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Pacific Northwest Region

State and Private Forestry

Cooperative Programs

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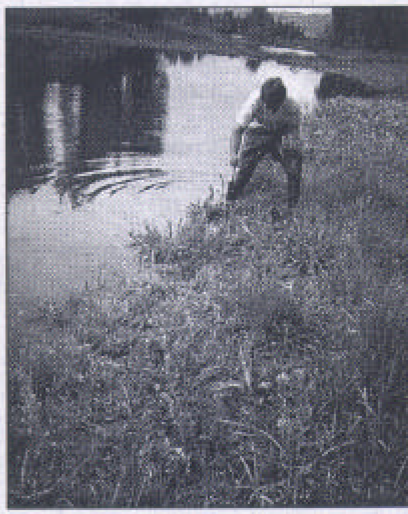
Forest Nursery Notes



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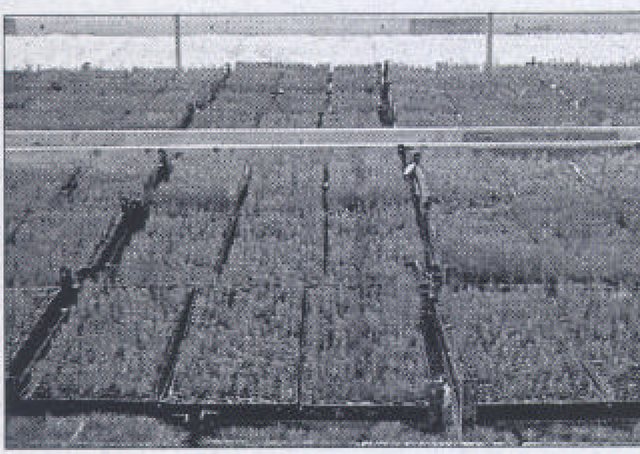

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Mosaic-pattern Stunting

Forest Nursery Notes
Production Team

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Thought for the Day

"Honor those that seek the truth, but beware those who have found it"

—*A*nonymous

I like this quotation because it reminds us that we should retain a healthy skepticism in our work and in our lives. Many of the problems that we encounter in our nurseries are more complicated than they appear, and we have to look a little deeper to find the real truth. It is always tempting to accept things at face value but it is usually better to resist the obvious conclusions. Quick decisions are often not the best ones, so take time to think problems over. You'll be glad that you did

Guest Editorial

I hope that all of you realize that I try to be impartial in everything that I write for FNN. Pat Burke of Bitterroot Restoration, Inc. wrote me recently and took exception to my pro-government nursery editorials in the last couple of issues. So, I invited him to write a guest editorial in this issue to refute some of the points that I had made. My objective in those articles was to show some of the services that government nurseries can provide and I did not intend to slight private nurseries in any way. So, read Pat's editorial and let's continue the dialogue!

Please Update Your Address

Our FNN mailing list is always out of date so we would like to make sure that we have your latest address. 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, check your telephone and FAX numbers 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!

Updated Directory of Forest & Conservation Nurseries

Just another reminder that we are updating the national nursery directory on our WWW home page. If you haven't already done it, fill-out and return the form in Table 10 in the Nursery Networks section.

Nursery Meetings and Workshops

This year's **Southern Nursery Association Conference** will be held on **July 13-16, 1998** at the Lafayette Hilton and Towers in Lafayette, LA. Lafayette is the French capital of Louisiana and lies in the heart of Acadiana or "Cajun Country". The technical sessions will include discussions of nursery culture of both pines and hardwoods, as well as updates on herbicides, methyl bromide, organic matter amendments and other topics. We will also be visiting the Beauregard Nursery and the Louisiana Forest Seed Company. For last minute details, you can contact:

Charlie Matherne
Louisiana Dept. of Agriculture and Forestry
PO Box 1628
Baton Rouge, LA 70821
USA
Tel: 504/925-4500
FAX: 504-922-1356
E-mail: charlim@ldaf.state.la.us

The **Northeastern Forest Nursery Conference and Workshop** will be held at the Wyndham Hotel in Annapolis, MD on **July 27-30, 1998**. The technical agenda contains presentations on nursery labor issues, state and national nursery perspectives, fumigants, organic matter, and a nursery panel on seedling packaging. The tours will include the Ayton State Tree Nursery and a private wetland plant nursery called Environmental Concern. If you need additional information, give Richard a call:

Richard Garrett
Maryland Dept. of Natural Resources
Ayton Tree Nursery
3424 Gallagher Road
Preston, MD 21655
USA
Tel: 410/673-2467
FAX: 410/673-7285

The **Forest Nursery Association of British Columbia (FNABC)** will host a joint meeting with the **Western Forest and Conservation Nursery Association (WFCNA)** on **August 10-13, 1998** at the Dunsmuir Lodge which is near Victoria, BC in CANADA. Dunsmuir Lodge is a great conference facility with beautiful views of the North Saanich peninsula and the surrounding bays. Technical presentations will include talks on national and international forest nursery issues, sessions on nursery culture, seedling contract specifications, vegetative propagation, seedling health, and native plant propagation. Nursery tours and a trip to the BC Forest Museum will round out the program. Contact Susan Zedel for a registration package, but call the Lodge directly for room reservations:

For Registration Packages:
Susan Zedel
Ministry of Forests
PO Box 9501
Victoria, BC V8W 9C1
CANADA
Tel: 250/356-1598
FAX: 250/356-0472
E-mail: Susan.Zedel@gems8.gov.bc.ca

For Motel Reservations:
Dunsmuir Lodge
PO Box 2369; 1515 McTavish Road
Sidney, BC V8L 3Y3
CANADA
Tel: 250/656-3166
FAX: 250/656-1999
E-mail: dunsmuir@uvic.ca

A **Refresher Course for Container Nursery Managers on Fertilization and Irrigation** is being offered by the Forest Research Nursery at the University of Idaho on **November 3-4, 1998.** This novel workshop is designed for both new and experienced growers who wish to increase their practical skills and understanding of container seedling fertilization and irrigation. Topics include a review of essential plant nutrients, irrigation monitoring, techniques for scheduling and conducting efficient fertilization and irrigation applications, monitoring water and growing media, and record keeping. Informal classroom discussions will be enhanced with "hands-on" laboratory exercises in the nursery greenhouses so students will "learn by doing". Course registration is $350 and enrollment is limited. For more information, please contact:

Kas Dumroese
Forest Research Nursery
University of Idaho
Moscow, ID 83844-1137
USA
Tel: 208 /885-3509
FAX: 208/885-6226
E-mail: < dumroese@uidaho.edu >
WWW: http://www.uidaho.edu/cfwr/forres/nursery/refresher.htm

The **Western Region of the International Plant Propagators' Society** will be meeting at the Ontario Airport Marriott Hotel in Ontario, California on **November 4 to 7, 1998.** These IPPS meetings always cover a wide range of basic plant propagation concepts, techniques, and technologies, and are an excellent opportunity to expand your horticultural horizons. The theme for this year's meeting is "Propagation in the Americas" and will include many interesting talks and field trips to local growers. For the latest information, contact:

Eugene K. Blythe
Monrovia Nursery Company
PO Box 1385
Azusa, CA 91702-1385
USA
Tel: 818/334-1264
FAX: 818/334-3126
E-mail: g_blythe@lightside.com

A **Native Plants: Propagation and Planting** conference will be held at the LaSells Stewart Center at Oregon State University in Corvallis, OR on **Dec. 9-10, 1998**. The conference will be jointly sponsored by the Nursery Technology Cooperative at OSU and the USDA Forest Service. The technical sessions will focus on seed collecting, processing, and propagation; vegetative propagation techniques; and an entire section devoted to types of outplanting projects that utilize native plants. To register or just get more information:

Conference Assistant
Oregon State University
College of Forestry
202 Peavy Hall
Corvallis, OR 97331
USA
Tel: 541-737-2329
FAX: 541 /737-4966
E-mail: duncanp@ccmail.orst.edu
WWW: http://www.coforst.edu/cof/extended/conferen/native/index.sht

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The **Annual International Conference on Methyl Bromide Alternatives and Emissions Reductions** will be held **December 7-9, 1998** in Orlando, Florida. Stan Barras is on the program committee representing forestry issues and is looking for presentations by scientists as well as practitioners on alternatives to methyl bromide. These can be a wide range of efforts including cultural, biocontrol, physical as well as other chemicals.

For Information on Paper and Posters:
Stanley J. Barras
USDA Forest Service, VMPR (ICEN)
PO Box 96090
Washington, DC 20090-6090
USA
Tel: 202/205-1532
FAX: 202/205-6207
E-mail: sbarras/wo@fs.fed.us

For General Information about the Conference:
Methyl Bromide Alternatives Outreach
144 W. Peace River Drive
Fresno, California 93711-6953
USA
Tel: 209/436-0691
FAX: 209/436-0692
WWW: http://www.epa.gov/ozone/mbr/altmet98.html

The **Southwestern Growers' Meeting** will be held on **February 8 to 11, 1999** in Los Lunas, NM. The host for this meeting will be Mike Melendrez of. Our focus topics for this year include irrigation techniques and water management, and native plant propagation and, as always, the meeting format will be informal discussions. Contact John Harrington or myself for the latest information:

John T. Harrington
New Mexico State University
Mora Research Center
PO Box 359, State Highway #518
Mora, NM 87732
Tel: 505/387-2319
FAX: 505/387-9012
E-MAIL: joharring@nmsu.edu

The **IUFRO Working Party on Diseases and Insects in Forest Nurseries** will meet on **August 1-5, 1999** at the Suonenjoki Research Station, Finland. For more information, contact

Aria Lilja
Finnish Forest Research Institute
P.O. Box 18
01301 Vantaa,
FINLAND
E-mail: arja.lilja@metla.fi

The Auburn University School of Forestry is hosting a meeting of the **IUFRO Working Party on Nursery Operations** to address "The Interaction between Seedling Stock Size and Plantation Silviculture and Productivity". The meeting intent is to provide a forum for a discussion of affects of seedling size on the biological and economic feasibility of silvicultural practices such as chemical and mechanical site preparation and control of competing vegetation. A special half-day session will address nursery and silvicultural practices for forestation of adverse or difficult sites where survival is the primary objective. For more information, contact:

Ken McNabb
Auburn University
School of Forestry
M. White Smith Hall, Rm. 108
Auburn University, AL 36849
Tel: 334/844-1044
FAX: 334/844-4873
E-mail: mcnabb@forestry.auburn.edu
WWW: http://www.forestry.auburn.edu/coops/sfnmc/intro/contact.html

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Crop Scheduling with Computers

Detailed crop planning is one of the basic tools of a successful nursery manager. Growing schedules provide a good way to record the various steps in crop production and how they relate in time. They also serve as visual time charts of the type of propagation environment that must be maintained, the various cultural operations that must be done, and the amount of labor that will be needed from seed preparation to seedling shipment.

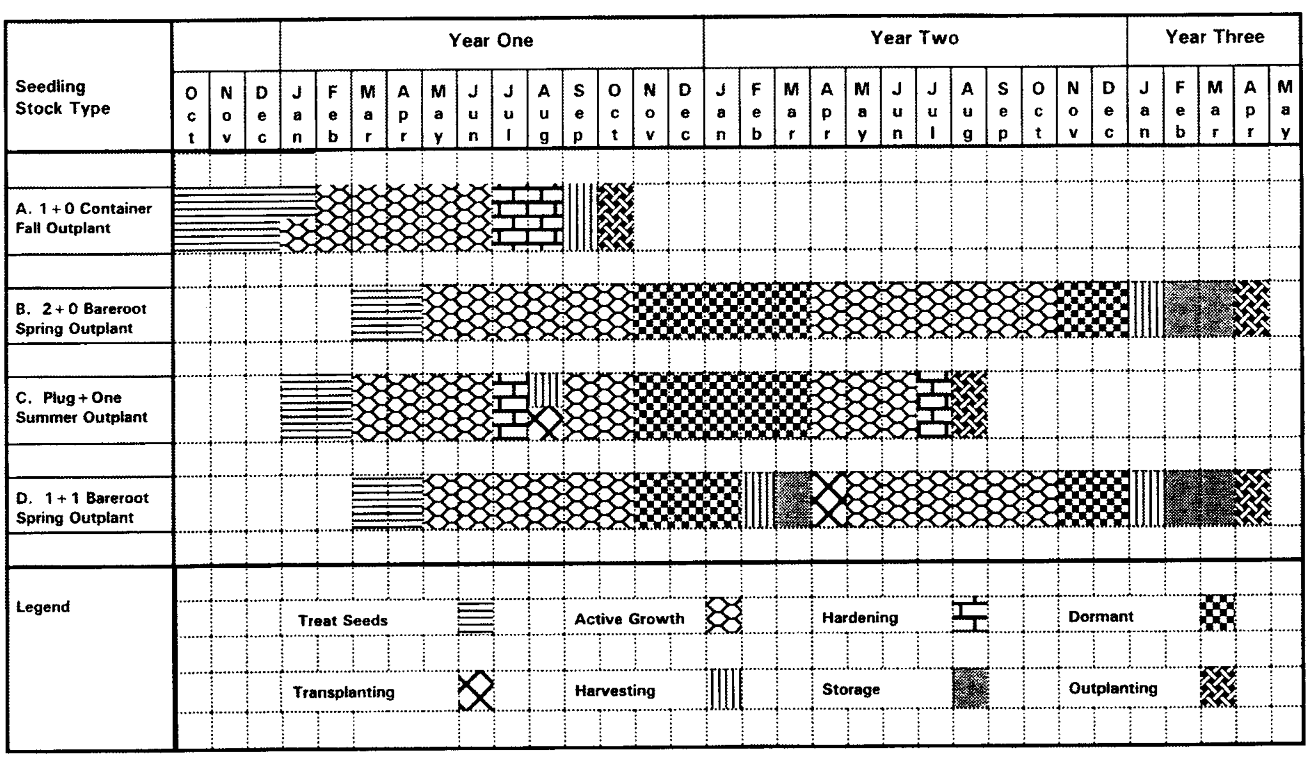
The format for a growing schedule can be as simple as a handmade chart on graph paper or as detailed as a commercial scheduling calendar. If you haven't already found out, growing schedules are easy to construct with modern word processing or spreadsheet computer software programs. The sample schedules in this article were developed in Corel WordPerfect 8.0® in a couple of hours using the "Table QuickCreate" feature. Microsoft Word' and other programs have similar capabilities. Not only are computer growing schedules easy to design, but multiple hard copies can be printed and given to workers or posted around the nursery. In addition, computer files are easy to store to make permanent records.

There are many different types of growing schedules but I have come up with three: **Crop Production schedules, Space and Facilities schedules,** and **Cultural schedules.** For each, the format is basically the same—time is plotted in columns along the top of the chart with cultural factors in rows along the left side. Time intervals in the columns will vary from weeks, to months, to years depending on which factors you are tracking and the amount of detail that you want. All growing schedules are filled-out in the same way-backwards. Start with the date that the crop must be shipped and work backwards, blocking out sections of time for the various operations until you reach the date at which the crop must be started. Once the overall time frame of the growing schedule is complete, then information can be easily typed into the cells. Visual enhancements like background shading and special fill designs make the information even easier to illustrate and understand.

Crop Production schedules. These long-term growing schedules help visualize the "big picture". Crop production schedules typically are designed on a month-to-month time scale, and include all phases of nursery production from presowing seed treatments to outplanting (Table 1). Thus, crop production schedules often cover more than one year.

Because many nursery customers fail to appreciate how long it really takes to grow forest and conservation species, crop production schedules are particularly useful for explaining all the various steps in the nursery process

Table 1. Crop production schedules for four typical stock types with different outplanting seasons



and the amount of time involved in each. For example, a crop production schedule will illustrate that it is necessary to ship seeds to the nursery several months prior to sowing, especially if germination tests and presowing seed treatments are necessary. These growing schedules are also useful in illustrating how different seedling stock types are produced, the time required to grow them, and when each would be available for outplanting (Table 1).

Space and Facilities schedules.

This second type of growing schedule is organized by months and goes for the entire crop cycle. Space and facilities schedules are particularly useful in container nurseries that produce multiple crops per year or move crops between various growing facilities. However, they can also be used for bareroot crops to show the sequence of the various cultural practices through the growing season. Combined with site maps, space and facilities schedules give a comprehensive picture of how much area each crop will require in the greenhouse or seedbed. In addition, they help schedule time and allocate space in processing and storage facilities as well as the required labor, equipment, and supplies.

For example, consider a space and facilities schedule for a crop of western white pine which will be grown in a greenhouse for fall outplanting (Table 2). Note that seeds must be received at the nursery by September of the year prior to sowing because this species requires an unusually long 90 to 120-day cold, moist stratification treatment. Because it is a one-year crop, the seeds must be sown in mid-January to allow enough time for seedlings to meet target specifications by the shipping date. This sowing is significantly earlier than normal and the space and facilities schedule helps illustrate this requirement. These schedules also show that workers will be needed during late fall to clean used containers in the headhouse and to sterilize the greenhouse before sowing. A sowing line must be assembled during early January and then crews will be needed again in late February for thinning. A small crew will be needed in July to move the seedlings from the greenhouse to the shadehouse. The final labor requirement will be in September when the packing line needs to be assembled so that seedlings can be graded, packed, and shipped during the fall outplanting window

Table 2. Space and facilities schedules show location, labor, equipment and supplies for a specific crop; in this case, a 1+0 container crop for fall outplanting (See #A in Table 1)

YEAR ONE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Seedling Growth Stage									Seed Stratification			
Facility Space										Refrigerator and Headhouse		
Labor Needs										Clean Containers and Greenhouse		
Equipment and Supplies									Seed		Growing Media and Fertilizer	

YEAR TWO	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Seedling Growth Stage	Establishment Phase		Rapid Growth Phase				Hardening Phase		Harvest	Outplant		
Facility Space Requirements	Greenhouse							Shadehouse				
Labor Needs	Sowing	Thinning					Moving		Packing	Loading		
Equipment and Supplies Required	Sowing Line						Conveyor		Packing Line	Conveyor		

(Table 2). This visual scheduling of equipment and labor needs can help anticipate and solve problems before they occur. Space and facilities schedules also make scheduling multiple greenhouse crops much simpler.

Cultural schedules. With weeks as the basic unit of time, cultural schedules are the most detailed of the growing schedules. Even though cultural schedules may differ slightly in format, there are several common factors that should be included: the month and week, the number of weeks from sowing, the propagation environment, target seedling specifications, and the growth stage at that particular time in the crop cycle (Tables 3A and 3B). Following this general information, the schedules can list specific cultural processes and operations, such as thinning or seedling inventory, as well as the number of workers that will be needed. Finally, each of the potentially growth-limiting environmental factors should be listed along with any pertinent information about how they will be controlled and monitored.

Cultural schedules will be much simpler for bareroot nurseries because growers have control over fewer factors. As an example, let's look at a four-week segment of a cultural schedule for a 1+1 transplant crop. (Note that this Cultural Schedule can be linked to the Crop Production Schedule-see #D in (Table I). Besides the general descriptive information, irrigation and fertilization are the principal limiting factors that can be controlled in a bareroot facility (Table 3A). In this example, the cultural schedule can be used to document the amount and type of fertilizer to be incorporated into the soil before the seedlings are transplanted and how much water to supply through irrigation. In addition, the schedule can highlight potential disease problems and the timing and application rate for pesticides.

A cultural schedule will typically be more detailed for a container nursery. Let's look at a four-week schedule for a crop of white spruce grown in a shelterhouse at the change between the

Table 3a. Four-week segment of a cultural schedule for a 1+1 bareroot nursery crop illustrating the time of transplanting (See #D in Table 1)

Customer: T. Planter | Species: Douglas-Fir | Seed Source: Zone 072 - 1000ft

Target Specifications: | Height: 18 in. (14 to 22) | Stem Diameter: 7.0mm (>6.0)

Month and Week	4/26-5/2	5/3-5/9		5/10-5/16	5/17-5/23
Weeks from Sowing	54	55		56	57
Propagation Environment	Refrigerated Storage		Transplanting	Transplant Bed	
Seedling Growth Stage	Dormant			Active Growth	
Cultural Activities	Form Transplant Bed				
Irrigation: Amount & Frequency				Irrigate as Needed to maintain Field Capacity	
Fertilization: N Rate & Frequency	Incorporate 18-46-0 at 100lbs/ac into transplant bed				
Pest Management: Monitoring Pesticide and Rate	Check for Botrytis storage mold			Apply Pre-emergence Herbicide	

Table 3B. Four-week segment of a cultural schedule for a container nursery crop illustrating the change from the Rapid Growth Phase to the Hardening Phase

Customer: T. Planter | Species: White Spruce | Seed Source: Zone 864-300m.

Target Specifications: | Height: 17cm (12 to 25) | Stem Diameter: 3.0mm (>2.4)

Month and Week	6/27-7/3	7/4-7/10		7/11-7/17	7/18-7/24
Weeks from Sowing	19	20		21	22
Propagation Environment	Shelterhouse				
Seedling Growth Stage	Rapid Growth Phase		Change Environment	Hardening Phase-Dormancy Induction	
Cultural Processes and Operations	Raise sides in good weather			Raise sides Permanently	
Labor: Crew Size (People Hours)					
Temperature: Day Setpoint(Range)	22°C (20 to 24 °C)			Ambient	
Temperature: Night Setpoint (Range)	18°C (16 to 20°C)			Ambient	
Relative Humidity: Setpoint (Range)	50 to 80%			Ambient	
Light: Ambient	Full Sunlight			Full Sunlight	
Light: Photoperiod Intensity & Duration	20 hour Photoperiod HPS@250 to 400 lux			None-Shut off Lights	
Carbon Dioxide: Rate & Timing	Yes-800 to 1000 ppm when sides are down			None-Shut off Lights	
Irrigation: Amount & Frequency	Wet-Dry Cycle Irrigate at 80% wet block weight			Mild Water Stress-Irrigate at 75% wet block weight	
Fertilization: N Rate & Frequency	Fertigation at 150 ppm N with each irrigation			Fertigation at 50 ppm N with each irrigation	
Pest Management: Monitoring Pesticide and Rate	Walk through every week			Walk through twice each week-Be alert for Botrytis	

Rapid Growth Phase and the Hardening Phase (Table 3B). Note that some environmental factors will be listed as discrete numbers whereas others should be listed as ranges. While the sides of the shelterhouse are down, temperatures are specified as discrete temperature **"set points"** which correspond to the setting on the thermostat or environmental control computer. Because it is more difficult to control precisely and is not as critical to seedling growth, relative humidity is listed only as an **"allowable range".** Note that both temperature and relative humidity are not controlled **("ambient")** after the Hardening Phase is initiated and the sides of the shelterhouse are raised permanently. Other cultural information is recorded according to the nature of the environmental factor and the ability to control it. For example, the carbon dioxide generators are operated only when the sides of the structure are down (Table 3B). As you can see from this example, cultural schedules for container nurseries can be as detailed as you want to make them.

Cultural schedules are valuable not only for planning and reference while the crop is growing, but also can be used to document the actual time and environmental conditions that were used to produce the crop. These "planned" and "actual" records can then be consulted and modified for subsequent crops and, because they are computer-generated, are much easier to store and retrieve than traditional planning calendars.

Summary and Recommendations. Standard word processing or spreadsheet software can be used to construct growing schedules that make it easy to plan nursery crops. Different formats can be designed to fit time frames from weeks to years depending on the objectives. Because they are based around the limiting factors concept, growing schedules can be customized to serve the needs of both bareroot and container nurseries. Although they will vary from nursery to nursery, the important point is not the growing schedule format itself but rather the fact that nursery managers have a detailed plan of action before starting the crop.

In addition, their utility extends beyond the current crop as actual conditions can be recorded along side planned conditions and this information used to fine-tune schedules for future crops. These accumulated cultural records can provide a wealth of information for years to come.

Source:

Landis, T.D.; Tinus, R.W.; Barnett, J.P. 1998. Seedling Propagation Vol. 6. The Container Tree Nursery Manual. Agric. Handbk. 674. Washington, DC: U.S. Department of Agriculture, Forest Service. In Press.

Micronutrients - Zinc

Zinc (Zn), the 25th most abundant element, is widely distributed in agricultural soils but deficiencies still have been documented with several crops. Although examples of wide spread micronutrient problems are rare in forestry, severe Zn deficiencies were found in Australian pine plantations in the 1930's. The diagnosis and treatment of "littleleaf' disease is a classic example of a micronutrient deficiency problem. Unlike the severe problems with iron, however, Zn deficiencies can be controlled relatively cheaply and easily once they are properly diagnosed.

Because of the widespread use of galvanized metal, Zn also has been added to agricultural soils through pollution. Galvanizing is the process of coating iron or steel with Zn to prevent corrosion and galvanized metal is used for many nursery applications including irrigation pipe, and sheeting for roofing and walls of buildings. The process is called "galvanizing" because the Zn coating gives the iron or steel "galvanic," or electrochemical, protection from corrosion.

Role in Plant Nutrition. Zinc has several roles in plant metabolism but knowledge of its many functions is incomplete. Like most of the essential metal micronutrients, Zn functions as an enzyme catalyst and at least four enzymes contain bound Zn. Zinc deficiencies are associated with impaired carbohydrate metabolism and protein synthesis. Impaired protein synthesis can lead to an accumulation of amino acids and amides in plant tissue which in turn can increase susceptibility to attack by high-sugar parasites such as Botrytis spp. The typical deficiency symptoms of stunting, however, can be attributed to inhibited production of auxins, specifically indoleacetic acid (IAA). This can be explained by the fact that Zn is necessary for the production of tryptophan which is one of the precursors for the synthesis of IAA.

Availability and Uptake. Zinc is the third metallic micronutrient that we have discussed but typically is found in much lower concentrations in plants than iron or manganese (Table 4). The Zn content of typical agricultural soil is between 30 and 100 ppm. Because Zn is found in many types of industrial and municipal sewage sludge, nurseries considering sewage

Table 4. 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 5.00
Boron	B	0.002	10 to 100	20 to 100
Chloride	Cl	0.01	10 to 3,000	--------

sludge as a soil amendment will want to do extensive testing beforehand.

Zinc is primarily absorbed as a divalent canon (Zn^{2+}) and therefore high concentrations of other divalent cations, like Cal^{2+}, can inhibit uptake. In addition to calcareous soils, deficiencies are common in organic soils and those that have been overly compacted. High soil phosphorus or the excessive use of phosphorus fertilizers also can inhibit Zn uptake.

Soil microbes apparently increase Zn availability because seedlings have been shown to increase in Zn concentration following soil fumigation. Also, under conditions of low soil availability, *Pisolithus tinctorius* ectomycorrhizae were found to increase the amount of Zn taken up by pecan seedlings.

Diagnosis of Deficiencies and Toxicities. Zinc deficiency is much more common than toxicity and, because Zn is immobile in the plant, symptoms are most prevalent in younger tissues.

Deficiency Symptoms—Classic Zn deficiency symptoms include reduced internode elongation' ("rosetting") and stunted foliage ("littleleaf"). Chlorosis or bronzing of younger leaves is also common with broadleaved species and the characteristic interveinal chlorosis or "mottle-leaf' is so diagnostic in citrus plantations that further soil or foliar analysis is considered unnecessary. Foliar symptoms are not so clear-cut with conifer seedlings, however. In a controlled experiment with Douglas-fir and white spruce seedlings, moderate stunting was the most obvious deficiency symptom (Figure IA). Although foliar discoloration was not observed, the apical needles of the Douglas-fir seedlings were twisted (Figure 1B). Zinc deficiency also retards the normal development of seedling foliage; in radiata pine, for example, seedlings grown under low Zn fertility did not develop mature secondary needles.

Toxicity Symptoms—Excessive amounts of Zn are extremely rare in natural soils. Zinc toxicity is more of a problem in soils contaminated by industrial pollution or

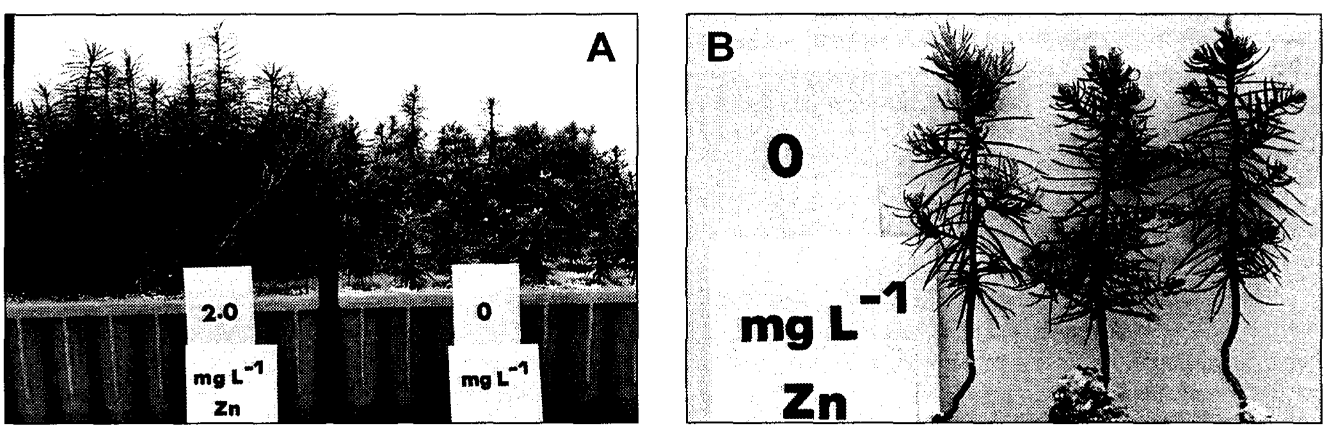


Figure 1. Compared to normal seedlings on the left, the block of Douglas-fir seedlings on the right exhibit the typical deficiency symptom of stunted terminal shoots (A). Shortened internodes ("rosetting") and stunted, distorted needles ("littleleaf") also are diagnostic (B) (from van den Driessche 1989)

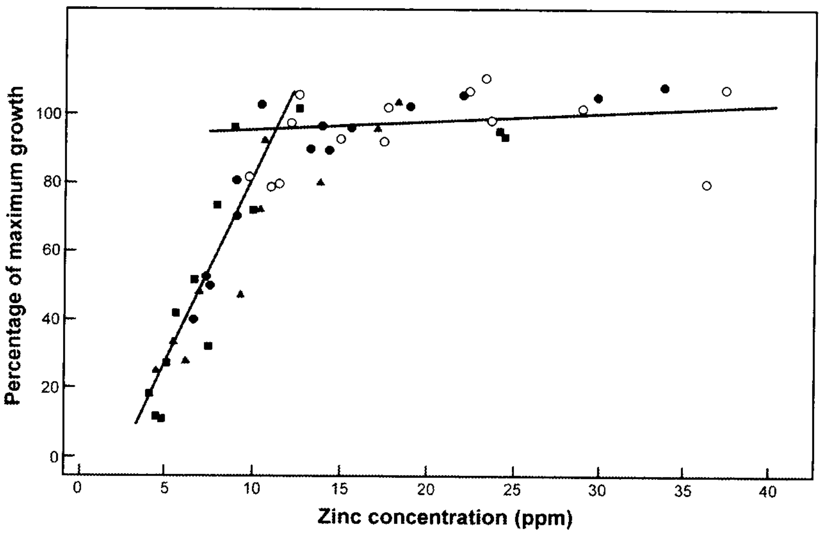


Figure 2. Shoot dry weight of Radiata pine seedlings increased steadily with additional zinc until around 11 parts per million (ppm) (modified from McGrath and Robson 1984)

where sewage sludge with a high content of Zn was used as a soil amendment. Localized problems also can occur where low pH water leaches Zn from galvanized tanks or pipes. Water in new tanks can contain as much as 7 to 8 ppm but this level would not cause problems unless Zn was allowed to accumulate in soils or growing media.

Monitoring Zinc in Nurseries. The availability of Zn to nursery crops can be monitored by chemical analysis of soils, growing media, and seedling tissue.

Analysis of Soil or Growing Media-Availability of Zn is related to pH, and most deficiencies occur above pH 6.0. As mentioned earlier, plants can develop deficiencies on calcareous soils which can be diagnosed either by the high pH or by the excessive calcium content. Diagnosing or predicting Zn availability with soil testing is imprecise because of the difficulty of predicting biological extraction by plants using chemical extraction in the laboratory. Although the diethylenetriaminepentaacetic acid (DTPA) chelating agent has been used successfully as a soil extractant for diagnosing Zn problems, analysis of seedling tissue is a more reliable test.

Tissue Analysis—The normal Zn concentration for seedling tissue can range between 10 and 150 ppm (Table 5), although foliar levels can vary widely by soil type and plant species. Some plants, including birches, poplars, and willows, accumulate excess Zn which can confound interpretation of foliar test results. This emphasizes the need for nurseries to develop their own standards for foliar nutrient levels. The actual physiological requirement for Zn is probably much lower. Controlled tests have shown that healthy Douglas-fir and white spruce container seedlings can be grown with Zn foliar contents of only 0.2 to 2 ppm. With radiata pine seedlings, primary needles at the shoot apex are considered the best tissue to analyze for diagnosing Zn deficiency. In these controlled tests, the critical concentration for optimum growth was 11 ppm (Fig. 2).

Zinc Management. Growers can insure an adequate supply of Zn by maintaining a slightly acid pH and, when warranted, applying fertilizer.

pH Maintenance—as mentioned earlier, Zn becomes less available under high pH conditions. Alkaline irrigation water can cause high pH in soils or growing media. This condition is easy to correct in container nurseries using artificial growing media by injecting a small quantity of mild acid into the irrigation water. The procedure for determining how much acid to use is described in detail in Volume Four: Seedling Nutrition and Irrigation of the Container Tree Nursery Manual.

Merely acidifying the water has not solved high pH problems in bareroot nurseries, however, and therefore soil amendments often are needed. The pH of naturally alkaline or over-limed soils can be lowered with sulfur applications although this can take many years. Calcareous soils are particularly difficult to treat. Not only are these soils highly buffered, but the excess calcium ions that result from sulfur amendments can still cause problems even after soil pH has gone down.

The situation is completely different in container nurseries. Typical peat-vermiculite growing media contain minimal amounts of Zn or other micronutrients, and most are organically bound so they are released slowly. Growers should be cautious of other potential growing media components, however. For example, media containing ground tires have been tested with horticultural crops but were found to have Zn levels of more than 200 ppm. Therefore, container growers should use a standard growing medium, maintain a target pH of 5.5 to 6.5 and provide a continuous supply of Zn through fertilization.

Fertilization-Fortunately, even severe Zn deficiencies have been easy to correct. For example, the stunting in the Australian pine plantations was even be cured by driving galvanized nails into the bole.

Zinc fertilizers come in two types: inorganic salts or organic compounds known as chelates (Table 5). Zinc sulfate is the most common inorganic fertilizer and can be applied as either a soil or foliar application. Zinc chelate consists of Zn2+ ions surrounded by an organic shell that maintains availability under adverse soil conditions, such as high pH, and is effective either as a foliar spray or soil incorporation. Chelation also helps protect against overfertilization because Zn2+ ions are slowly released from the organic complex. Unlike iron, which is available in several types of chelates, Zn is not as affected by pH so the EDTA chelate works well under all conditions.

In bareroot nurseries, Zn sulfate has been effective on many agricultural soils. Zinc is relatively immobile in the soil, however, so incorporation or banding is recommended. Application rates vary considerably with crop species, type of fertilizer, and application method but 10 kg/ha (8.9 lb/ha) of Zn sulfate heptahydrate (Table 5) was found to be effective in bareroot nurseries in British Columbia. Although more expensive, Zn chelates would be justified under calcareous soil conditions where inorganic Zn is quickly chemically bound and rendered unavailable to the crop. In containers, foliar applications of either Zn sulfate or Zn chelate work well.

The balance of micronutrients is often more important than the actual concentration of any one. Therefore, some growers prefer to use micronutrient mixes which can be either incorporated into the growing medium or injected into the irrigation system. Although the actual Zn concentration can vary considerably between the various products, all supply adequate levels (Table 5). Frits are slow-release fertilizers that consist of a mix of micronutrients impregnated in a glass powder which have release rates of up to one year. However, Zn frits were found to be much less effective than other fertilizer sources. In container nurseries, fertigation is recommended whenever possible because it insures that a uniform amount of Zn will be available throughout the growing season.

Irrigation water can supply adequate levels of several micronutrients, or significant levels of competing and complexing ions such as calcium, iron, or bicarbonate. Therefore, growers will want to test their water or even consult an expert before designing a fertigation program.

The most comprehensive list of Zn 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 fertilizers.

Summary. In conclusion, zinc availability is not usually a problem in nurseries with good quality soil

Table 5. Some common fertilizers containing Zinc (Zn)

Fertilizer	Chemical Notation	Zn (%)	Use in Nurseries
	Single Nutrient Fertilizers		
Zn sulfate monohydrate	$ZnS0_4 \bullet H_2O$	35	Foliar or soil applications
Zn sulfate heptahydrate	$ZnS0_4 \bullet 7\ H_2O$	23	Foliar or soil applications
Basic Zn sulfate	$ZnS0_4 \bullet 4\ Zn(OH)_2$	55	Foliar or soil applications
Zn oxide	ZnO	78	Foliar or soil applications
Zn frits	ZnO_2	1.5 to 14	Only for soil applications
Zn chelate	ZnEDTA	14	Foliar or soil applications
	Multinutrient Fertilizers		
Soluble Trace Element Mix – STEM®	Zn as Zn SO_4	4.5	Foliar or soil applications
Micromax®	Zn as Zn SO_4	1.0	Incorporation in growing media
Plant-Prod ® Chelated Micronutrient Mix	Zn as EDTA	0.4	Foliar or soil applications
Compound 111®	Zn as EDTA	0.075	Incorporation in growing media
Osmocote Plus®	Zn as Zn $S0_4$	0.05	Incorporation in growing media

except in areas that have been affected by industrial pollution or sewage sludge. Diagnosis of zinc deficiency can often be made based on the characteristic stunting or rosetting of seedling foliage. Maintaining a slightly acid pH in the soil or growing medium will insure good Zn availability and, compared to iron, correcting Zn deficiencies is relatively easy with either zinc sulfate or chelate fertilizers. Because the balance of micronutrients is so important, growers should consider using a micronutrient mix to prevent either deficiencies or toxicities.

Eric van Steenis of the British Columbia Ministry of Forests assisted with the writing of this article, and his help is gratefully acknowledged.

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Mosaic-pattern Stunting

Good nursery managers keep a close eye on their crops for the first hint of something wrong, but diagnosing the true cause of abnormal growth can be challenging. One of the most puzzling growth patterns that I have seen is where individuals or groups of seedlings are severely stunted, but are interspersed with others that are growing normally. This "mosaic" stunting can occur in both bareroot and container nurseries but the cause is quite different for soil or artificial growing media.

Soil. Mosaic stunting has been observed in bareroot nurseries for many years and with a wide variety of species. There have been many different diagnoses for this disorder but they have been difficult to prove because the stunted seedlings often fail to respond to corrective treatments. About 10 years ago, nursery pathologists in the Great Lakes region did detailed study of "scatter pattern" stunting of 1+0 bareroot white spruce seedlings and found that it had a serious effect on nursery production. Inventories revealed that the stunting ranged from 10 to 35% of the crop and that affected seedlings often did not reach shippable size by the end of the season. After careful study, the ultimate diagnosis was mycorrhizal deficiency because normal seedlings were found to have significantly more mycorrhizal root tips than stunted ones.

Similar symptoms were observed with Douglas-fir seedlings in the Pacific Northwest and the same conclusion was reached - mycorrhizal deficiency. The explanation is logical enough. Soil fumigation kills the mycorrhizal fungi so these beneficial microorganisms must then reinvade the treated seedbeds. Airborne spores of ectomycorrhizal (ECM) fungi enter fumigated seedbeds and reinfect seedlings in a random pattern. These mycorrhizal seedlings develop normally and soon grow much larger than those which remain uninfected and become stunted - resulting in the mosaic pattern. Observations have supported this diagnosis as fruiting bodies of mycorrhizal fungi can sometimes be seen in association with the normally-appearing seedlings (Fig. 3).

Mosaic stunting is especially severe with species which have vesicular-arbuscular (VAM) mycorrhizae such as redwood and many hardwood seedlings. This is

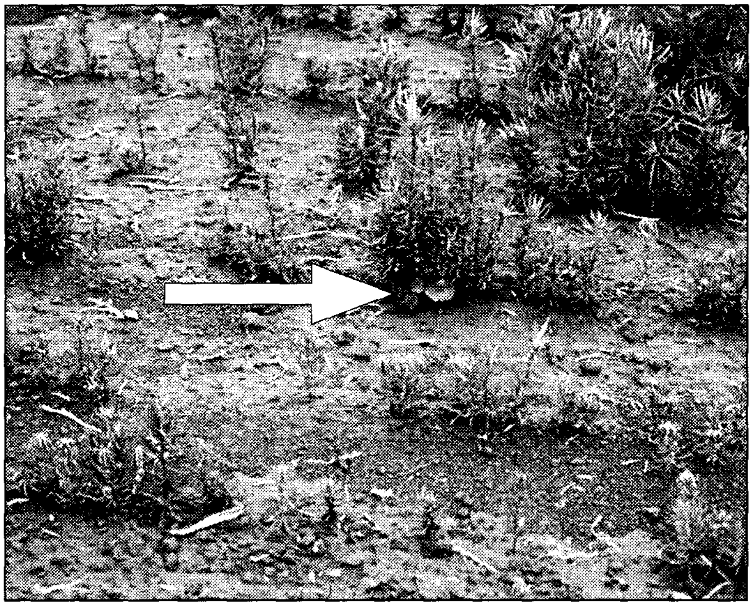

Figure 3. Mycorrhizal fungi make phosphorus available to seedlings but erratic reinvasion after soil fumigation can cause mosaic pattern stunting (note fruiting bodies under larger seedlings.

because **VAM** fungi have relatively large soilborne spores that reinvade fumigated seedbeds very slowly. Unfortunately, the diagnosis of mycorrhizal deficiency has not been confirmed in other investigations of mosaic stunting so there must be more to the story.

A few years ago, I happened to be browsing through an old nursery manual from Great Britain and saw some photographs of "manure" (fertilizer) trials with bareroot Sitka spruce seedlings. One photo in particular caught my eye with because patches of normal and stunted seedlings growing were growing side by side (Fig. 4). The cause for this "patchiness" or "island effect" was phosphorus (P) deficiency. This diagnosis was confirmed when an operational application of superphosphate (0-46-0) fertilizer cured the symptoms.

Reconciling these two diagnoses isn't too difficult as one of the primary benefits of mycorrhizae is that the fungi help seedlings absorb P. This makes sense because young emerging seedlings with small root systems have difficulty obtaining enough P following fumigation unless they become inoculated with mycorrhizal fungi. This hypothesis is further supported by the fact that the stunted Sitka spruce seedlings in the Great Lakes nurseries exhibited purple needle discoloration - a classic P deficiency symptom. Some nurseries have been able to treat mosaic stunting with P fertilizer applications. Timing is critical, however, because the physiological processes leading to stunting take place soon after germination. The limited root system of a germinant is not able to access very much soil and therefore growers should make sure than phosphorus fertilizers are mixed into the top layers of the seedbed. Also, phosphate ions are not mobile in the soil profile so P fertilizers should be applied as an incorporation before sowing. Banding P fertilizer in the zone below the seed is ideal if nurseries have this type of equipment. One easy application method that doesn't take any special equipment is to broadcast P fertilizer on the soil surface, and then mix it into the root zone when the raised seedbeds are formed. Several types of P fertilizer have been effective but concentrated superphosphate (0-46-0) is a good choice. Agronomic research has shown that nitrogen often increases the uptake of P so fertilizers, such as ammonium phosphate (11-55-0), are very effective. Application rates should be based on soil analysis but recommendations typically range from 25 to 50 lbs/ac (28 to 56 kg/ha) of 11-55-0, or 100 to 500 lbs/ac (112 to 560 kg/ha) of 0-46-0.

Mosaic stunting can also be prevented by encouraging mycorrhizae. Most productive nursery soils contain adequate populations of mycorrhizal fungi but inoculation may be warranted in new nurseries or when new areas are developed for seedbeds. Reinoculation

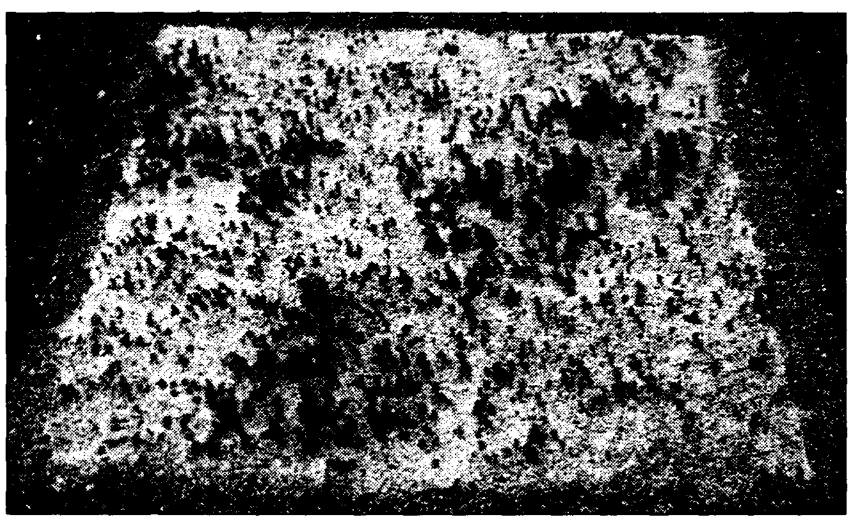

Figure 4. When phosphorus was withheld from these Sitka spruce seedlings in a controlled experiment, they developed a mosaic pattern of stunting which is one of the characteristic symptoms of phosphorus deficiency (from Benzian 1965)

Table 6. Overmixing in a mechanical mixer significantly reduced the size of Sphagnum peat moss particles which can lead to compaction in the container

Mixing Time	Percentage of peat particles in various size classes			
(min)	<0.85mm	<1.18mm	<2.00mm	> 2.00 mm
5	59.4	11.3	11.7	17.6
10	63.8	11.0	8.0	16.6
15	70.2	10.5	7.9	11.4
20	73.5	8.2	7.0	11.3
25	76.4	8.3	6.6	8.7

Source: McDonald (1989)

may also be needed following soil fumigation, especially when growing species requiring VAM fungi. Inoculation options include:

Soil or root inoculum—Incorporating 10% (v\v) of topsoil from beneath known mycorrhizal hosts has been widely used. Since VAM fungi have such a wide host range, some nurseries have grow nurse crops of species such as Sudan grass and then used a mixture of soil and chopped roots as inoculum in fumigated beds.

Nurse seedlings—Transplanting single seedlings that are known to be mycorrhizal is also effective but not practical on an operational scale. Using deficient areas as transplant beds for one season would be more feasible.

Spores-Spores or chopped sporocarps have been successfully used for inoculation of ECM fungi. Spore inoculum also is available commercially.

Cultured inoculum—Many ECM fungi can be grown in pure culture containing vermiculite or other carrier material which can be used as inoculum. VAM fungi also have been grown in pot culture. Vegetative inocula of several ECM and VAM fungi are on the market.

Artificial growing media.
Mosaic pattern stunting also occurs in containers with artificial growing media (Fig. 5). In this case, however, the cause cannot be attributed to phosphorus deficiency or lack of mycorrhizae. Container nursery managers are able to supply their crops with a steady supply of phosphorus, and artificial growing media does not tie-up this nutrient like some soils do. In addition, mycorrhizae are not absolutely necessary during the crop cycle where growers are able to supply all potentially growth-limiting factors. So, the causes of mosaic stunting are different in artificial growing media and there are a couple of possibilities:

Variable compaction of growing media-Porosity in artificial growing media is always critical but especially so in small volume containers. Smaller pores (micropores) must supply seedlings with water and mineral nutrients while larger ones (macropores) provide gas exchange for the roots. Over-compaction of growing media eliminates the macropores which causes reduced growth and eventual stunting. Uneven compaction between individual cells or areas in blocks of containers can result in mosaic seedling growth patterns (Fig. 5). One common cause of compaction is overmixing with

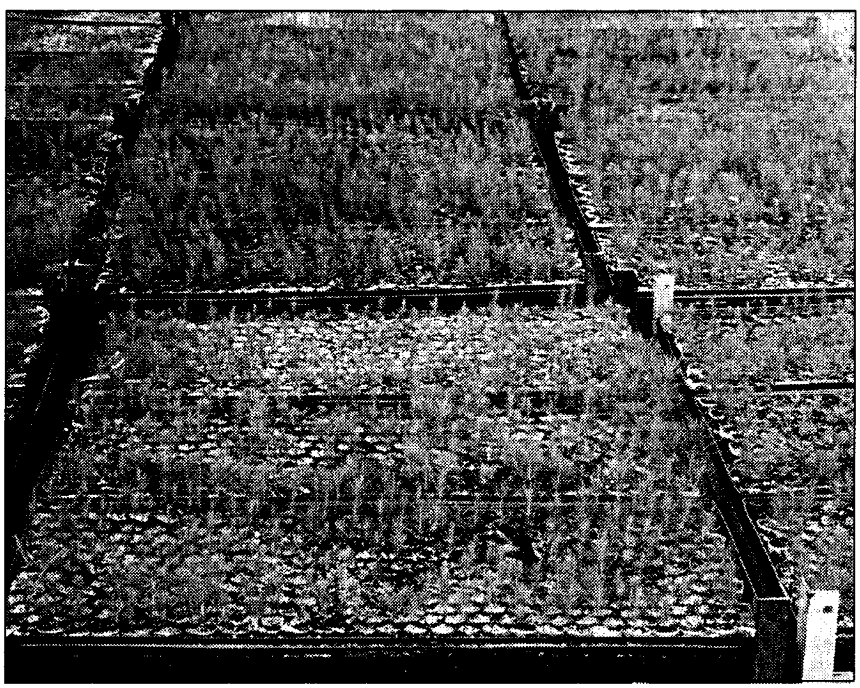

Fig. 5. Mosaic pattern stunting can also occur in containers. In this case, the cause is uneven compaction of the growing medium.

mechanical mixers which reduces particle sizes of fragile growing media components like peat moss and verm iculite. **(Table 6).**

Uneven incorporation of lime or fertilizer - Some growers incorporate "lime" (dolomitic limestone) or slow-release fertilizers into their growing medium before filling the containers. Dolomitic limestone raises the growing medium pH whereas "starter" fertilizers give seedlings a little boost early in the growing season. However, a mosaic seedling growth pattern often results when each cavity does not receive the same amount of limestone or fertilizer. This problem rarely occurs with commercial brands of media because they have specially designed mixing equipment that can evenly incorporate even small amounts of material. It is more common when nurseries mix their own growing medium by hand or with mixers that are not designed for this purpose.

So, in conclusion, these mosaic growth patterns can be puzzling but hopefully these examples will help in their diagnosis and cure.

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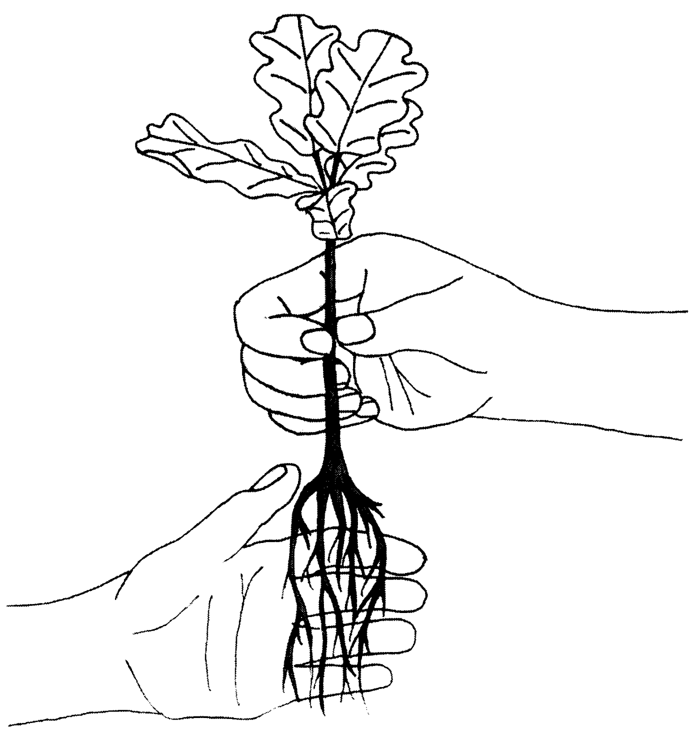

Controlling Crytogams

First of all, what the heck is a "cryptogam"? Well, when writing the Nursery Pests chapter for the Container Tree Nursery Manual, I wanted to find an all-inclusive term for those plant pests which weren't weeds in the classical sense. Cryptogam is an old botany term for plants that reproduce from spores instead of seeds so we can use it as a collective term for algae, moss, and liverworts.

Before we start the game, let's meet our contestants. Algae are simple plants that can be single cells, loose conglomerations of cells, or matted colonies. They reproduce vegetatively by single cell division or fragmentation of colonies, but also have a sexual cycle which produces motile zoospores or thick-walled resting spores. Mosses and liverworts are classified as bryophytes and are multicellular plants with nonvascular stems and simple leaves. Because they lack true roots, bryophytes must depend on small, threadlike rhizoids for the absorption of water and nutrients and anchorage. Mosses and liverworts have complicated life cycles with alternation of generations but, for our purposes, they reproduce sexually by spores or vegetatively by division. Although there are many different species of algae, mosses and liverworts, only a relatively few are nursery pests. In a comprehensive study of cryptogams in forest nurseries in British Columbia, only three species of algae and one each of mosses and liverworts were consistently isolated from containers **(Table 7).**

Unfortunately, nurseries are the perfect home for cryptogams because we encourage them with plenty of water and mineral nutrients. Cryptogams can be a annoyance in bareroot nurseries but they are a serious problem in containers, especially with mufti-year crops. For example, liverworts are one of the most serious pests of 2+0 container crops that are grown in outdoor compounds. Cryptogams are particularly troublesome in seedbeds or container blocks with poor stocking because they thrive on the extra water and nutrients **(Fig. 6A)**. In fact, all of these relatively primitive plants are nitrophilous (they *love* nitrogen) and so thrive in the nursery environment. Cryptogams are resilient pests because, although they need high moisture levels to grow and reproduce, they can also tolerate long dry periods.

Cryptogams have both direct and indirect effects on seedling growth. First of all, they limit water infiltration into the soil or growing medium and intercept water and nutrients meant for the seedling crop. Because of their relatively fast growth rates, mosses and liverworts can quickly overtop and smother small, slow-growing seedlings, such as *Abies* spp. **(Fig. 6B)**. Cryptogams also provide an ideal physical environment for other nursery pests, especially fungus gnats (*Bradysia* spp.). And, although it has not been definitely proven, pathologists suspect that some algae may even produce allelopathic chemicals which inhibit seedling growth.

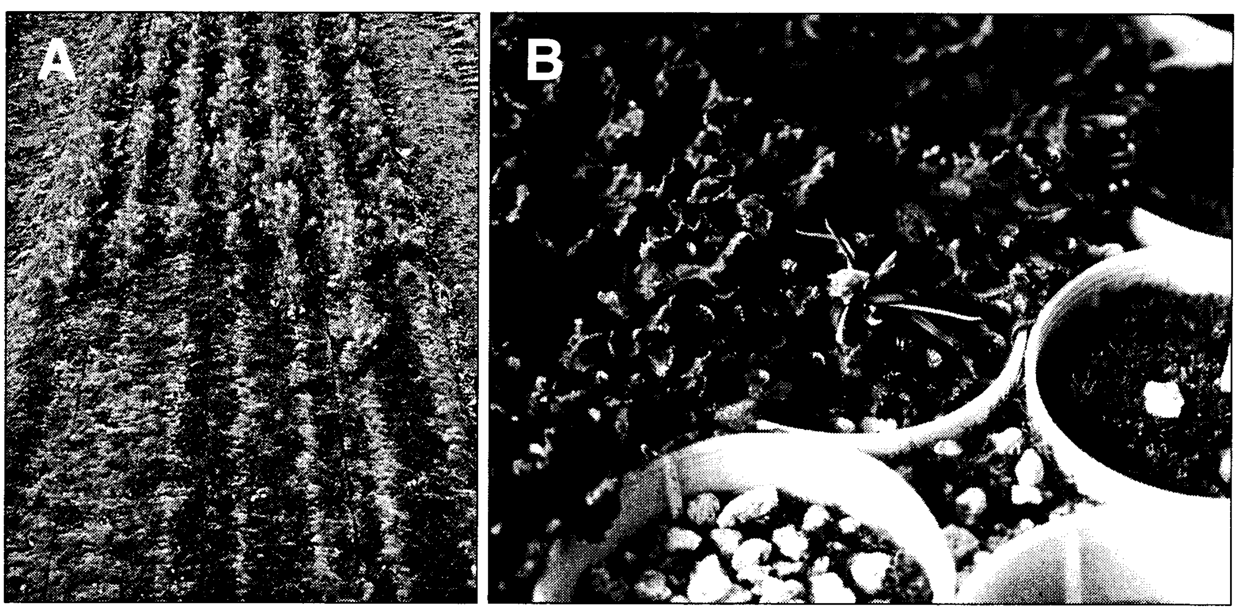

Figure 6A/B - Cryptogams (algae, mosses, and liverworts) are common nursery pests that intercept water and nutrients (A), harbor other pests, and can even physically smother small seedlings (B)

Table 7. Frequency of occurrence and location of common cryptogams within five container tree nurseries in British Columbia

Cryptogams Collected from Containers		Sampling Location and Relative Frequency		
Type	**Species**	**Irrigation Water**	**Growing Media**	**Air**
Algae	*Klebsormidiun; substillissimum*	*0* of 5	0 of 5	5 of 5
	Chlorococcum humicola	*0* of 5	0 of 5	5 of 5
	Chlamydomonas spp.	*0* of 5	0 of 5	5 of 5
Moss	*Bryum argenteum*	*0* of 5	0 of 5	1 of 5
Liverwort	*Marchantia polymorpha*	*0* of 5	0 of 5	3 of 5

Source: Modified from Ross and Puritch (1981)

Algae, mosses and liverworts typically enter the nursery as spores but also can be introduced through vegetative means. For example, the liverwort ***Marchantia polymorpha*** produces gemmae which are small budlike structures that detach from the parent plant and serve as vegetative propagules. Algae are easily carried in water and so can be a serious problem where irrigation water is obtained from surface water sources, especially ponds. However, in the British Columbia study, none of the common cryptogamic pests were found in irrigation water or in samples of commercial growing media. Instead, algal spores were sampled from the air in all the nurseries and spores of the moss and liverwort species were also frequently detected (Table 7). For nurseries that do not sterilize theirs between crops, used containers are undoubtedly one of the major sources of entry.

Because it is impossible to completely exclude airborne spores (Table 7), cryptogams will eventually invade any nursery. Therefore, growers must use cultural controls to prevent their establishment or at least minimize their growth.

Cultural Controls. Prevention is the first line of defense against cryptogams as it is with any nursery pest. If obtained from surface water sources, irrigation water should be filtered to exclude algae. Unfortunately, algal spores are very small (1 to 100 microns) and so specialized filtration systems may be required. Chlorination has been shown to be effective against waterborne algae when done in conjunction with filtration. Used containers should be sanitized between crops with hot water, steam, or chemical sterilants. Bags of growing media should be kept covered to prevent contamination, especially when stored between crops. Nurseries mixing their own media may want to consider steam pasteurization, especially the organic components.

Water is undoubtedly the most critical environmental factor affecting the presence and growth of cryptogams. In fact, you can predict whether a person is a "wet grower" or "dry grower" by the abundance of algae, moss, and liverworts. Many chemical controls will be less effective when applied under excessively wet cultural regimes. So, irrigate only when necessary by using block weights or some other monitoring system. Schedule irrigation early in the day so that the surface of the soil or growing media will dry quickly. Injecting surfactants will help keep surfaces dry and some products have even been shown to have cryptocidal properties.

Cryptogams need relatively high light levels so use shade wherever possible to discourage their growth. Apply weed barrier fabrics under benches in greenhouses and propagation environments. Not only do they physically restrict the growth of algae, mosses and liverworts but the shade prevents their establishment in the first place. Because copper has herbicidal properties, the nav landscape fabrics treatr=1 w :dh Sp>n0 ut® would be a good choice. Seed coverings and mulches should be used after sowing in both bareroot and container nurseries. Not only do they provide a beneficial micro-environment to speed germination, but mulches physically inhibit growth of cryptograms by excluding light. Coarse-textured materials with smooth surfaces are particularly effective because they dry quickly. For instance, grit particles will be more effective than perlite because algae can grow in the rough surface of the latter material. Light-colored mulches are preferred because they reflect sunlight and will not generate high temperatures which could damage young germinants. Finally, encourage rapid seed germination and early seedling growth because, once seedling crown closure is achieved, the heavy shade will stop establishment or growth of cryptogams.

Chemical Controls. Pesticides for controlling algae are called algaecides but, because mosses and liverworts are plants, chemicals used to control them are considered herbicides. Herbicides have traditionally been divided into non-selective sterilants for use in non-crop areas and selective herbicides that can be applied "over-the-crop"(Table 8).

All standard sterilants or disinfectants work well if applied early in the crop cycle and then re-applied frequently enough to keep cryptogams from reinvading. Regular sanitation with greenhouse disinfectants such as Green-Shield® or Physan® prevent cryptogams from even getting established. Although many products can be used, try to select those with the least potential for pollution. Products like Safers® DeMoss are essentially soaps (Table 8) and are therefore more "environmentally friendly" than some other products.

Many pesticides are effective against cryptogams in containers or seedbeds but, as is often the case, label registration is a major restriction. If cryptogams are not specifically mentioned on the label, then this use is illegal. For example, Scythe" is an herbicide registered for use in greenhouses that is effective against cryptograms but they are not listed on the label. A nursery in Washington State discovered that a combination of X-77® surfactant and Captan 50W1 gave good control of moss in containers. Unfortunately, captan is a fungicide that is not registered for this use.

The same situation exists for the fungicide dodine (Cyprex 65W®) which was reported to give good control of liverworts in British Columbia container nurseries.

Fortunately, a few new products are on the horizon that show real potential for controlling cryptogams within the crop. Zero Tol (ZT) (Table 8) is a general disinfectant that attacks cryptogams, bacteria, and fungi through oxidation. Because it primarily works against the spore stage, ZT should be applied twice per week to prevent cryptogams from getting established. It is safe to use and environmentally friendly because its active ingredients break down into water and oxygen. Several container nurseries are currently testing ZT and it will interesting to see if it also can control existing cryptogams.

Mogeton (Table 8) is a herbicide that has been used in Japan since 1971 for controlling weeds in rice paddies, but was observed to also kill algae and mosses. Currently, it is being used to control cryptogams, especially liverworts, in container nurseries in Northern Europe with no apparent phytotoxicity to commercial conifers. I've been hearing rave reviews of this product for the past couple of years and but, again, this product is

Table 8 - Typical pesticides used to control cryptogams in nurseries

Type of Pesticide	Trade Name	Cryptogams Controlled	Active Ingredient	Manufacturer	Label Coverage
Non-Selective: for surfaces and non-crop areas	Algae-Rhap® CU7®	Algae	Copper-triethanolamine complex	Agtrol Chemical	Surface spray and water applications
	Greenshield®	Algae, Mosses	Benzyl ammonium chlorides	Whitmire	General disinfectant & algaecide
	Safers DeMoss®	Algae, Mosses, Liverworts	Cryptocidal soap (Potassium salts of fatty acids)	Mycogen Corp.	Floors, surfaces and structures (Re-registration pending)
	Barespot® Monobor-chlorate	Algae, Mosses, Liverworts	Sodium metaborate + sodium chlorate	Simplot	Seedbeds or open compounds
Selective: can be applied over seedlings	Zero Tol®	Algae, Mosses	Hydrogen dioxide, peroxyacetic acid	BioSafe Systems	General disinfectant & algaecide
	Mogeton 25 WP	Algae, Mosses, Liverworts	Quinoclamine	Agro-Kanesho (Japan)	*** Not registered in US or Canada**

not registered in North America. Currently, the Wilbur-Ellis company is trying to obtain samples under an experimental use permit for eventual Environmental Protection Agency registration.

Many nurseries have found that micronutrient fertilizers also are effective against cryptogams, especially those containing zinc, iron, or copper. For example, ferrous sulfate and zinc sulfate will kill established mosses and liverworts but growers have to be careful not to oveapply them or they can reach toxic levels or induce deficiencies of other micronutrients. This is more of a problem in containers but may have promise in bareroot beds where the larger volume of soils will buffer any adverse effects.

Summary. In conclusion, cryptogams are serious nursery pests that can best be prevented through good sanitation. Managing water is critical for controlling crytogam establishment and growth so apply irrigation judiciously, promote good drainage and encourage ventilation in closed structures. Since they primarily enter nurseries through airborne spores, do not allow cryptogams to get established around the nursery and control existing infestations quickly with disinfectants. It is difficult to chemically control kill cryptogams in containers or seedbeds without phytotoxicity although there are some exciting new products just coming on the market.

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Disinfecting seeds with hydrogen peroxide

Back in the July 1994 issue of FNN, we talked about using household laundry bleach as a nursery disinfectant. The practical benefits of bleach are that it is inexpensive, safe to use, and available around the world. Also, since it is not considered to be a pesticide, bleach has fewer restrictions on its use than other products. Hydrogen peroxide (H202) is another common household product that can be used to control pathogens around the nursery. Since it shares the same practical benefits as bleach, H202 is an ideal candidate for your IPM program. Actually, H202 is superior to bleach in that it breaks down into oxygen and water and so leaves no toxic residue. Because of its strong oxidizing properties, however, H20z can be used to disinfect tools or surfaces around the nursery, but has most widely been used to surface sterilize seeds. (Table 9) H20z is commercially available in 30% and 3% solutions and both have been used in forest and conservation nurseries. A 40-minute soak in 30% HZOZ virtually eliminated all seedborne organisms on Douglas-fir seeds, and also was effective on southern pines with

Table 9. A 4-hour soak in 3% hydrogen peroxide (H202) cleansed seed coats of Fusarium spp. without adversely affecting germination of these Douglas-fir seeds

	Greenhouse Germination (%)	
Douglas-fir Seedlot Number	Control	3% H_2O_2 for 4 h
424	80.0	78.3
479	78.3	81.7
501	87.2	96.1
510	90.6	94.4
1262	79.4	78.9
1270	80.0	85.0
1292	70.6	68.9
4532	63.3	58.3
4605	71.7	64.4
31902	96.1	92.8
Average	79.7	79.9

treatment times ranging from 15 minutes to 1 hour. In particular, longleaf pine seeds are infested with pathogenic fungi. So, the North Carolina Claridge State Nursery operationally soaks their longleaf pine seeds in 30% H_2O_2 to reduce fungal contamination. The procedure is as follows: seed lots of 9 to 11 kg (20 to 25 lbs) are placed in porous nylon mesh bags and soaked for 55 minutes in the H_2O_2 solution at 24 °C (75 °F). Then, the bags are drained and triple rinsed in clean water before being allowed to surface dry.

The more common antiseptic grade of 3% H_2O_2 **(Fig. 7)** is less caustic than the laboratory grade chemical and therefore safer to use. Recent operational trials in British Columbia found that a 4-hour treatment with 3% H_2O_2 was quite effective in reducing seedborne pathogens on seeds of three commercial conifers. For example, seeds from ten coastal Douglas-fir seedlots that were known to be infested with Fusarium spp. were selected for a test. Following normal cold-moist stratification, the lots were soaked in one of four different H_2O_2 solutions (0, 1 and 3%) for one of three treatment intervals (1, 4 and 16 hours). Then, the treated seeds were rinsed in running water, surface-dried and cultured on selective media. After 10 to 14 days, the culture plates were rated for growth of *Fusarium*. All of the 16-hour treatments were too caustic and resulted in seedcoat damage with decreased germination. However, the 4-hour soak in 3% H_2O_2 was consistently effective in removing Fusarium from the seed coats **(Fig. 8)** without

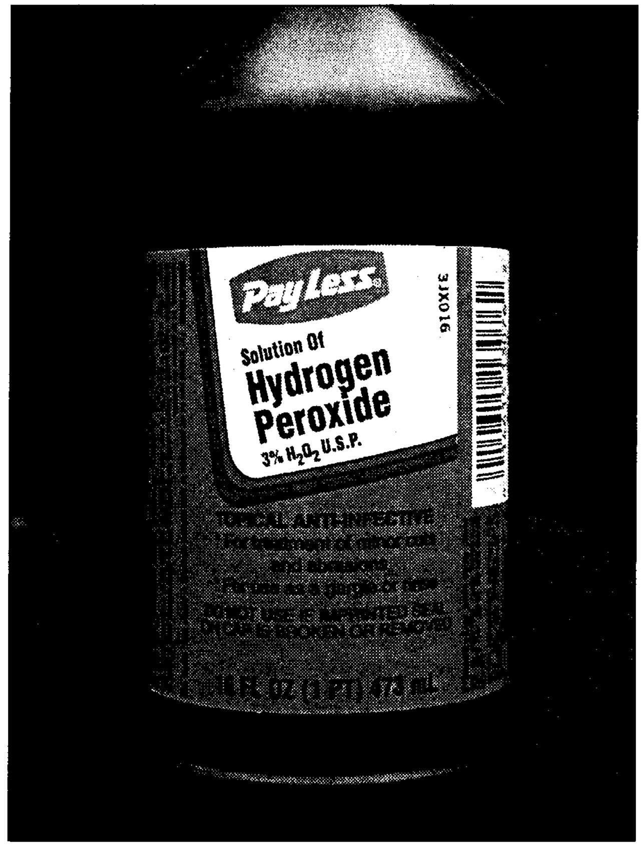


Figure 7. The common medicinal disinfectant hydrogen peroxide is a 3% solution

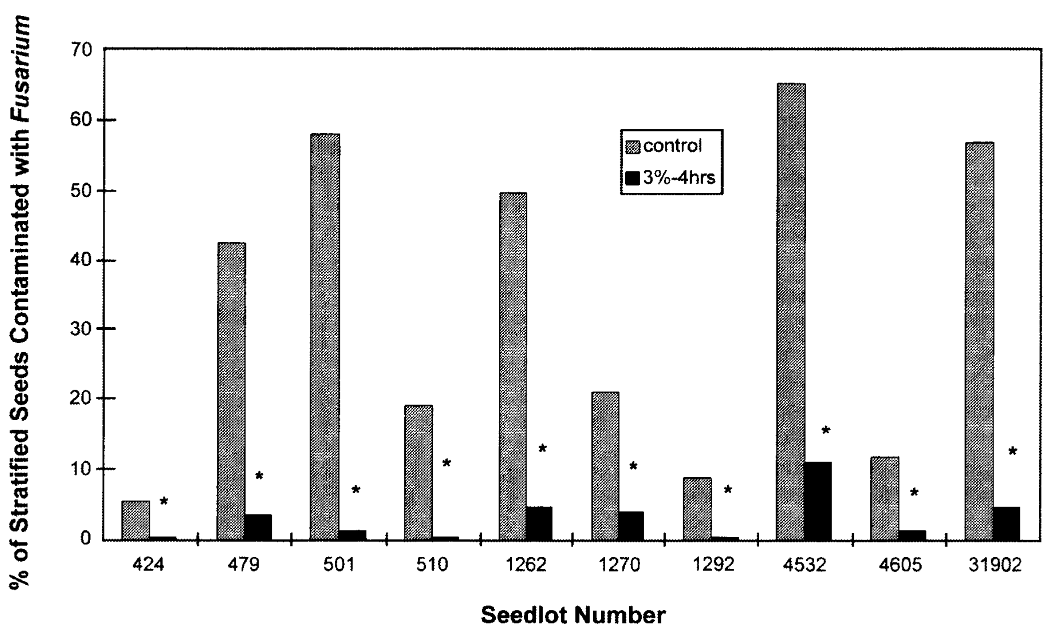


Figure 8. A soak in 3% hydrogen peroxide solution for 4 hours significantly reduced the incidence of the pathogenic fungi, *Fusarium* spp., on these Douglas-fir seeds (from Neumann and others 1997)

reducing germination in the greenhouse (Table 9). Results were just as good for western larch seeds but those of subalpine fir were more sensitive as greenhouse germination was significantly reduced after the 4-hour/ 3% H_2O_2 treatment. This would be expected because seeds of Abies spp. have thinner seed coats than most other commercial conifers. However, the 1-hour/3% H_2O_2 treatment gave reasonably good control without significantly reducing germination.

In addition to effectively sterilizing seed coats, H_2O_2 has been found to increase germination of some pine seeds because it softens their seedcoats and increases permeability to water and oxygen. This was found to be the case in the North Carolina nursery where better seed germination increased longleaf pine seedling density by about 10% after the 30% H_2O_2 treatment. I'm not aware of any test results with 3% H_2O_2 but the beneficial germination effect should be the same once the proper treatment time has been worked out.

Hydrogen peroxide seed treatments should be evaluated for other forest and conservation seeds, not only as a seed disinfectant but also for the potential increase in germination. However, because of variation in seed coat thickness, the choice of 3% or 30% H_2O_2 and the best treatment time will have to be determined on a species by species basis. Nevertheless, H_2O_2 has tremendous potential as a relatively safe chemical to add to your IPM arsenal.

Sources:

Barnett, J.P.; McGilvray, J.M. 1997. Practical guidelines for producing longleaf pine seedlings in containers. Gen. Tech. Rep. SRS-14. Ashville, NC: USDA Forest Service, Southern Research Station. 28 p.

Barnett, J.P. 1976. Sterilizing southern pine seeds with hydrogen peroxide. Tree Planters' Notes 27(3): 17-19.

Neuman, M.; Trotter, D.; Kolotelo, D. 1997. Seed stratification method to reduce seedborne Fusarium levels on conifer seed. Surrey, BC: British Columbia Ministry of Forests, Seed and Seedling Extension Topics 10(1&2): 18-23

RNGR Home Page

We have changed our name on our homepage from Seedlings, Nurseries, and Tree Improvement to Reforestation, Nurseries, and Genetic Resources. Not earthshaking news, but we thought that it was more descriptive.

Besides this cosmetic change, we are also gradually updating the features and adding new material. As we announced in the last issue, we have completed uploading past issues of FNN to the home page ("A" in Fig. 9). We now have all the FNN issues on-line from January, 1992 to the present. The layout of each issue was done by sections so that you can download individual articles. Readers can even order copies of technical articles listed in the New Nursery Literature section of the last 3 issues using an easy pre-addressed electronic order form. We hope to have an index done soon so that the contents of each issue can be viewed quickly and easily.

National Nursery Directory Update. In the last issue of FNN, I mentioned that we are updating the Directory of Forest and Conservation Nurseries on our home page (B in Fig. 9). In our first effort, we asked for nursery managers to contact us but response was less than phenomenal. So, a few months ago, we sent letters and update forms to all the nurseries listed in the 1994 hardbound edition of the Directory. This got a better response but we still haven't heard from many of you. Okay, last chance - three strikes and you're out!! A copy of the update form is provided (Table 10) and, if you want your nursery listed in the Directory, you'd better get your information to us soon. If ***we don't get a response within 4 weeks, we'll remove your nursery from our homepage.***

Check out the new Directory at: <http://willow.ncfes.unm.edu/snti dir/ nurdirl.htm> and you can see how useful the format can be. Net surfers and potential customers will not only be able to learn the location of a nursery but they will be able to send E-mail messages or visit the nursery Web page by direct links.

Native Plant Network. This was another project that I started back in the July, 1997 issue but have never got around to completing. In that issue, we talked about developing propagation protocols for native plants using a standard format. We could then upload them on our home page and eventually we would built a library of information on how to propagate natives. This system has a couple of advantages: first, it is relatively inexpensive compared to trying to publish in hard copy, and second, these computer files would be easy to update.

Well, like most of my great ideas, I haven't had time to follow-up yet. We are making progres, however. When I was back in Colorado last winter, I had the opportunity to work with the staff of the Colorado State Forest Service Nursery on a protocol for propagating quaking aspen by seed (Fig. 10 and 11). They collect and process their own seed and then grow container seedlings in one year. In fact, the aspen seedlings grow so fast that they have to grow them in their shadehouse and have had to limit nitrogen fertilization to maintain a good shoot: root ratio.

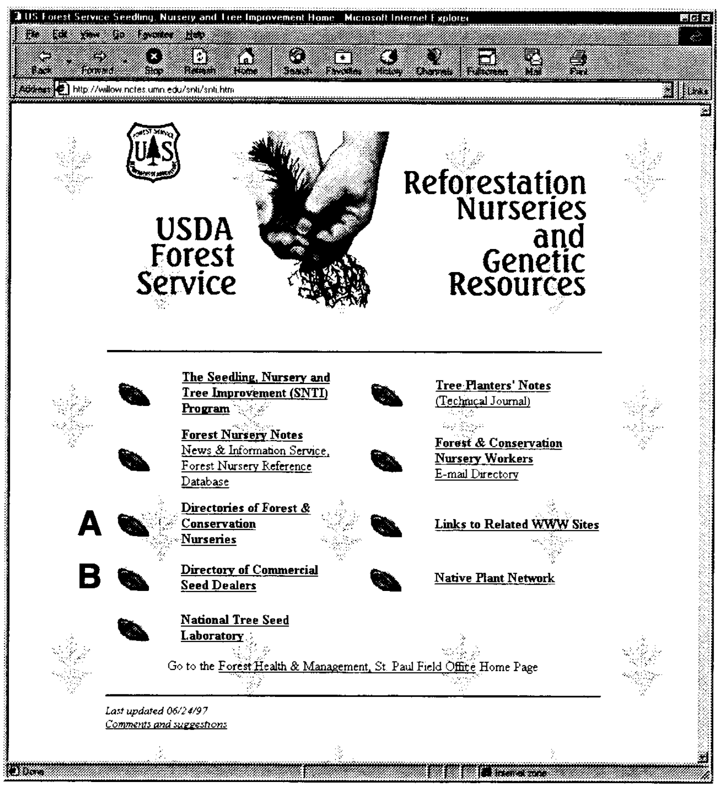


Figure 9. Opening panel on the RNGR home page showing location of Forest Nursery Notes (A) and the Directory of Forest and Conversation Nurseries (B).

Table 10. Update form for the Directory of Forest and Conservation Nurseries (see "B" in Fig. 9)

STATE:	UPDATED:			
Nursery Name & Address	Ownership Type: Federal, State, Industry, or Private	Stock Type: BR or C	Last Season Seedling Distribution	Potential Seedling Distribution
NAME ADDRESS CITY: STATE: ZIP CODE: TEL: FAX: E-MAIL: WWW URL:				

I've also been working with the native plant nursery staff at Glacier National Park in Montana to capture the wealth of propagation information that they have been accumulating over the past decade. Like most of you, they just haven't had time to organize and publish propagation protocols for the wide variety of plants that they have grown. So, I managed to scrape-up enough funding to pay for one of their propagators, Tara Luna, to write-up propagation protocols for over 100 plants ranging from ferns to trees. We're doing the final editing and will be uploading the protocols to the Native Plant Network in the next few months.

I'm interested in working with other nurseries who would like to share their propagation information and would be able to provide funds to pay for salary. If you would like to participate, give me a call or send me an E-mail at < nurseries@aol.com >.

Figure 10. Protocol for seed propagation of quaking aspen at the Colorado State Forest Nursery

QUAKING ASPEN

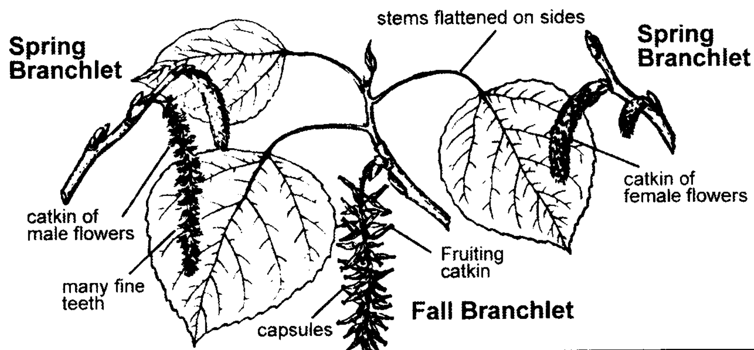
Species: Quaking aspen *(Populus tremuloides)* - POPTRE

Ecotype: Larimer county, 7500-8000' elevation.

Stock Type: Container seedling

Outplanting Site: Colorado

Outplanting Date: April - June



(Continued on page 26)

(Continued from page 25)

Figure 10. Protocol for seed propagation of Quaking Aspen at the Colorado State Forest Nursery

TARGET SEEDLING INFORMATION

Height: 12 in.

Caliper: 4 mm

Root System: Firm plug

PROPAGATION AND CROP SCHEDULING—Seed Propagation

Propagation Environment: Shadehouse

Source of Seeds: self collected

Collection Date: Start looking in early June, but check frequently because seeds develop and blow away within a few weeks.

Seeds/Kg: 3,000,000 **% Germination:** 90%+ % **Purity:** Contains leaf chaff.

Seed Processing: Collect branches with mature yet closed catkins. Put branches in water-filled large garbage cans in a warm enclosed room with little air movement. Within 5 days catkins will open releasing cotton in a controlled fashion. Vacuum up cotton. Separate seeds from cotton in center sieve between two additional standard testing sieves (total of three), middle sieve sized to permit seed passage. Sieve sizes top to bottom: Gilson #18 (1.00 mm), #35 (500 micrometer), #140 (106 micrometer). Gently blowing air from a reversed shop-vac through the sieves removes the seed from the cotton. Seed collects in bottom sieve.

Seed treatments: None, usually collected in spring of year one, seed is sown spring of year two.

Seed storage: Store at -7 °C (20 °F) in sealed glass vial to eliminate drying.

Container Type and Volume: Colorado Styroblock - 492 cm3 (30 in')

Growing Media: Scotts Forestry Mix

Total Time to Harvest: Seedlings can be grown to specifications in five months, stored overwinter in the shadehouse, and ready to ship the following spring. - See Figure 11

Sowing Date: Late May

% Emergence and Date: Germination within 24 hours, cotyledons within 48.

Sowing/Planting Technique: Manual sowing with salt shaker

Establishment Phase: Light misting twice a day until germination. Germination to two true leaf stage takes two weeks and seedlings are thinned to one per container at that time. Regular deep watering twice a week with complete fertigation solution based on 100 ppm nitrogen.

Rapid Growth Phase: Late June to mid-August. Continue twice a week fertigation. Apply VA mycorrhizae beginning of phase. We use a product called Bultize from Buckman Labortories.

Hardening Phase: In mid-August cease fertilizing, flush with clear water, reduce waterings until leaf drop in early October.

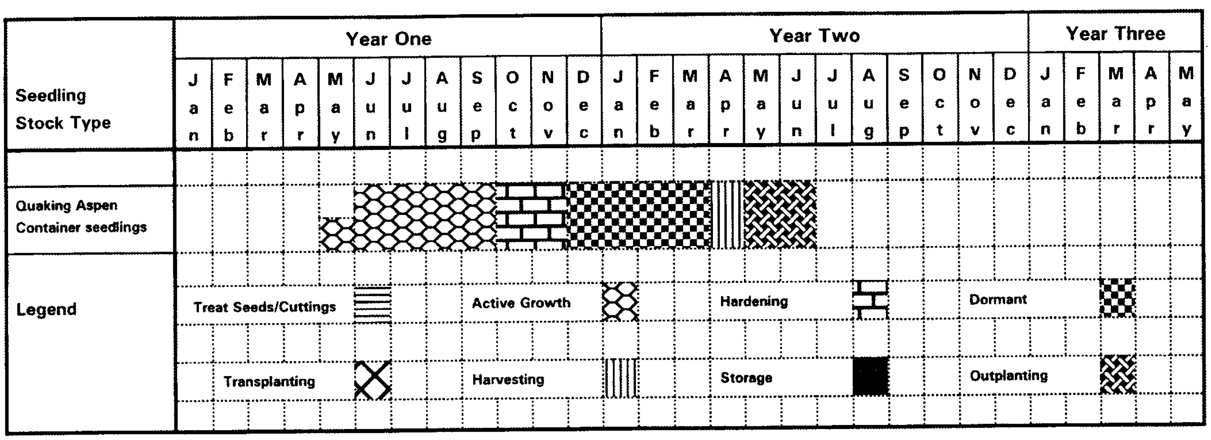
Harvest Date: Seedlings can be graded after leaf drop in early October or prior to shipping the following spring.

Storage Conditions: Outdoor shadehouse.

Storage Duration. October to April

Propagators: Allen Hackleman, Alan Tull, Randy Moench
Colorado State Forest Service
Foothills Campus, Building 1060
Fort Collins, CO 80523
TEL: 970/491-8429
FAX: 970/491-8645
E-MAIL: rmoench@lamar.colostate.edu

Figure 11. Crop production schedule for propagating quaking aspen from seed



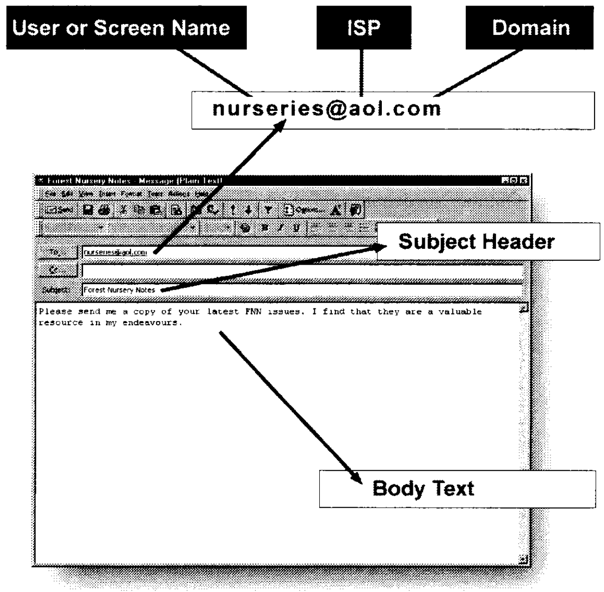


Figure 12. A typical E-mail memo contains the address, a subject header, and a place for the text of your message and can be sent instantly around the world.

The Internet and E-mail

In my mind, E-mail (electronic mail) is a revolution in communication and information exchange. Through the Internet, I can send instant messages to another nursery person on the other side of the world. Exactly what is the internet? Some people use the words "internet" and "web" (World Wide Web) interchangeably but actually, the web is a subset of the internet. The web is a set of files on the internet that can be viewed with a specialized web browser software. The internet, on the other hand, is a physical network. Each individual computer user is linked into a small network (primarily by telephone lines) which in turn is linked to a larger network, and so on until you get to the "backbones" which are actual physical cables which connect major points (Fig. 12). Each computer on the network has an address, called an IP (Internet Protocol) address.

The Internet is based on client/host computing. The host, or server, serves up files at the request of the client computer and the client can access a copy of the information that's on the host computer. All this interchange of information works because of a set of rules ("protocols") that allow the computers to "talk" to each other. The number of host computers connected to the internet has grown from 100,000 in 1989 to about 10 million today. It is projected that by the year 2001, one billion computers will be connected.

Before you can get on-line and start sending E-mail, however, you will need three things: a computer with a modem, an internet service provider (ISP), and some computer software:

Modems. A modem (modulator-demodulator) allows your computer to hook up to the internet via phone lines. If your computer isn't equipped with one, modems can be purchased from computer stores, and also from discount computer catalogs. The main characteristics of a modem is its "speed", which determines how quickly your computer will be able to "talk" to the internet. The fastest speed available today is 56K, but 28.8K is good enough.

Internet Service Provider (ISP). There are many ISPs to choose from although the choices are more restricted in some rural areas. Cost is generally less of a consideration than service as most ISPs will cost around $20 per month for unlimited access time. If you have friends or coworkers who are already online in your area, ask them which ISP they like. Your local computer store is user-to-modem ratio: a low ratio will keep you from always getting a busy signal. If you travel a lot, you might want to choose a large ISP that has local numbers in many cities (*e.g.* America-On-Line). This will let you carry your laptop and access your email wherever you are.

Your E-mail address consists of your "user" or "screen" name (one you choose or one assigned to you by your ISP), and the "domain" which consists of the name and class of your ISP (e.g. "aol.com" = America-On-Line which is a commercial ISP) **(Fig. 12)**.

Internet Connection Software. You will need two types of software to get started with E-mail. The first is TCP/IP (Transmission Control Protocol/Internet Protocol) software which lets your computer talk to the rest of the network. The second type is browser software that lets you see files on your computer. TCP/IP software is now included with most standard computer operating systems but, if not, you can get it from your ISP for free. Browser software is also supplied by most large ISPs, you can purchase it from computer stores, or download it from the internet.

I am a great fan of Email and many of you have found that sending me an E-mail message is easier than trying to catch me on the phone or by FAX. E-mail is quick, cheap, and best of all, is a non-intrusive way to send messages. Most of us are scrambling most of the time that we've at work, and telephone calls tend to break your concentration. E-mail messages are a nice alternative because you can receive them when you have a few minutes and can respond at your convenience. I monitor my E-mail mailbox at nurseries@aol.com every few hours and can check it while I'm at home or even on the road when I carry my portable computer. E-mail is particularly good for international communications because messages are inexpensive and you can even attach computer software files. Finally, you don't have to worry about time zones. As of January, 1997, a total of 194 countries had access to the internet, and more are hooking-up all the time. So, regardless of whether you are technophobic or a technowienie, you should really consider getting E-mail service.

Sources:

Chazanof, J. Internet basics and improving your business. American Nurseryman 187(7): 10, 12.

Rice, C.; Bruce, V. 1997. The Internet: What's out there for you? IN: Landis, T.D.; Thompson, J.R. tech. coords. National proceedings, Forest and Conservation Nursery Associations, 1997. General Technical Report PNW-419. Portland, OR: USDA Forest Service, Pacific Northwest Research Station: 125-131.

I like trees because they seem more resigned to the way they have to live than other things do.

Willa Cather 1873-1947

A Private Nursery Perspective

There are several aspects of the July 1997 and January 1998 Editorials in Forest Nursery Notes on the role of government nurseries that deserve comment. My perspective is not derived from the anti-government sentiments mentioned in the first article. It is rather a matter of economics and unfair competition by governmental agencies with private native plant nurseries and ecological restoration companies. I am the President of Bitterroot Restoration Inc., an ecological restoration firm that provides comprehensive restoration services including the production of site specific, source-identified, native plants for sites throughout the Western United States, Alaska and Canada. We have been doing this for 12 years and I believe we are one of the pioneers in the propagation of native plants and in the field of ecological restoration. Currently we grow over 300 species of native plants with often 15-20 seedlots per species and we provide these in a wide range of sizes appropriate for restoration projects. We work with many federal agencies including the USDA Forest Service, state land management agencies and private companies.

In the July 1997 article, the proud past of public nurseries and their ability to produce inexpensive seedlings are cited as justifications for their continued existence. In the January 1998 article, the recent and continuing conversion of the J. Herbert Stone Nursery to a native plant nursery as a result of the decline in the need for reforestation seedlings is discussed. It is asserted that little is known about native plant propagation and that native plants are not widely available. Hence, the need for Forest Service nurseries to convert to native plant production as the need for reforestation seedlings declines.

I believe that these assertions are wrong and would like to note the following realities.

First, many private nurseries including ours are very advanced in terms of both native plant propagation and research. (Fig. 13). A great deal is known about native plant propagation. One need only look at the range of species and the quality of the plants that we and other nurseries offer. Propagation research by Forest Service Nurseries such as that cited in the editorial is mostly an exercise in reinventing the wheel. Secondly, there is a rapidly increasing, reliable supply, of source identified native plants. Thirdly, the Forest Service is not providing inexpensive seedlings but rather very expensive seedlings at a cheap price. Their pricing reflects only a portion of their costs and the balance is subsidized by the taxpayer. Private nurseries must reflect their real costs of production in their pricing. Therefore, true competition does not exist and the private company necessarily loses.

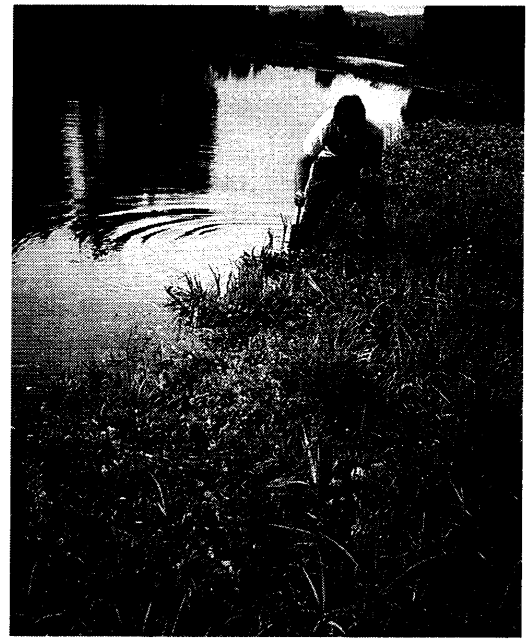


Figure 13. Private nurseries are growing a variety of forest and conservation species, including native plants for riparian restoration projects.

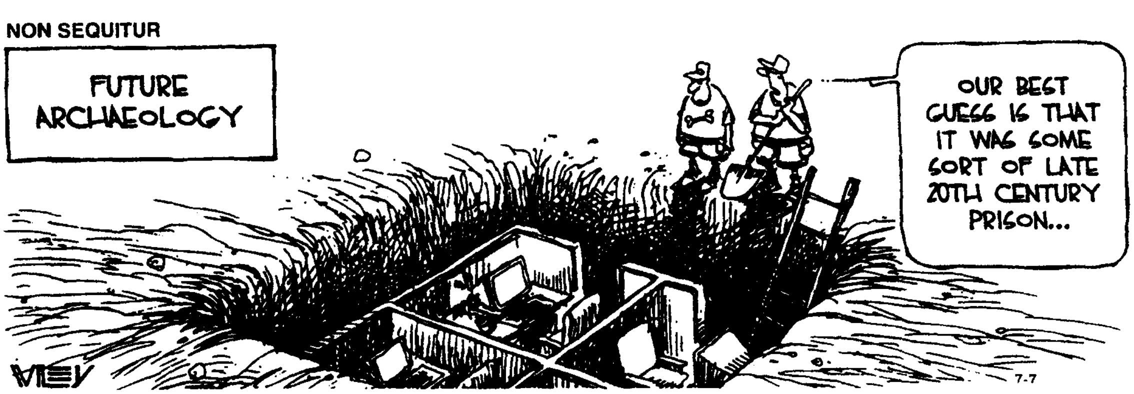
Finally, it is patently unfair for government to be competing directly with private industry. There is no more need or justification for government production of native plants than there is for government production of corn, lettuce, automobiles or steel.

All that we are asking for is a level playing field on which we can freely compete with other companies to produce the highest quality, source-identified seedlings at the lowest true price. Everything that governmental nurseries are now doing can and is being done by the private sector. Indeed, public nurseries have a proud past but the future is with private nursery production of native plants.

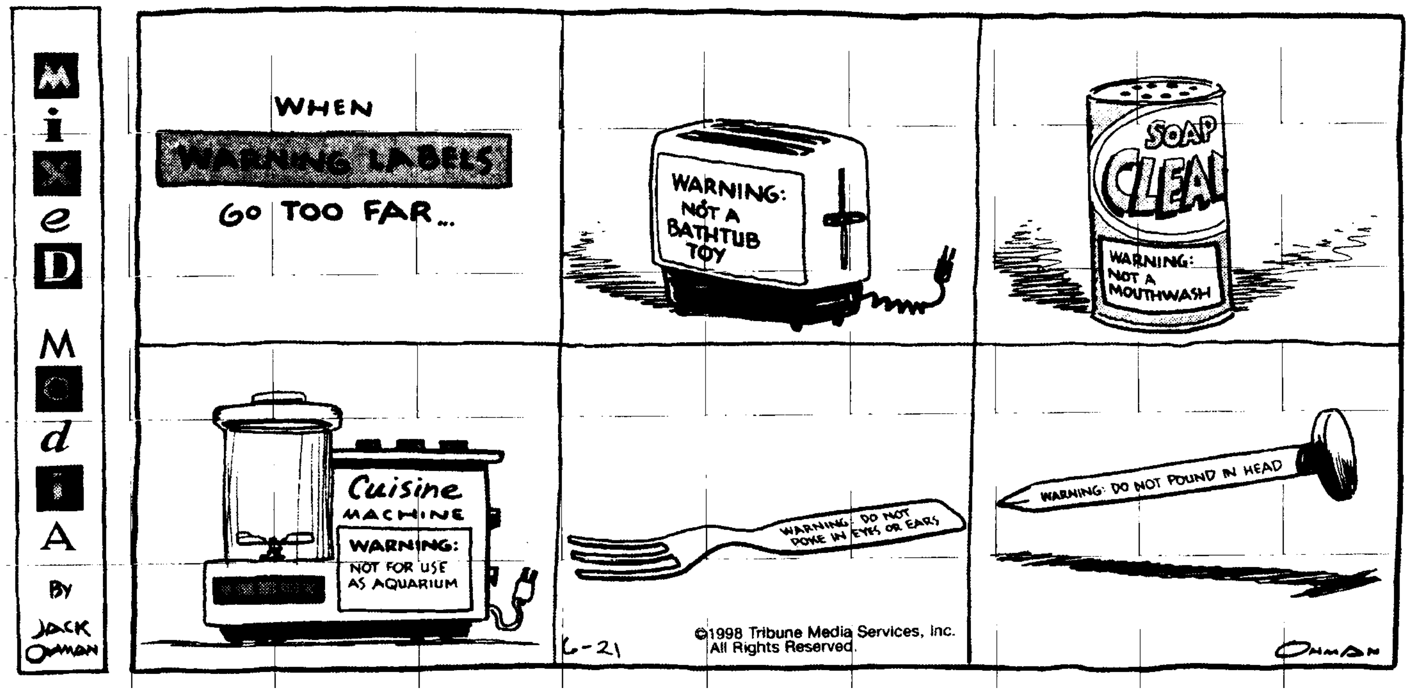
BITTERROOT RESTORATION

Pat Burke, President
Bitterroot Restoration Inc.
445 Quast Lane
Hamilton, MT 59840
Tel: 406/961-4991
FAX: 406/961-4626
E-Mail: pat@revegetation.com
WWW: http://www.revegetation.com

In case you are wondering why FNN is usually late:



What if OSHA labeling was done at home:



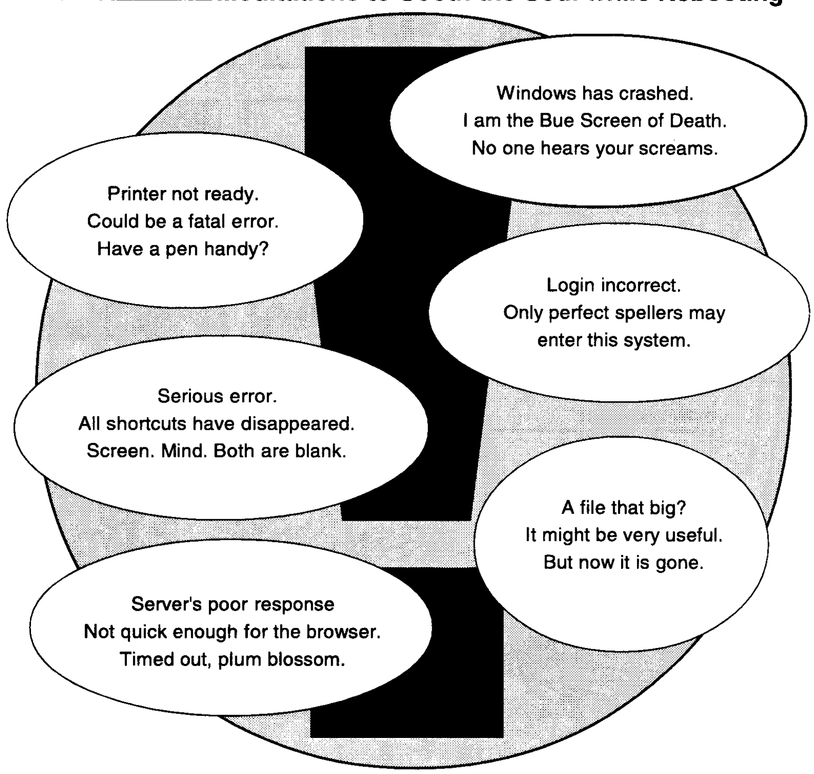
Another Reason to Plant More Trees

The following theory was submitted to a contest by Omni magazine, and sounded reasonable to me:

"The earth may spin faster on its axis due to deforestation. Just as a figure skater's rate of spin increases when the arms are brought in close to the body, the cutting of tall trees may cause our planet to spin dangerously fast"

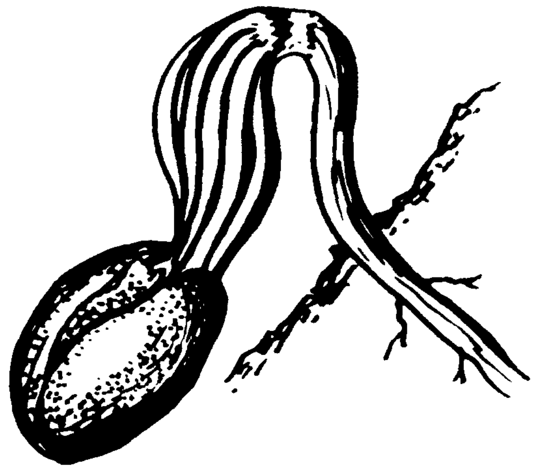
Haiku Computer Error Messages

Meditations to Sooth the Soul while Rebooting



New Nursery Literature

This section contains a listing of all the latest published articles that I could find regarding forest and conservation nurseries. There are two basic categories of literature offered through this service: **Special Orders and Articles Available on the Literature Order Form.**



Special Orders

Special Order (SO) publications are books or other publications that are too long or too expensive for us to provide free copies. Prices and ordering instructions are given here or following each listing in the New Nursery Literature section.

SO. **Tree Planters' Notes, Volume 47, No. 4, Fall 1996.**
This volume contains a 10-year index of past Tree Planters' Notes (TPN) issues as well as a couple of technical articles. So, I thought that offering it as a SO publications would be a good way to advertise the technical content of TPN and how inexpensive it really is ($8.00 per year). Order a free copy and, if you like what you see, you can use the handy order form on the back this issue to subscribe.

COST: Free

ORDER FROM: Write #A on Literature Order Form on the back page of this issue.

SO. Prochazkova, Z.; Sutherland, J.R. eds.1997. **Proceedings of the ISTA Tree Seed Pathology Meeting,** Opocno, Czech Republic, October 9-11, 1996. International Seed Testing Association, Zurich, Switzerland, 114 p.
This spiral-bound publication contains 18 papers presented by authors from 17 countries around the world. A range of topics are covered including detection, biology, and management of seed-borne fungus, bacterial and virus pathogens of temperate and tropical conifer and hardwood seeds. Copies of individual articles can also be found in the Seeds category in the New Nursery Literature in this issue.

COST: 29 CHF (Swiss Francs) + postage

ORDER FROM: Secretariat
International Seed Testing Assoc.
Reckenholzstrasse 191
P.O Box 412
SWITZERLAND
Tel: (41)-371-31-33
FAX: (41)-371-34-27
E-mail: istach@iprolink.ch

SO. **Proceedings of the Forest Seed Collection, Treatment and Storage Workshop.** Czech Republic: Forestry and Game Management Research Institute.

This softbound publication contain many interesting articles dealing with all aspects of forest seeds from around the world. Copies of individual articles can also be found in the Seeds category in the New Nursery Literature in this issue.

COST: $5 for S&H

ORDER FROM: **Forestry and Game Mgmt. Instit.**
Res. Stn. Uherske Hradist
686 04 Kunovice
CZECH REPUBLIC
Tel: 420-632/549-115
FAX: 420-632/549-119
E-mail: vulhmvs@brn.pvtnet.cz

SO. Rose, R.; Chachulski, C.E.C. ; Haase, D.L. 1998. **Propagation of Pacific Northwest Native Plants.** Corvallis, OR: Oregon State University Press. 256 p.

This paperback book contains propagation information on nearly one hundred and forty native plants, and is divided into four sections: shrubs, trees, forbs, and grasses. In addition to propagation techniques, each plant listing features physical descriptions and information on habitat and geographic range. Numerous line drawings and an illustrated glossary make this a valuable new resource for both nursery workers and land managers.

Cost: $21.95+ 2.00 (S&H)

ORDER FROM: **University of Arizona Press**
Tel: 800/426-3797
or 520/621-1441
FAX: 520/621-8899
E-mail: <uapress.arizona.edu>

SO. Eastham, A. tech. coord. 1998. **Provincial seedling stock type selection and ordering guidelines.** Victoria, BC: British Columbia Ministry of Forests. 71 p.

This is an update of the popular 1993 publication-"Provincial seedling stock type selection and ordering guidelines". It is an excellent example of the process that customers should go through to determine the target seedling for their particular outplanting site. Although written specifically for British Columbia, the numerous examples and good illustrations give this spiral-bound publication a much wider appeal.

Cost: Free

Order From: **Ministry of Forests**
Publications Distribution Coordinator
595 Pandora Ave.
Victoria, BC V8W 3E7
CANADA
FAX: 250/356-2093
E-mail: For.Prodres@gems5.gov.bc.ca

SO. Barnett, J. P.; McGilvray, J. M. 1997. Practical guidelines for producing longleaf pine seedlings in containers. Gen. Tech. Rep. SRS-14. Asheville, NC: USDA Forest Service, Southern Research Station, 28 p.

Cost: Free

Order From: **USDA Forest Service**
Southern Research Station
P.O. Box 2680
Asheville, NC 28802
USA
Tel: 704/257-4392
FAX: 704/257-4340

Articles 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 write the appropriate number or letter in the space provided and return it to us. Note that there are two restrictions.

1. 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. 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 Donna Loucks the librarian who maintains the FNN database. Fill in the numbers on the second half of the Form, return it to us, and we will forward it to Donna.

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 you want desire the entire article, then you can order a copy from a library service Donna's address is on the inside front cover of this issue.

Bareroot Production

1. **Basics of frost and freeze protection for horticultural crops.** Perry, K. B. HortTechnology 8(1):10-15. 1998. Reviews basic meteorology and methods of frost protection such as site selection, irrigation, wind machines, heaters, covers, and sprayable materials.

Business Management

2. **Optimizing nursery operation schedules with multi-period linear programming.** van Rensburg, R. J.; Bredenkamp, B. V. Southern African Forestry Journal 179:7-11. 1997.

3. **A quick read.** Harter, K. American Nurseryman 187(9);28-33. 1998. Bar codes and scanners for inventory.

Container Production

4. **Containing root problems**. Gainer, B. L. American Nurseryman 187(12):34-36, 38-39. 1998. Preventing root circling with use of innovative containers such as RootMaker or Root Builder.

5. **Effects of air current speeds on the microclimate of plug stand under artificial lighting**. Kim, Y. H.; Kozai, T.; Kubota, C.; Kitaya, Y. Acta Horticulturae 440:354-359. 1996.

6. **In-ground fabric containers as an alternative nursery crop production system.** Cole, J. C.; Kjelgren, R.; Hensley, D. L. HortTechnology 8(2):159-163. 1998. Evaluation of grow bags or root bags.

SO. **Provincial seedling stock type selection and ordering guidelines.** British Columbia Ministry of Forests. 71 p. 1998. ORDER FROM: Ministry of Forests, Publications Distribution Coordinator, 1st Floor, 595 Pandora Ave., Victoria, BC V8W 3E7 Canada Fax: (250) 356-2093. E-mail: For.Prodres@gems5.gov.bc.ca. Free.

SO. **Practical guidelines for producing longleaf pine seedlings in containers.** Barnett, J. P.; McGilvray, J. M. USDA Forest Service, Southern Research Station, General Technical Report SRS-14. 28 p. 1997. ORDER FROM: USDA Forest Service, Southern Research Station, P.O. Box 2680, Asheville, NC 28802. Free.

Diverse Species

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