magnesium, and sulfur levels are above the recommended levels, this nursery has had continual problems with direct toxicity from high chloride levels. Another problem is that high levels of some nutrient ions, for example calcium, can caused reduced availability of other nutrients including iron and phosphorus. Finally, note the high pH of the California water. The pH of water generally increases with the EC reading although the exact nature of the dissolved salts, especially carbonate and bicarbonates, have the major effect on the pH reading. Although pH is the most discussed aspect of irrigation water quality, it has a very minor influence and so should only be used as an indication that a more complete analysis is required.

The take-home message is that irrigation water should be tested during the nursery site selection process and periodically thereafter because water quality can change over time. Be sure to test for all the nutrient ions because the full range of mineral nutrients is not included in most standard water quality tests. This increases the cost of the analysis but this information is essential when formulating fertilizer programs.

Sources:

Landis, T.D.; Tinus, R.W.; McDonald, S.E.; Barnett, J.P. 1989. Seedling nutrition and irrigation, Vol. 4, The Container Tree Nursery Manual. Agric. Handbk. 674. Washington, DC: USDA, Forest Service. 119 p.

Secondary Mineral Nutrients—Sulfur

With this section, we will complete our three-part discussion of the so-called secondary macronutrients. We looked at calcium in the January, 1996 issue of FNN, magnesium in July of that year, and will conclude with sulfur in this issue. As in past issues, Eric van Steenis of the British Columbia Ministry of Forests helped with the writing of this section.

Sulfur has been known to be an essential plant nutrient for over 100 years, and is considered a macronutrient because it is required by plants in approximately the same concentration as phosphorus and magnesium. It is rarely applied as a fertilizer in traditional agriculture, however, because sulfur is commonly found in soils and is also supplied in rain and irrigation water. The other fascinating aspect of this mineral nutrient is that it cycles through nature in both organic and inorganic forms and under both aerobic and anaerobic conditions **(Figure** 5).

Role in Plant Nutrition

Although plants can absorb a small amount of gaseous sulfur dioxide (SO_2) through their foliage, the most common method of uptake is by the roots as sulfate ions ($SO_4^{=}$). These sulfate ions are transported throughout the plant in the xylem and also are stored in this form. In some ways, the assimilation of sulfur is similar to nitrogen because sulfate ions must be reduced in the chloroplasts of the leaves before they can be incorporated into amino acids and proteins. Proteins are

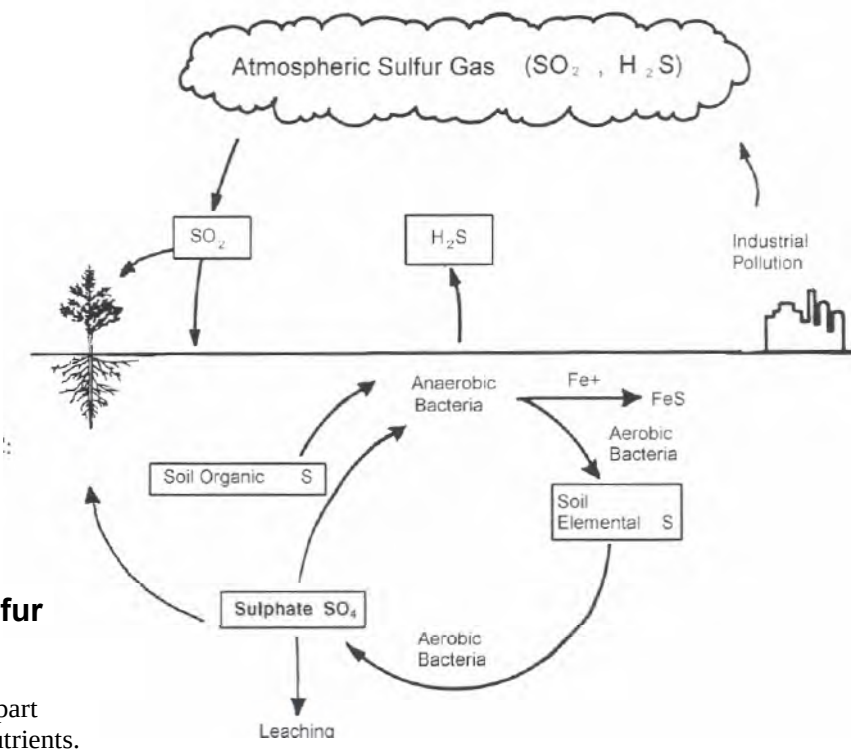

Figure 5. The sulfur cycle in nature. Although plants can absorb minute amounts of sulfur dioxide (SO_2) from the air, the) obtain most of this essential mineral nutrient as sulfate ions ($SO_4^{=}$)from the soil (modified from Mengel and Kirkby 1979)

constructed from combinations of 22 different amino acids. Sulfur is critical to the structure of the 2 keys amino acids, cysteine and methionine, which is reflected in the approximate 10:1 nitrogen:sulfur ratio of all proteins. Disulfide bonds or bridges help maintain the 3-dimensional structure of proteins, and need to be maintained to prevent denaturation as can happen during dehydration or frost injury **(Figure 6).** This essential nutrient also is a component of several vitamins, such as thiamine and biotin, as well as coenzyme A which is involved in the Krebs cycle. Non-reduced sulfate is used structurally in sulfolipids in cell membranes and polysaccharides, and there is evidence that sulfolipids also are involved in the regulation of ion transport across membranes.

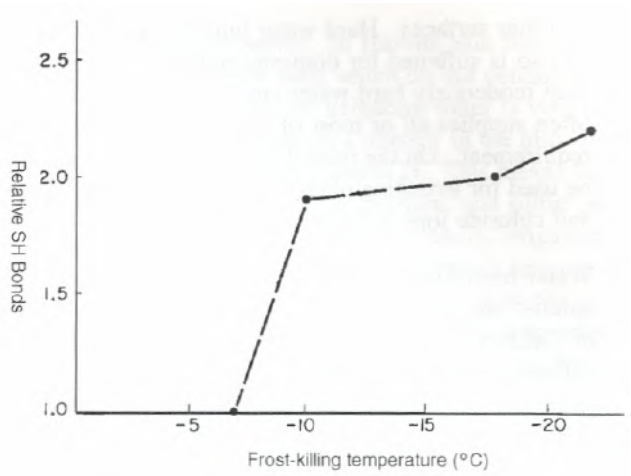

Figure 6. Sulfhydryl (SH) bonds in plant proteins are thought to be related to cold hardiness, as shown in this example for Pinus sylvestris *(modified from Levitt and others 1961)*

Availability and Uptake

Bareroot nursery soils contain sulfur in both organic and inorganic forms **(Figure 5)** but only the inorganic fraction is normally available for plant uptake. When organic matter decomposes under aerobic conditions, sulfur is released in the sulfate form but this happens too slowly to be of practical significance. The sulfur in soil minerals, such as gypsum ($CaSO_4 \cdot 2H_70$), is only available for plant uptake after it has been oxidized into sulfate ions. Because sulfur is found in both available and unavailable forms in the soil and the concentrations of these form varies over time, bareroot nurseries should have their soils tested for S on an annual basis to determine if fertilization is warranted. Artificial growing media components like peat moss, vermiculite and perlite contain essentially no available sulfur.

Small amounts of sulfur dioxide are found in the atmosphere due to the burning of fossil fuels and decomposition of organic matter **(Figure 5).** Because sulfur dioxide is very soluble, it can be deposited in rainfall and therefore supplied to crops in ground water. In industrialized areas, this source is considered to be sufficient to meet crop needs. The amount of sulfur in irrigation water varies widely, however: a recent survey from across the US found that 4% of the water samples contained no S, and another 65% contained less than 10 ppm. Compared to a target level of around 60 ppm, this is too low to supply the needs of rapidly growing seedlings. Even within a state like Texas, however, the S content of irrigation water varied from 0 to 510 ppm so the only way to know how much your water contains is to have it chemically analyzed. (See The Nutritive Value of Water in this section for more information)

The fact that sulfate is an anion affects its availability in two ways: first, elemental sulfur must be oxidized before it can become absorbed, and second, sulfate anions are not strongly held in the soil or growing medium. So, unlike calcium and magnesium which can accumulate on the cation exchange sites in the soil, sulfur must be regularly supplied to a growing crop.

Diagnosis of Deficiencies and Toxicities

Healthy seedlings should contain from 0.10 to 0.20 % sulfur on a dry weight basis **(Table 3).** The symptoms of sulfur deficiency are often difficult to distinguish from those of nitrogen because deficiencies of both nutrients result in a shortage of proteins. Sulfur is not as mobile in the plant as nitrogen so chlorosis due to sulfur deficiency is most severe on the younger foliage whereas nitrogen chlorosis shows up first in older leaves.

Conifers: In general, sulfur deficient crops are chlorotic and slightly stunted but the severity can vary considerably by species. In a controlled experiment with container seedlings, the needles of sulfur deficient Douglas-fir seedlings were chlorotic and severely twisted. With white spruce, the symptoms were much less severe and only the ends of the needles became golden towards the end of the growing season.

Broadleaves: Sulfur deficiency causes a moderate reduction in height growth compared to nitrogen deficiency. The first signs of sulfur deficiency show on the younger leaves which are initially light green but eventually develop scorched and curled margins. Necrotic areas can form along the margins and then spread inward to the leaf midrib. In some species, sulfur deficiency also affected root growth.

Table 3. The three "secondary nutrients": Calcium, Magnesium, and Sulfur

Element	Symbol	Average Concentration in Plant Tissue (%)	Adequate Range in Seedling Tissue (%) Container	Bareroot
Nitrogen	N	1.5	1.20 to 2.00	1.30 to 3.50
Potassium	K	1.0	0.30 to 0.80	0.70 to 2.50
Calcium	Ca	0.5	0.20 to 0.50	0.30 to 1.00
Magnesium	Mg	0.2	0.10 to 0.15	0.10 to 0.30
Phosphorus	P	0.2	0.10 to 0.20	0.20 to 0.60
Sulfur	**S**	**0.1**	**0.10 to 0.20**	**0.10 to 0.20**

Toxicity: Sulfur toxicity is rare in soils but two types of plant injury are common under conditions of acid rain in heavily industrialized regions. The symptoms of acute SO_2 injury include marginal and interveinal chlorosis and necrosis. Chronic injury is diagnosed as leaf chlorosis and bleaching which may continue until the chlorophyll is destroyed and the interveinal portions of the leaf are nearly white.

Monitoring

Most good agricultural soils contain adequate S in organic and inorganic forms although the amount in the available sulfate form can vary considerably. Soil tests can only measure the inorganic fraction and so give only a partial picture of total available sulfur. Tests can be used to determine whether fertilization is required, and should be done annually especially in high rainfall areas where leaching is severe. Container growers should assume that their media does not contain any sulfur and that the only possible source is the irrigation water. The most appropriate way to monitor mineral nutrients is to collect the applied solution while fertigating and have it chemically analyzed. It also is possible to collect the saturated media extract and leachate but the results of these tests are more difficult to interpret.

Plant tissue analysis can be helpful in diagnosing sulfur deficiencies, especially when paired tests with healthy seedlings are run. Because considerable variation can exist, establishing base nutrient standards for your own species is highly recommended.

Sulfur Management

- Analyze your irrigation water. Since sulfur is often carried in water, both bareroot and container nurseries should have their irrigation water analyzed.
- In container nurseries, formulate and apply well-balanced fertigation solutions. Because growing media contains no sulfur and container crops are often grown in enclosed structures, nursery managers must supplement the amount of sulfur that is found in their irrigation water. Gypsum or slow-release fertilizers like Osmocote® can be incorporated into the growing media although the heavy irrigation rates in container nurseries can cause the sulfate to be quickly leached. Magnesium sulfate and potassium sulfate are inexpensive soluble fertilizers for fertigation **(Table 4),** and a target concentration of around 60 ppm SO,-S should be adequate for all forest and conservation crops. Remember that sulfate is not adsorbed on the cation exchange sites and therefore regular fertigation is necessary to maintain a good supply during periods of rapid growth.
- In bareroot nurseries, apply sulfur fertilizers if warranted. When a need for supplemental sulfur has been confirmed, then the next step is to select the most appropriate fertilizer. There are many options when it comes to selecting a sulfur fertilizer **(Table 4).** Gypsum and superphoshate can be easily and cheaply applied to the soil and incorporated prior to sowing, and so the best choice will depend on what other nutrients are also needed. Other more soluble sources of sulfur like ammonium sulfate and Epsom salts can be applied during the growing season as a top dressing.

In conclusion, sulfur is an essential mineral nutrient that is often overlooked because small amounts are found in the soil and water. Less than optimal seedling growth rate ("hidden hunger") may be the most common symptom of a minor sulfur deficiency because background levels can be just high enough to avoid severe nutrient deficiencies from becoming apparent. Analyzing your irrigation water and soil is the only way to know if you have a problem.

Table 4. Some common fertilizers containing sulfur

Fertilizer	Sulfur Content	Other Nutrients	Use in Nurseries
Ammonium sulfate	24%	21 %N	Top dressing in bareroot beds; available as a soluble for container crops; lowers soil pH
Ammonium sulfate nitrate	15%	26% N	Top dressing in bareroot beds
Gypsum	18%	22 % Ca	Relatively insoluble soil amendment that should be incorporated prior to sowing
Magnesium sulfate (Epsom salts)	13%	10 % Mg	An excellent fertilizer for container crops - very soluble, and contains no inert materials.
Osmocote® 18-10-10	34%	18% N 4.8 % P 8.3% K + Others	Slow-release fertilizer with an 8 to 9 month release rate. Incorporate into growing media.
Potassium sulfate	18%	44%K	Good soluble fertilizer for container crops.
Sul-Po-Mag®	18%	25 % K 8 % Mg	Good multinutrient fertilizer which can be top-dressed
Superphosphate	16%	8 % P 14 % Ca	Good multinutrient fertilizer but insoluble so incorporate prior to sowing.

Sources:

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Reddy, S.K. 1996. Sulfur on tap. Greenhouse Grower 14(1): 58, 60.

van den Driessche, R. 1989. Nutrient deficiency symptoms in container-grown Douglas-fir and white spruce seedlings. FRDA Report 100. Victoria, BC: B.C. Ministry of Forests. 29 p.

Don't Overlook Abiotic Diseases

In the last FNN issue, we discussed scouting tools and techniques and so I'd like to continue with the next step of considering abiotic disease. Nursery workers, and many pathologists as well, tend to overlook or minimize the importance of abiotic diseases or cultural injuries in causing problems. Before we go any further, note that I take the broad view of what constitutes a disease: "any sustained departure from the normal physiological or morphological condition that characterizes a healthy seedling". Therefore, the chlorosis and stunting from nitrogen deficiency is just as much a disease as is the chlorosis and stunting caused by Phytophthora root rot. Other abiotic injuries and cultural problems don't fit the definition, however, as they happen too quickly - for example, frost injury or fertilizer burn.

So, the first step in disease diagnosis is to eliminate abiotic diseases. When they first detect a disease symptom, most people immediately start looking for some critter with the "smoking gun". I guess that it's normal to think that some organism is causing the problem, and of course, it perfectly human to tend to skirt the issue that *you* may be the real pest. Actually, more nursery problems are caused by abiotic diseases than biotic pests **(Figure** 7).

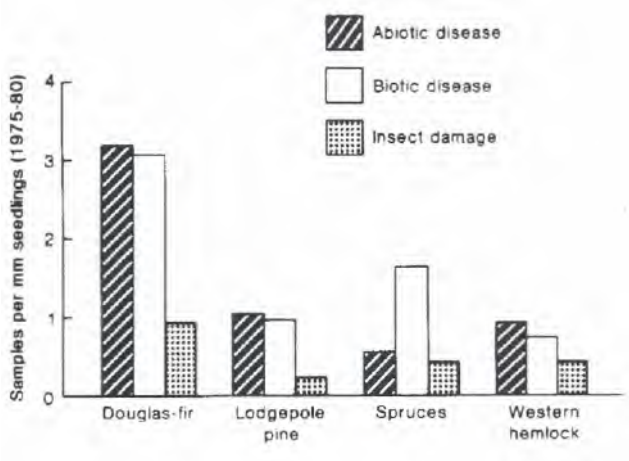

Figure 7. Abiotic diseases are usually more common than diseases or insect pests as shown by these samples received at a British Columbia pest laboratory (modified from Sutherland and others 1982)

Some things to consider during disease diagnosis:

The nursery environment itself predisposes seedlings to abiotic damage. In the nursery business, we try to minimize all the limiting factors that control seedling growth. Like all things in life, however, there are trade-offs and the trade-off for this perfect propagation environment is an increased risk of problems. For example, nursery seedlings are more succulent than naturally-growing seedlings and are therefore at a greater risk of cold injury. This is particularly true for container seedlings grown in greenhouses. Taking the seedling out of its normal environment also upsets the natural balance of things, and the perfect propagation environment is also a perfect breeding ground for many fungi, insects, and other pests. Any pathologist will tell you that common nursery pathogens, such as *Botrytis cinerea,* are rarely seen in native forests.

Secondary pathogens. Another problem that complicates diagnoses is that many fungi quickly colonize injured seedling tissue and these secondary pathogens quickly mask the true cause of the problem. A perfect example is seedling storage diseases. I don't know how many times I've been asked to look at storage molds and sure enough, the seedlings arc completely covered with fungal mycelia. The normal conclusion is that these fungi are pathogenic but they are rarely the true cause of the problem. Most storage molds of bareroot stock are caused by soil contamination. If you have a pathologist culture the suspect fungus they will usually tell you that it is a normal soil fungus, not a typical seedling pathogen. With container seedlings, you will be seeing *Botrytis cinerea* but the predisposing factor is often mechanical injury or climatic damage. If you ask enough questions and get honest answers, you will often discover that the seedlings were damaged by a frost or were not completely dormant and cold hardy when they were packed.

Use all sources of information. When faced with a puzzling, abiotic problem, check with other members of the nursery staff who might have noticed something unusual. Consult with other local nurseries to see if they have had similar problems. Check the published literature, and don't overlook older books and journals. Our society continually tells us that what is new is best, but the past is a tremendous source of information. For example, several years ago a bareroot nursery sent me several *Abies* spp. seedlings that had a curious corkscrew curvature to the root system. The nursery manager hadn't noticed anything that could have caused this symptom, so I examined them and found no evidence of pests or environmental injury. Puzzled, I asked

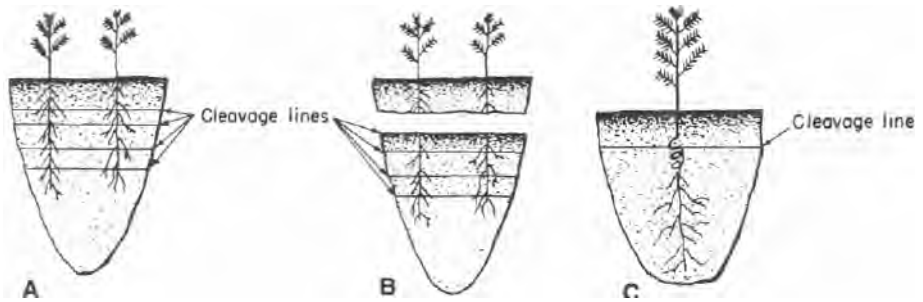

Figure 8 A/B/C - The corkscrew root syndrome. Surface freezing causes cleavage lines to form in the soil of the seedbed (A). Repeated frost heaving lifts the seedlings out of the soil (B), and then subsequent soil thawing lowers them back into place. After this occurs several times during the winter, the seedlings developed a corkscrew or "pigtail" curvature in the lower stem (Arnold 1958).

other nursery pathologists if they had ever seen similar symptoms but nobody had never seen anything like it. As much as I hate to do so, I had to call back the nursery manager and tell him that I just didn't know what had caused the problem. Several years later, however, I was looking through some old issues of Tree Planters' Notes and stumbled onto an article that described the situation perfectly and even had good illustrations **(Figure 8).**

Aids for diagnosing abiotic diseases.

Nursery managers can do a couple of things that will make diagnosing and preventing abiotic problems much easier:

1. **Promote regular scouting.** Try to schedule periodic walks through your nursery and follow a systematic route so that you check all species, seed lots, and locations in the growing area. Bring key members of the nursery staff along such as irrigators, and talk to other workers, such as weeding or thinning crews, to see if they have noticed anything unusual. Ask about any unusual weather or cultural events: was there an unseasonable frost, or did the irrigation boom work properly? When scouting, use all your senses and remember that the most important attribute in disease diagnosis is "the ability to observe accurately."
2. **Keep a daily log.** Taking written notes in a daily journal or log is an excellent way to record climatic and cultural events and also document unusual symptoms that could develop into a disease. This is particularly important for the nursery scout but all members of the crew should be encouraged to jot down anything unusual that they see. In this computer age, we all too often tend to skip some of the simplest and most basic techniques. Keeping a daily journal is a cheap and easy way to gather and document valuable cultural information.
3. **Use growth curves to detect stunting.** Minor growth losses are often the first symptoms of an abiotic problem but they can be very difficult to detect. Taking regular measurements of height, caliper, ovendry weight, and root growth and plotting these growth measurements on graph paper or on the computer will produce a cumulative growth curve that expose minor stunting. And, as you accumulate this information over the years, you will be an generating an invaluable cultural record.
4. **Monitor the weather in the propagation area** Use computer weather systems if you can afford them but at the least, put max/min thermometers and hygrothermographs throughout the nursery and check them regularly. You or your staff can't be around all the time and you know that something weird is going to happen as soon as you leave. Document weather records in your daily log so that you can use them to diagnose potential problems later in the growing season.
5. **Install history plots.** I have advocated the use of history plots in bareroot nurseries for many years, but the same principle can be applied in container nurseries. The basic idea is to establish a series of permanent comparison plots in the nursery so that abnormal growth problems and diseases can be detected early. Since history plots are established at the time of sowing, they can expose problems with poor germination and early growth which may often go unnoticed. Since this is such a complicated subject, I'll discuss history plots in detail in the next issue of FNN.

In conclusion, the take-home lesson is that nursery IPM scouts must always be on the alert for abiotic disorders and realize that Murphy's law applies in spades to nurseries.

Sources:

Arnold, C.A. 1958. Frost damage. Tree Planters' Notes 31: 8-9.

Landis, T.D.; Tinus, R.W.; McDonald, S.E.; Barnett, J.P. 1989. The Biological Component: Nursery Pests and Mycorrhizae, Vol. 5, The Container Tree Nursery Manual. Agric. Handbk. 674. Washington, DC: USDA Forest Service. 171 p.

New IPM References

Every nursery should have a permanent library of books and catalogs that contain the latest information on pesticides and other chemicals that you use at your nursery. If you don't have them already, I'd recommend starting with the following:

Order from: Meister Publishing Company
37733 Euclid Avenue
Willoughby, OH 44094-5992
Tel: 216-942-2000
Fax: 216/942-0662

Cost: $84.00
+ $7.00 S&H (US)
+ $15.00 S&H (Canada)
+ $25.00 S&H (International)

Farm Chemicals Handbook '96.

This annual reference provides specifications on every fertilizer and pesticide, including the latest biologicals. Over 17,000 product names and trade names are cross-referenced in the SINE Index, and environmental and safety information and company names and addresses also are provided . One feature that I especially like is the Regulatory File which contains common-sense information on environmental laws like the Clean Air Act and FIFRA (Federal Instecticide, Fungicide, and Rodenticide Act) along with telephone and FAX numbers of who to call for more information including your State Pesticide Coordinator. The WPS Quick Reference to Product Labels is particularly useful **(Table** 5).

Table 5. Sample from Farm Chemicals Handbook

Product Name	EPA Number	Active Ingredient(s)	RUP	Signal Word	Action	Notification	REI	PPE	Early Entry PPE
Abbott Laboratories									
Accel*	275-92	gibberellic acid	No	Warning	PGR	Oral	12	a g	a e g
DiPel* 6L	275-46	Bacillus thuringiensis var. kurstaki	No	Caution	IN	Oral	12	a f g	b f g
DiPel* 6AF	275-59	Bacillus thuringiensis var. kurstaki	No	Caution	IN	Oral	12	a e g	b e g
DiPel* 8AF	275-67	Bacillus thuringiensis var. kurstaki	No	Caution	IN	Oral	12	a e g	b e g
DiPel* ES	275-65	Bacillus thuringiensis var. kurstaki	No	Caution	IN	Oral	12	a f g	b f g
DiPel* ES-CPI	275-66	Bacillus thuringiensis var. kurstaki	No	Caution	IN	Oral	12	a f g	b f g
DiPel* ES-NT	275-93	Bacillus thuringiensis var. kurstaki	No	Caution	IN	Oral	12	a f g	b f g
DiPel* 10G	275-55	Bacillus thuringiensis var. kurstaki	No	Caution	IN	Oral	12	a g	b e g
DiPel* 4L	275-36	Bacillus thuringiensis var. kurstaki	No	Caution	IN	Oral	12	a f g	b f g
DiPel* 8L	275-51	Bacillus thuringiensis var. kurstaki	No	Caution	IN	Oral	12	a e g	b e g
DiPel* 2X	275-37	Bacillus thuringiensis var. kurstaki	No	Caution	IN	Oral	12	a e g	b e g
Gnatrol*	275-52	Bacillus thuringiensis serotype H-14	No	Caution	IN	Oral	12	a e g	b e g
ProGibb* 4%	275-61	gibberellic acid	No	Warning	PGR	Oral	12	a f g	b f g
ProGibb* Plus 2X	275-62	gibberellic acid	No	Caution	PGR	Oral	12	a e g	b e g
Promalin*	275-32	gibberellic acid	No	Caution	PGR	Oral	14	a e g	b e g
Provide*	275-2	gibberellic acid	No	Caution	PGR	Oral	12	a g	b e g
Release*	275-20	gibberellic acid	No	Caution	PGR	Oral	12	a e g	b e g

Action Word Abbreviations

AC	Acaricide	HE	Herbicide	PGR	Plant Growth Regulator
AD	Adjuvant	IGR	Insect Growth Regulator	PH	Pheromone
AL	Algicide	IN	Insecticide	RE	Repellent
BA	Bactericide	LA	Larvicide	RO	Rodenticide
CS	Chemosterilant	MI	Miticide	SP	Seed Protectant
DE	Defoliant	MO	Molluscicide	ST	Seed Treatment
FM	Fumigant	NE	Nematicide	SU	Surfactant
FN	Fungicide	OM	Ovicidal Miticide	SYN	Synergist
GE	Germicide	OV	Ovicide	WP	Wood Preservative

Personal Protective Equipment (PPE) Abbreviations

a ... Long-sleeved shirt and long pants
b ... Coveralls
c ... Coveralls over short-sleeved shirt and short pants
d ... Coveralls over long-sleeved shirt and long pants
e ... Waterproof gloves
f ... Chemical-resistant gloves
g ... Shoes plus socks
h ... Chemical-resistant footwear plus socks
i ... Protective eyewear
k ... Chemical-resistant apron when cleaning equipment, mixing, or loading
l ... Chemical-resistant headgear for overhead exposure
m ... Approved respirator
n ... Chemical-resistant protective suit

* = Trade Name/R/TM † May vary; please refer to product label for complete information.
Information presented herein is for preliminary planning only. Exclusive reliance must be placed on information/directions supplied by the manufacturer

FCHB Electronic Pesticide Dictionary

This companion software to the Farm Chemicals Handbook allows growers to use computer searches to find information on agricultural chemicals. It is in IPM format and contains data on thousands of current and discontinued products plus a biocontrols dictionary, toxicity charts, summaries of key laws, and company contact information. Search results can be viewed on the computer screen, printed, exported to use with word processing programs, or copied and pasted into any Windows application.

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Cost: $129.95
+ $7.00 S&H in the US
+ $15.00 S&H in Canada
+ $25.00 S&H for International Orders

New Pesticide Tracking Software

The paperwork associated with using pesticides is a major headache at all nurseries but, as you know, it is a legal necessity. Keeping track of pesticide use and complying with the federal Worker Protection Standard (WPS) and Restricted Use Pesticide (RUP) requirements are good examples. A company called Sea-Tac Inc. of Huntsville, AL has developed a windows-based software program called PARTS@ (Pesticide Application Record-keeping and Tracking System) that should be of immediate use in forest and conservation nurseries. Some of the features include:

- Easy to use pull-down menu's and pop-up windows that minimize keyboard entry
- Chemical tracking by seedbed or growing area
- Ability to log multiple locations and chemicals for each application
- Detailed reports of pesticide use and cost by chemical, location, and date
- Permanent records of pest levels and application conditions
- Chemical mix instructions
- User-defined application rates
- Chemical inventory and purchases

Upon starting the PARTS® software, the main window appears allowing data to be added, edited, or deleted by simply clicking on icons **(Figure 9A).** The six middle buttons allow input of basic nursery information into databases, such as crops, nursery locations, protective clothing, and chemical data. After the basic information is set-up, the next step is to create Usage Records. PARTS® automatically pulls in specific database information when creating a record, minimizing user input.

The Products Database window is a key interface **(Figure 9B),** allowing the user to develop pesticide specific data that is used in the Usage Database. The Products database has four tabs: a product, rates and ratios, worker protection and safety, and comments tabs. When building a pesticide usage record, PARTS automatically pulls-in the appropriate product data such as application application rates, PPE and tank mixture ratios. By clicking on the Usage Database icon (Figure **9A - left button),** the Usage Interface window pops-up **(Figure 9C)** in which there are 5 tabs. By selecting a tab, the user can quickly view and edit relevant data fields about a specific pesticide application. PARTS® supports both English and SI units.

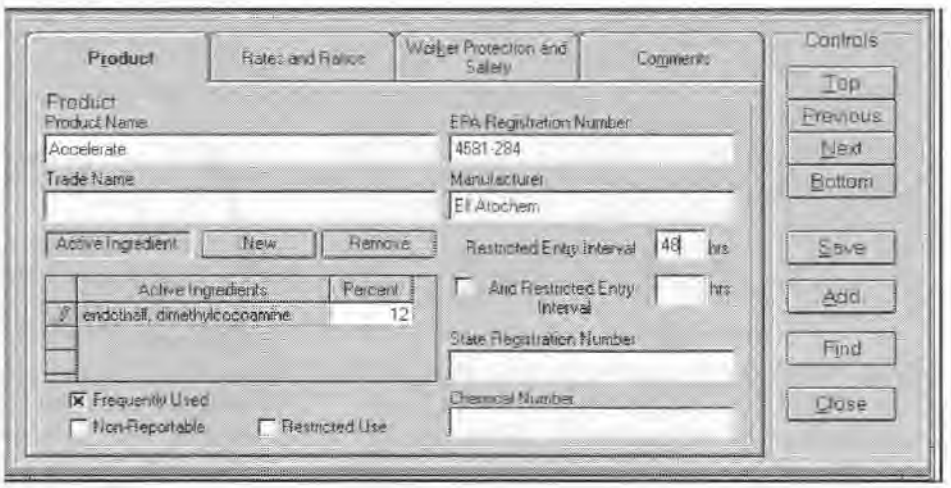
Any data management software is only as good as the outputs that you can produce. This is where PARTS® excels, providing a variety of options for both WPS and RUP compliance reports as well as for general pesticide usage. Usage can be sorted by location, pesticides or combinations thereof, annually or over any date range. The reportin[g] package allows the user to view reports generated before they are printed or stored. Exported reports are compatible with many other windows applications such as Lotus 1-2-3 , Excel and Word and, because it is built around the Microsoft Access database platform, PARTS® users can integrate their pesticide usage records into other information systems.

PARTS® is available through the A.M. Leonard catalog, or directly from the company. For more information, contact:

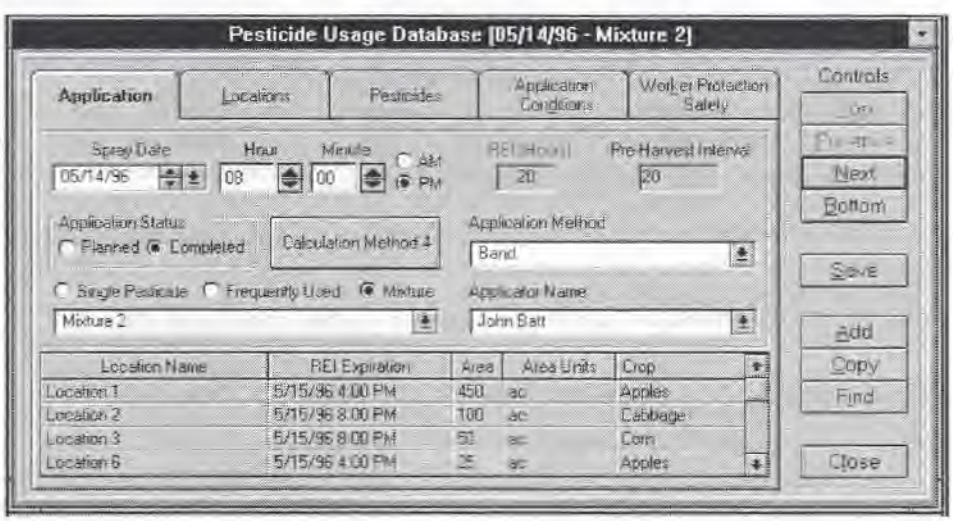
Clay Horan
Sea-Tac
P.O. Box 14005
Huntsville AL 35815 USA
Tel: 800/654-1255
Fax: 205/882-3666
E-mail: horanc@traveller.com

Figure 9A/B/C. With PARTS® software, database buttons (A) provide the interface allowing nursery managers to keep accurate records on pesticide applications (B), and to document specific details of applications (C)

A



B



C

Carbon Monoxide—The Silent Killer

Because you can't smell it, see it, or taste it, carbon monoxide (CO) is an insidious poison that is the leading cause of accidental poisoning deaths in the United States. It's difficult to gain accurate statistics because the symptoms of minor poisoning are so similar to the flu and other common ailments **(Table 6).** Because CO is the product of the incomplete combustion of carbon-based fuels, nursery workers exposed to gasoline motors, gas heaters, and defective stoves and furnaces are at risk.

During normal aerobic combustion, each atom of carbon in the fuel joins with two atoms of oxygen to form a harmless gas called carbon dioxide. When there is insufficient oxygen, however, each carbon atom links with only one of oxygen and forms carbon dioxide.

Poisoning occurs when the CO replaces the oxygen (02) in the blood. When CO is inhaled, the molecules pass quickly into the bloodstream and attach themselves to the hemoglobin in the blood to form carboxyhemoglobin. Hemoglobin is the red oxygen-carrying pigment in the blood, and its affinity for CO is 210 times greater than for 0_2 **(Figure 10).** This means that CO will begin

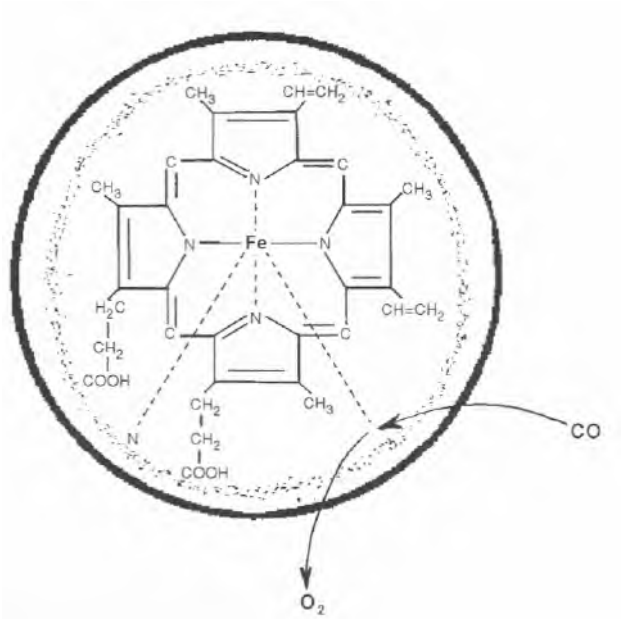


Figure 10. Even low levels of carbon monoxide (CO) in a closed environment will replace the oxygen (O_2) on the hemoglobin molecule in blood (modified from Ganong 1969)

Table 6. Health effects of human exposure to carbon monoxide (CO)

CO Level (ppm)	Exposure Time	Signs and Symptoms
200	2 to 3 hours	Mild headache
400	1 hour	Headache, muscle weakness, and nausea
800	45 minutes	Headache, dizziness, and nausea
1,300	45 minutes	Cherry-red colored skin, violent headache
1,600	30 minutes 2 hours	Headache, dizziness, and nausea Irreversible damage - death
2,000	1 hour	Irreversible damage - death
3,200	5 to 10 minutes 30 minutes	Immediate headache and dizziness Irreversible damage - death
6,400	10 minutes	Irreversible damage - death
> 10,000 (1%)	3 minutes	Irreversible damage - death

replacing 0_2 even if the ambient concentration is extremely low - 200 to 400 ppm. Workers complaining of multiple flu-like symptoms is a common indication that chronic CO poisoning is a problem. Under high CO concentrations, the blood quickly becomes oxygen deficient, leading to dizziness, nausea, and eventual death by suffocation **(Table 6).** A distinctive sign of carbon monoxide poisoning is a cherry-red coloring of the mucous membranes; people of light complexion may show a similar coloring of the skin. Although more is known about the acute symptoms, chronic CO poisoning is a more of a real hazard in the workplace.

First aid for CO poisoning is immediate exposure to fresh air followed by notification of emergency personnel to administer pure oxygen. Recovery from CO poisoning takes a long time because the hemoglobin slowly exchanges the CO for 0_2. As with most hazards, the best treatment is prevention so be sure and periodically check the exhaust system of all heaters, motors, and engines for leaks and never operate gas-powered equipment in a closed facility like the packing shed. You can usually get the fire department or other municipal safety officials to come and check for high CO levels if a problem is suspected. New digital monitoring equipment which costs less than $50 and plugs right into electrical wall sockets should be installed in all closed work areas.

Sources:

Callan, M.J. 1995. Carbon monoxide: the number one hazard. NFPA Journal, Sept./Oct. 1995: 23

Davidsohn, I.; Henry, J.B. 1974. Clinical diagnosis by laboratory methods. Philadelphia: W.B. Saunders Company. 1443 p.

Ganong, W.F. 1969. Review of medical physiology. Los Altos, CA: Lange Medical Publications. 628 p.

Back Belts Receive Support

Is it possible the government made a mistake?? Lower-back pain is one of the major hazards of nursery work and, according to the latest estimates, these types of injuries account for 25% of all workers' compensation claims in the US. Back in 1994, a government research agency called the National Institute for Occupational Safety and Health (NIOSH) reviewed the published literature and concluded that there just wasn't enough evidence to recommend the use of back belts or safety corsets for workers who do a lot of lifting. And, being the dutiful public servant that I am, I passed on this information in the January, 1995 issue of FNN - "Back Belts May Not Protect While Lifting".

A recent study by the University of California at Los Angeles (UCLA) casts some doubt on the NIOSH conclusion, however. The study used corsets made of black lycra polyester which were worn by workers at Home Depot stores in Southern California. The research was tightly controlled and the principal researcher visited the stores to make sure that the corsets were being worn properly (back belts should be cinched tightly when lifting but loosened or removed at other times). The initial results show that the back belts may be beneficial after all. The biggest benefit was for workers who were under 25 or older than 55 years of age, and women were helped more than men. To validate these findings, NIOSH has just initiated a similar study at Wal-Mart Stores. We'll keep our ears to the ground and let you know more information as we hear of it.

Source:

Rundle, R.L. Back corsets receive support in UCLA study. The Wall Street Journal, Oct. 9, 1996.

Cooperatives

In our continuing effort to keep FNN readers informed of the various nursery networks and services we are highlighting the **Southern Forest Nursery Cooperative,** which is headquartered at Auburn University in Auburn, AL **(Figure 11).**

Figure 11. The Southern Forest Nursery Cooperative is headquartered at Auburn University, AL and serves forest and conservation nurseries in the southeastern states.

Mission: To develop and disseminate technologies for the production and utilization of forest tree seedlings in the southeastern United States.

Brief Historical Background and Current Programs: The Nursery Cooperative was formed in the early 1970's when a task force recognized that nursery managers in the Southeast were facing severe pest management issues. Following this emphasis, the Coop initially devoted considerable research effort to developing effective weed and disease control technologies and to transfer this knowledge to nursery managers. During the 1980's, the Coop program moved more into the area of seedling quality as research showed that nursery related factors such as seedling size, fertility, and health had a significant affect on seedling performance after outplanting. In recent years, Coop programs have become even more diverse.

Staff: Several School of Forestry faculty work with the Coop on research, technology transfer, and development activities, including:

Ken Mc Nabb,
Associate Professor and Coop Director

David South,
Professor (Nursery Management)

Scott Enebak,
Assistant *Professor (Pathology)*

Lisa Samuelson,
Assistant Professor (Physiology)

Mark Dubois,
Assistant Professor (Economics)

The Coop also employs two full time Research Associates; Dr. Bill Carey in Forest Pathology, and Allan Bradley, M.S. in Forest Economics; two full-time technicians and a half-time secretary. The coop currently has six Masters level graduate students and has a position for one more in the area of nutsedge control.

Cooperators: The Nursery Management Cooperative currently has 26 full members consisting of 13 forest industries, 10 state forestry organizations, two private nurseries, and the USDA Forest Service. There is one Associate Member, which is a separate membership category with different responsibilities and privileges.

Research: The Coop has a very active research program that includes at least 25 individual research projects covering four general areas:

1. Evaluating new pesticides
2. Refining cultural practices
3. Minimizing environmental impacts
4. Defining the "optimal" seedling

Examples of individual projects include: testing new hardwood nursery herbicides, methyl-bromide substitution, slow-release fertilization, plant growth promoting rhizobacteria, chlorophyll fluorescence, nitrate modeling, seedling quality interactions with silvicultural options, and seedling storage.

Technology Transfer: Technology transfer is an essential component of the Coop program. Not only are there periodic Research Reports and Technical Notes which are distributed to the membership, but the Coop also has a biennial newsletter and special publications such as a recently completed "Nursery Herbicide Label Book" which contains current labels for nursery herbicides. Each year, a "Contact Meeting" is conducted where nursery managers learn of recent Coop accomplishments along with special presentations by invited speakers. In 1996, they offered a basic nursery management shortcourse for the first time. One of the most important benefits the Coop provides to the membership is a diagnostic service which helps identify nursery pests at the request of individual members.

Program Development: The Coop develops a plan of work during the annual Advisory Committee meeting which is used as a basis for the following year's activities. This plan of work is based on the Coop's Strategic Plan and addresses the three basic components of the Coop program—research, technology transfer, and coop development. Faculty and staff are encouraged to participate in regional, national, and international meetings to further their own knowledge base, communicate with others and highlight the role of the Auburn Coop in the development of nursery science.

For more information on the Southern Forest Nursery Cooperative, contact:

Ken McNabb
Auburn University
School of Forestry
Auburn University, AL 36849
Tel: 334/844-1044
Fax: 334/844-1084
E-mail: mcnabb@forestry.auburn.edu
WWW: http:/www.forestry.auburn.edui coops/sfnmc/sfnmc.html

E-mail Addresses and World Wide Web (WWW) Sites

As I stated in the last FNN issue, we're accumulating a list of E-mail addresses and World Wide Web (WWW) Sites and will list them on the Forest Service Home Page. If you would like me to list your nursery or company WWW page, send the address to us. We've included a E-mail and WWW address location on the Literature Order Form on the back page.

New E-mail Address for FNN:"nurseries @ aol.com"

Please note that I have changed my E-mail address to America On-Line (AOL), and make the change in your computer address file. It should be an easy one to remember!

FNN World Wide Web (WWW) Home Page: "http://willow.ncfes.umn.edu/snti/snti.htm"

We arc designing a Home Page that will be headquartered at the Northeastern Area site in St. Paul, MN. As is the case with most things that I am involved with, we are way behind where I would like to be. I really thought that we would have the Home Page up and running by this time but we are still in the construction phase. In the meantime, have patience!

We envision a site that contains a variety of technology transfer services:

- Directories of forest and conservation nurseries and seed suppliers.
- A full set of Forest Nursery Notes including back issues.
- A list of Forest Service nursery and tree improvement publications and how to order them.
- Cross-references to other sources of information like the nursery cooperatives
- Information on how to contact the Forest Service nursery and tree improvement specialists

As with everything, however, the project is taking longer than expected but we still hope to have it fully operational in the next couple of months. So, check us out the next time that your are surfing the Net.

Native Grasses:

•http://www.batnet.com/rwc-seed/juicy.gossip.one.html

•http://www.batnet.com/rwc-se,cd/juicy.gossip.two.html

•http://www.batnet.com/rwc-seed/juicy.gossip.three.html

Anyone interested in the collection, genetics, or propagation of native grass seed will be interested in visiting these Home Pages. Craig Dremann is the co-owner of The Reveg Edge in Redwood City, CA and has gathered a wealth on information in the newsletter that he calls *Craig's Juicy Native Grass Gossip & Research*. Each of the above home pages is a different issue. One of the features that I especially appreciate is the linkage to the Forest Service nurseries who are producing native grass seed and container seedlings for revegetation projects. Craig also distributes the newsletter in hard copy for those without internet access. If you would like more information, you can reach him at:

Craig Dremann
The Reveg Edge
PO Box 609
Redwood City, CA 94604
Tel: 415/325-7333

Editorial

The Costs and Impacts of Technology Transfer

The beginning of a new year is a good time to take a hard look at what you are doing and why you are doing it. Since my primary job is providing technology transfer (TT) to people who grow forest and conservation plants, I decided to review the various methods that I use to provide TT and assign some new priorities. In the process, I learned several new things and thought that I'd share some of them with you.

There are many options when it comes to providing TT, and I have listed them in a matrix for ease of comparison **(Table** 7). The first major distinction that I made is between "individual" and "group" contacts. The first category refers to one-on-one contacts where I am providing services to one person at a time. Because of my increased workload as National Nursery Specialist, some individual contacts such as nursery visits to provide TT will have to be a much lower priority.

Other individual TT methods includin[g] telephone inquiries, letters, FAXes, and E-mail will continue to receive high priority. The telephone has been a popular method of TT delivery for decades and is still a good way to provide one-on-one assistance. One of the drawbacks with telephone calls, however, is that they represent an interruption to the person you are calling. I don't know about you, but phone calls break my concentration and it always takes me some extra time to get back to what I was doing before the call.

Writin[g], and answering letters and other correspondence has always been a big part of my job. I get mail from around the world requesting copies of publications or asking for information. Since I don't have a secretary, I write all my own correspondence and even print mailing labels. One of my latest triumphs has been learning how to print laser labels from the Forest Nursery Notes mailing list and I even know how to print the bar codes used by the US Postal Service. A few years ago, I didn't have to worry about mailing costs because they were considered part of overhead for which I just paid one overall fee. With government cost cutting, however, I now have to pay for all mailing and so I've done some cost comparisons. Mailing a 1 lb. (0.45 kg) package of publications by first class mail was costing me from $3.00 to 15.00! By changing to library rate mailing, the same package costs only S1.50 to $3.00—a considerable savings.

FAXes are very popular with many of my correspondents, especially from foreign countries where ordinary mail is either slow or just unreliable. One interesting thing that I found out about FAXing is that computer FAXes can be expensive. A hard copy FAX through a typical FAX machine costs me around 50.04 per page. Compare that to some types of computer FAXes which can cost around 50.75 per page with some servers like MCI mail. So, if you have to use a computer FAX, use software like WINFAX and you'll only pay for the long distance call.

E-mail is the newest addition to my daily load of correspondence, and I dutifully check my inbox several times a day. (Note the change of my E-mail address on inside cover or in Nursery Networks section). After looking into the costs of E-mail, I decided to change internet servers. MCI mail is fast and convenient but charges by both the number and length of the message and so my monthly E-mail costs were running from S20 to $50!! Changing to America-On-Line which has an unlimited monthly fee of $19.95 including E-mail was a much more economical option.

We've all been bombarded with news of the World Wide Web (WWW) and how it is going to revolutionize information transfer. I'm not so sure about this, but we're following the trend and have established a SNTI (Seedlings, Nurseries and Tree Improvement) Home Page—see the Nursery Networks section for the URL. Economically, a WWW Home Page will be very cost effective because, once we pay the personnel costs to have the material uploaded, it will be available to anyone for 24 hours a day, 7 days a week. For someone who has a computer and subscribes to an internet server, they can access a wide variety of technical information for less than $20 per month. My major question about TT efficiency over the WWW involves access. One article that I read said that only one-third of US households had computers and a survey of FNN subscribers is even more limited. Only 6.5% of FNN subscribers who filled out and returned their Literature Order Forms reported that they had access to the WWW. I suspect that this number is conservative and will undoubtedly increase, but it still poses some interesting questions about equatability of service.

So, you will be noticing some changes as we continue to evaluate the economics of our various TT services. I feel that information should be free to everyone and so find it irritating to have to compromise quality to save a few bucks, but I guess that's the way the world is going. If you have any suggestions on how we can be doing a better job, we'd sure appreciate hearing from you.

Source:

Landis, T.D. 1991. The Container Tree Nursery Manual - an experience in technology transfer. Combined Proceedings, The International Plant Propagators' Society 40: 151-154.

Table 7. Comparison of different Technology Transfer (TT) methods

TT Methods	Type of Contact	Program Impact: Time	Program Impact: Cost	Effectiveness Period	Specialist Efficiency Ratio	New Priority based on Workload
Telephone Inquiries	Individual	Low	Low	Short-term	Low	High
Letters, FAXes, and E-mail	Individual	Low	Low	Short-term	Low	High
Nursery Visits	Individual	Medium	High	Short-term	Low	Low
Newsletters (FNN)	Group	Medium	Low	Short-term	High	High
Workshops	Group	Medium	Medium	Short-term	Medium	High
Conferences	Group	High	High	Short-term	Medium	Low
Proceedings	Group	High	Medium	Long-term	High	Medium
Journal Articles (TPN)	Group	Medium	Low	Long-term	High	Low
Technical Manuals (CTNM)	Group	High	High	Long-term	High	Medium
World Wide Web (WWW)	Group	Medium	Low	Long-term	High	Medium

*= Specialist-to-User ratio, assuming that a ratio of one specialist to many users is most efficient.

Horticultural Humor

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"C'mon, Dad. You look great for 50...compared to, let's say, Keith Richards."

I passed this milestone this month!

Dan

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New Nursery Literature

There are two classes of literature offered through this service: Special Orders, and Articles Available on the Literature Order Form:

Special Orders (SO)

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

SO. Suppliers of Beneficial Organisms of North America. 1997. Hunter, C. D. Sacramento, CA: California Environmental Protection Agency. Environmental Monitoring and Pest Management Branch. 32 p.

This 1994 edition lists the commercial suppliers of over 120 different insects, mites and other multi-celled organ-**isms (Figure 12)** that are used for biological control in the US, Canada, and Mexico. Note that single-celled organisms such as bacteria and fungi are defined and regulated as pesticides by the United States Environmental Protection Agency and are not included in this directory. The 1997 edition will be available in March but, in the meantime, a copy of the 1994 edition can be viewed on the World Wide Web on the following homepage: http:// www.cdpr.ca.gov/docs/dprdocs/goodbug/organism.htm

Order from: California Environmental Protection Agency
Dept. Of Pesticide Regulation
Environmental Monitoring and Pest Mgmt.
1020 N. Street, Rm 161
Sacramento, CA 95814-5604
Tel: 916-324-4100
Fax: 916-324-4088
E-mail: chunter@cdpr.ca.gov

Cost: Free

Figure 12. Encarsia formosa *is a wasp that is used for biological control of the greenhouse whitefly (drawing by Linda Heath Clark from Hunter 1994)*

SO. Black spruce cutting propagation at the Pépinière de Saint-Modeste. Tousignant, D.; Périnet, P.; Rioux, M. 1996. Saint-Modeste, QC: Ministère s Ressources Naturalles, Pépinière de Saint-Modeste. 38 p. (Also available in the original French version)

This spiral-bound report does an excellent job of describing an innovative propagation system for producing stecklings (rooted cuttings) of genetically-improved black spruce. The Saint-Modeste nursery has developed the Bouturathéque production system in which cuttings are collected year-round from greenhouse-grown stock plants and rooted in containers within special lighted rack propagation structures. After the cuttings are rooted, they are acclimated in conventional greenhouses, transplanted into larger containers or bareroot beds where they grow to shippable size in two or more years. This publication is well-illustrated with excellent graphics and color photographs.

Order from: Pépinière de Saint-Modeste.
Ministère des Ressources naturalles
410, rue Principale
Saint-Modeste, QC GOL 3W0
CANADA
Tel: 418-862-5511
Fax: 418-862-0564
E-mail: dtstmod@icrdl.net

Cost: FREE

SO. Propagation of Pacific Northwest Native Plants: a Manual, Volume Two. Rose, R.; Chachulski, C.E.C.; Haase, D. L. 1996. Corvallis, OR: Oregon State University, Nursery Technology Cooperative. 73 p.

The first publication in this 3-part series was announced in the July, 1996 issue of FNN. This second volume lists biological descriptions and both seed and vegetative propagation methods for 40 more native plants from sedges to small trees, as well as a glossary of propagation terms. The authors are still collecting information for the third and final volume which will be completed early next year. Then, all this information will be updated, compiled, and republished as a single book.

Order from: Forestry Publications Office
Oregon State University
Forest Research Laboratory 227
Corvallis, OR 97331
USA
Tel: 541-737-4271
Fax: 541-737- 3385

Cost: FREE

SO. A **Guide to the Biology and Use of Forest Tree Seeds.** Leadem, C. L. 1996. Land Management Handbook 30. Victoria, BC: British Columbia Ministry of Forests, Research Branch. 21 p.

This softbound publication begins with an examination of the basic principles of tree seed biology and then discusses how to practically apply this information in nurseries. The text is well-written and handsomely illustrated with both B/W photographs and line drawings; for example, the relatively new stratification-redry technique is compared to traditional stratification and a control **(Figure 13).** Although oriented to Pacific Northwest tree species, these basic principles will be useful to both nursery workers and reforestation specialists in other regions.

Order from: Ministry of Forests
Forestry Division, Services Branch
Production Resources Section
PO Box 9528, Stn. Prov. Gvt.
Victoria, BC V8W 9C3
CANADA
Tel: 250-387-6719
Fax: 250-356-2093

Cost: FREE (Limited Time Only)

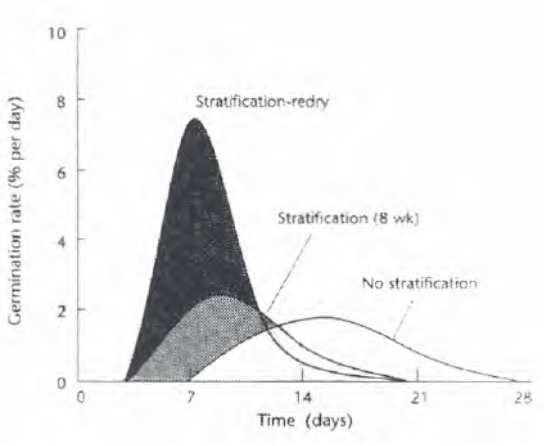

Figure 13. The stratification-redry technique resulted in significantly faster germination of these Abies amabilis *seed compared to the traditional cold-wet stratification (Leadem 1996)*

Articles Available on the Literature Order Form

Copies of the following journal articles or publications are free and can be ordered using the Literature Order Form on the last page. Subscribers should circle the appropriate number or letter on the form and return it to us. Note that there are two restrictions:

I. Limit in the Number of Free Articles: In an effort to reduce mailing costs, we are limiting the number of free articles that can be ordered through our Forest Nursery Notes (FNN) literature service. From now on, all FNN subscribers will be *restricted to 25 free articles* per issue. If you still want additional articles, then you will have to order them on a fee basis from the librarian who maintains the FNN database. Make another copy of the Literature Order Form, circle the numbers of the additional articles, and mail or FAX it to:

Donna M. Loucks
Forestry Information Specialist
174 Jones Road
Centralia, WA 98531 USA
Tel: 360-736-2147
Fax: 360-736-5629

2. Copyrighted Material. Items with © are copyrighted and require a fee for each copy, so only the title page and abstract will be provided through this service. If subscribers desire the entire article, they can order a copy from another library service (see above address).

A. **National Proceedings, Forest and Conservation Nursery Associations.** Landis, T.D.; South, D.B., tech. coords. 1996. Gen. Tech. Rep. PNW-GTR-389. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 282 p.

This proceedings is a compilation of 51 papers which were presented at the regional meetings of the forest and conservation nursery associations in the United States in 1996. The Southern Nursery Association meetings was held in Salem, OR on June 25-27, 1996; the Northeastern Forest Nursery Association Conference was held in New England, CT on August 19-22, 1996; and the Western Forest and Conservation Nursery Association meeting was held in Salem, OR, on August 20-22, 1996. The subject matter ranges from seed collection and processing, through nursery cultural practices, to harvesting, storage, and outplanting.

Bareroot Production

Bottom-kind hardwoods for today's market. Rentz, R. IN: National proceedings, Forest and Conservation Nursery Associations, p. 38-40. Landis, T.D. and South, D.B., tech. coords. USDA Forest Service, Pacific Northwest Research Station, General Technical Report PNW-GTR-389. 1996.

2. *Cultural practices to improve survival and growth of loblolly and white pine seedlings.* Dierauf, T. IN: National proceedings, Forest and Conservation Nursery Associations, p. 53-58. Landis, T.D. and South, D.B.. tech. coords. USDA Forest Service, Pacific Northwest Research Station, General Technical Report PNW-GTR-389. 1996.

3. *The effect of irrigation and root pruning on the growth of sycamore (Acer pseudoplatanus) seedlings in nursery beds and after transplantation.* Hipps, N. A.; Higgs, K. H.; Collard, L. G. Journal of Horticultural Science 71(5):819-828. 1996.

4. *Effect of plant densities and root pruning on seedling quality of three hardwood species.* Mishra, K. K.; Feret, P. P. Indian Journal of Forestry 19(2):164-173. 1996.

5. *Seedling conditioning for improved outplanting survival in chir pine (Pinus roxburghii Sargent).* Dhiman, R. C.; Joshi, N. K.; van Dorsser, J. Indian Forester 122(5):371-376. 1996.

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

7. *Software for the green industry.* Farwest Magazine 40(8):122-123, 125-128. 1996.

8. *Taking the pain out of ergonomics.* Burris, K. Farwest Magazine 40(8): 114-117. 1996.

Container Production

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