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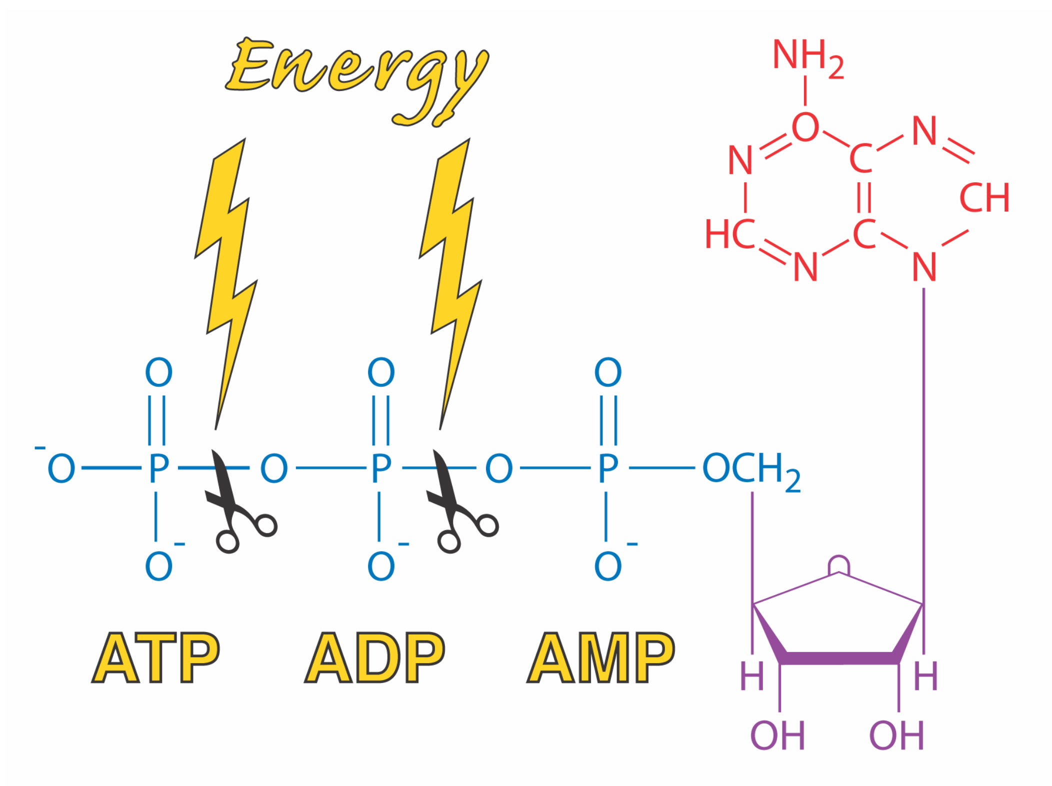
Forest Nursery Notes

Summer 2004



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USDA Forest Service, State and Private Forestry

Reforestation, Nurseries, and Genetic Resources (RNGR) Web Page: <http://www.rngr.net/>

The all new "Directory of Plant Material Providers" is now online and is a combination of three previous hard copy directories:

1) Directory of Forest and Conservation Nurseries
2) Commercial Seed Dealers Directory
3) Native Plant Materials Directory.

As you can probably imagine, it is almost impossible to keep hard copy directories up-to-date because as soon as they are printed, addresses, phone numbers, FAX numbers and E-mail addresses begin to change.

By combining three directories into one, now you can find nurseries, seed dealers, and native plant producers by location, products or services. In addition, suppliers can manage their respective information directly through the RNGR website. For more information on the directory, how to update information, or how to become a part of this powerful tool, please contact:

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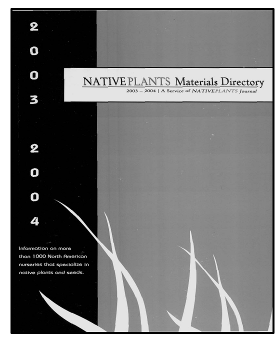
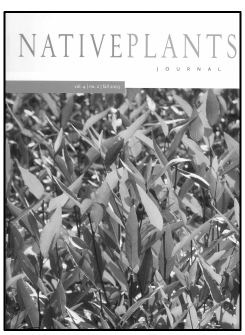
Native Plant Materials Directory



The Native Plants Materials Directory is an essential guide for anyone working in the burgeoning native plants field. It contains more than 1000 listings of North American producers and suppliers of materials necessary to users of native plants. The Directory is mainly for people and organizations working with native plants in conservation, restoration, reforestation, landscaping, and highway corridor projects. Copies are available for $20.00 through the University of Idaho Press.

Native Plants Journal



Hopefully, many of you already subscribe to NPJ but, if you don't, you should consider doing so. In a few short years, NPJ has established itself as one of the best journals in horticulture. Not only does it contain a wealth of technical information but the color photographs and illustrations are of the highest quality. Many people think that "native plants" doesn't mean forest trees but NPJ has featured articles on Douglas-fir and longleaf pine as well as ninebark and Nebraska sedge. Many issues also contain focus topics which have ranged from "Nasty Plants" (Poison-oak and stinging nettle) to the Salicaceae family in the latest issue. Each issue also contains a good mix of propagation protocols, nursery equipment, refereed research articles, and outplanting considerations. NPJ is published twice per year, and annual subscriptions are a bargain at $25 for students and $30 for individuals.

Both the Native Plants Materials Directory and the Native Plants Journal can be ordered from:

University of Idaho Press
PO Box 444416
Moscow, ID 83844-4416
TEL: 800.847.7377
FAX: 208.885.3301
E-mail: nativeplants@uidaho.edu
Website: www.nativeplantsnetwork.org

Nursery Meetings

This section lists upcoming meetings and conferences that would be of interest to nursery, reforestation, and restoration personnel. Please send us any additions or corrections as soon as possible and we will get them into the next issue.

The **2004 Southern Forest Tree Nursery Association Meeting** will be hosted by the SC Forestry Commission and held at the Embassy Suites Hotel Airport-Convention Center, located at 5055 International Blvd., North Charleston, SC 29418, on **July 12-15, 2004.** Reservations can be made now at 1-800-Embassy or directly at 843-747-1882. Mention the Southern Forest Nursery Group for the $106/night rate. Contact Mr. Stephen Cantrell at 803-275-3578 or by email at taylortree@pbtcomm.net for more information.

The **Western Forest and Conservation Nursery Association (WFCNA)** will be meeting at the Red Lion Inn in Medford, OR on **July 26 to 29 2004**. The theme for this conference is *Diverse Plant Materials and Fire Restoration.* For more information please contact:

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Again this year, the ***Intertribal Nursery Council*** will hold its annual meeting in conjunction with the 2004 WFCNA meeting described above. The INC meeting will be start early on Monday morning, July 26 with a bus trip to the northern California coast to visit the redwoods and the Yurok tribe. On Thursday afternoon and Friday morning, July 29-30, the emphasis will be on environmental education with a Project Learning Tree certification session. Our meeting will close with a discussion session and farewell dinner. All American Indians interested in nurseries and native plants and people working with tribes are encouraged to attend. The Forest Service will provide the funds for travel and per diem for Indian people attending these sessions on a first-come, first served basis. If you would like more information, contact:

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The 24th Annual Meeting, Forest Nursery Association of British Columbia will be hosted at the Sheraton Guildford in Surrey, BC, **September 27-29, 2004.** The conference theme is "Do's, Don'ts and Diligence". For more information please contact:

Dave Trotter
TEL: 604.556.3148
E-Mail: david.trotter@gems2.gov.bc.ca

or

John Kitchen
TEL: 604.687.1404
E-Mail: john.kitchen@prtgroup.com

For reservations, contact the Sheraton Guildford directly by September 13, 2004 for the "2004 FNABC" limited standard group rate.

TEL: 800.661.2818 Group code:FNA
FAX: 604.582.9712
Website: http://www.sheratonguildford.com

The Department of Forestry, University of Kentucky and Touchstone Energy Cooperatives are hosting the **4th Eastern Native Grass Symposium** which will be held **October 3-5, 2004** at the 4-Points Sheraton in **Lexington, KY.** The purpose of the symposium is to share information, experiences and research about recent projects involving native grasses in the eastern United States. Information is available online at:

<http:\\forestry2.ca.uky.edu/grass_symposium>

The Nursery Technology Cooperative at Oregon State University will be hosting another **Native Plants Conference.** This one is scheduled for **December 15-16, 2004** and will be held in **Eugene, Oregon**.
For more information please contact:

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Macronutrients - Phosphorus

by Thomas D. Landis and Eric van Steenis

Introduction

Of the three "fertilizer elements" (N-P-K), phosphorus (P) is found in the lowest concentration in plant tissue - only about 5% (Table 1). As a limiting factor, however, phosphorus is second only to nitrogen in terms of its importance to plant growth and development. Phosphorus is essential to all forms of life and it can be found in every cell in all living organisms. The element phosphorus is never found in nature but is always combined with other elements to form phosphates, for example calcium phosphate.

Nearly 80% of the phosphorus in animals is found in bones and teeth. Because of this, farmers historically used ground bones as fertilizer even though very little of this phosphorus is immediately available to plants. In 1808, Sir James Murray produced the first effective phosphorus fertilizer in Ireland by treating bones with sulfuric acid and creating water soluble phosphate. He later found that rock phosphate (calcium phosphate) could be treated similarly. Significant deposits of rock phosphate were discovered in New York and, by the late-1800s, America was producing 90% of the phosphate fertilizer in the world.

Role in Plant Nutrition

Phosphorus has several critical physiological and structural functions in plants.

- Energy storage and release - All living things need a constant source of energy to survive and grow. The solar energy captured in photosynthesis is stored in the chemical bonds between phosphorus atoms in adenosine triphosphate (ATP) molecules (Figure 1). When triggered by an enzyme, the endmost phosphate group is cleaved from the ATP molecule and energy is released. Even more energy can be gained by breaking the second phosphate group. These chemical reactions are reversed when phosphate groups are reattached in the chloroplasts using the energy from photosynthesis. Thus, ATP molecules function like a "battery"- storing energy when it is not needed, but able to release it when it is. Uridine triphosphate, cytidine triphosphate, and guanosine triphosphate function similarly to ATP and together provide an energy storage and release system for almost all the metabolic reactions in plants.

Table 1 - The three major macronutrients and their typical concentration in seedling tissue

Element	Symbol	% of Total Mineral Nutrients in Plants	Adequate Range in Tree SeedlingTissue %		Where and When Published
			Bareroot	Container	
Nitrogen	N	37.5	1.2 to 2.0	1.3 to 3.5	Summer, 2003 & Winter, 2004
Phosphorus	P	5.0	0.1 to 0.2	0.2 to 0.6	This issue
Potassium	K	25.0	0.3 to 0.8	0.7 to 2.5	To Do - Winter, 2005

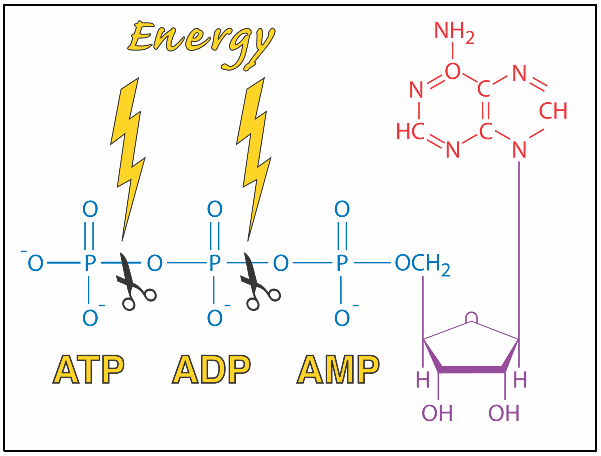

Figure 1 - The chemical energy captured in photosynthesis is stored in the phosphate-to-phosphate bonds in adenosine triphosphate (ATP) molecules.

- Component of nucleic acids - Nucleic acids are found in all plant cells and allow the replication and transcription of genetic information for reproducing and synthesizing compounds like proteins. Sugar phosphates form the double helix "backbone" for dioxyribonucleic acid (DNA) which contains the complete genetic blueprint of every organism. Phosphorus is also a constituent of ribonucleic acid (RNA) which serves as a chemical messenger, carrying genetic instructions through the plant.

- Structure and function of cell membranes - The membranes inside plant cell walls are composed primarily of phospholipids, long fatty acid chains which are attached to phosphate ions. The cell membrane could not perform its structural and chemical functions without phosphorus.

- Regulator of enzymes - Phosphorus helps regulate the activity of enzymes involved in critical metabolic processes such as starch synthesis.

- Cell buffer system - Phosphoric acid helps buffer cell pH and maintain homeostasis.

- Storage in seeds and fruits - Both contain high concentrations of phytin, which can be hydrolyzed to release phosphate for metabolism and cell wall formation. This ready source of stored phosphorus is critical during seed germination and emergence before the seedlings can begin to obtain phosphorus from the soil.

Availability to plants.

Phosphorus availability is radically different between field soil and artificial growing media.

Soil - Phosphorus is found in many organic and inorganic forms in soils but only a very small percentage is available for uptake by plant roots Calcium, magnesium, iron, and aluminum all chemically bond with phosphorus, and it is also found in minerals such as apatite. These unavailable forms are known as "nonlabile" phosphorus (Figure 2). Free phosphate ions ("labile P") are chemically adsorbed onto clay or organic particles and are gradually released into the soil solution. In addition, all organic matter contains a considerable amount of phosphorus. As it is decomposed by microorganisms and as these microorganisms themselves die, phosphorus is slowly released into the soil solution. Because the available forms of phosphate are negatively-charged anions, they are not held on soil cation exchange sites and can be easily leached from the root zone (Figure 2). Because of the very low concentration of soluble phosphorus in the soil, availability is highest when soil water is near field capacity. Due to the fact that the majority of soil phosphorus is so unavailable, nursery managers must supply it from fertilizers or green manure crops, and encourage beneficial microorganisms like mycorrhizal fungi.

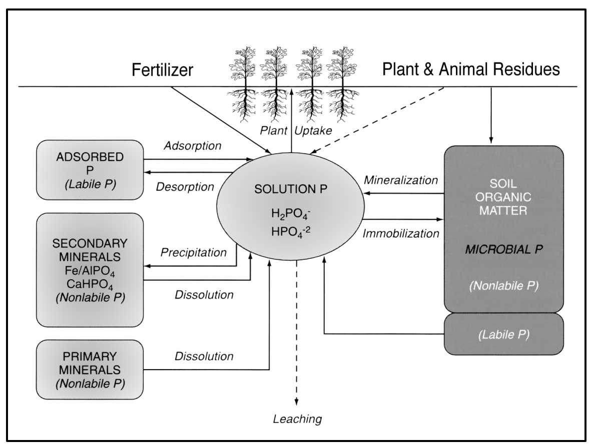

Figure 2 - Phosphorus is found in both organic and inorganic forms in field soil and is slowly released to form the small percentage of available P in the soil solution. This situation does not apply to artificial growing media, however (modified from Havlin and others 1999).

Growing media - Common artificial growing media contain very little phosphorus but do not chemically fix it like field soils. Although peat moss and vermiculite both have high cation exchange capacities, this does not affect the negatively-charged phosphate ions. There is some evidence that vermiculite has a limited anion exchange capacity. Therefore, a very high percentage of the phosphorus applied to container growing media remains soluble and available to plants. The down side is that this phosphorus is very easily leached by the high amounts of water used in container nurseries. Therefore, growers must continually supply phosphorus to achieve the rapid growth rates desired in container nurseries.

Affects of pH - The relative acidity or alkalinity of soils or growing media has a significant effect on the type of the orthophosphate ions and their availability. At lower pH, iron and aluminum form insoluble complexes with free phosphate ions whereas, at higher pH values, calcium ions tie-up the phosphate. The take-home lesson for nursery managers is that maintenance of a slightly acid pH is critical for optimum phosphate availability (Figure 3). Because artificial growing media do not contain these complexing agents, phosphorus availability in container nurseries is not limited by pH.

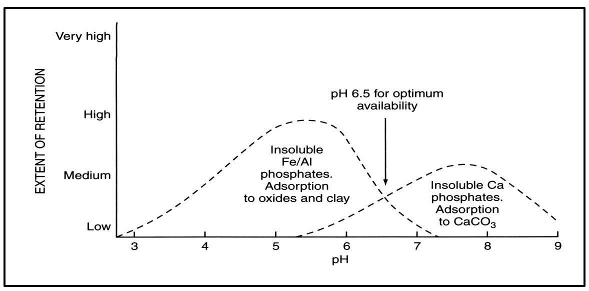

Figure 3 - Maintenance of proper soil pH is critical to phosphorus availability in bareroot nurseries (modified from Havlin and others 1999).

Importance of mycorrhizal fungi - Mycorrhizae are unique structures on plant roots which develop through a symbiotic association with specific fungi. One primary benefit of this symbiosis is that the presence of mycorrhizal fungi greatly increases phosphorus availability. As we have already discussed, the vast majority of soil phosphorus is unavailable to plants so mycorrhizae have a major role in phosphorus nutrition. In fact, mycorrhizae do not even form on seedling roots where phosphorus is readily available and this explains the difficulty of trying to inoculate with mycorrhizal fungi in nurseries where high fertilization rates are the rule. Studies have shown that the benefits of mycorrhizae are greatest when soil phosphorus levels are at or below 50 ppm and that inoculation is poor when levels exceed 100 ppm.

One of the classic symptoms of mycorrhizal deficiency in bareroot nurseries is a mosaic stunting pattern where patches of normal sized seedlings are interspersed with patches of stunted ones (Figure 4A). This typically occurs after soil fumigation has eliminated all the mycorrhizal fungi in the seedbeds, and the healthy patches are where random reinoculation has occurred. This same mosaic pattern can be seen in the "no phosphorus" treatment of a controlled fertilization study (Figure 4B), illustrating the strong link between mycorrhizae and phosphorus nutrition.

What does this mean to nursery managers? Should they restrict phosphorus fertilization to encourage mycorrhizal fungi? Phosphorus fertilizer is inexpensive and, if applied at the proper time and with the proper technique, can produce vigorous seedling growth whether mycorrhizae are present or not. Some species of fungi (*Rhizopogon* spp., for example) have been shown to be more tolerant of the high fertilization rates in nurseries. The real benefit of mycorrhizae come after outplanting and so nursery managers should encourage them during the hardening period when fertilization levels are lower and there are many sites on the roots available for infection.

Uptake and mobility in plants. Phosphorus is adsorbed by plants largely as the negatively charged orthophosphate ions ($H_2PO_4^-$ & HPO_4^-) which are present in the soil solution (Figure 2). The young, vigorous roots of nursery seedlings take up phosphate rapidly from the rhizosphere and so a strong gradient always exists between the rhizosphere and the soil solution. Therefore, most phosphorus absorption is active, requiring energy.

Phosphorus is very mobile in plants and can be translocated in either an upward or downward direction. Young rapidly growing leaves and meristems create a sink for phosphate and, if the supply from the roots is insufficient, phosphate can be remobilized from older leaves and transferred to new ones. During seed formation, phosphate is stored as phytin and is released for metabolic processes when the seeds germinate.

Influences on Plant Growth and Development

Phosphorus fertilization can have a profound influence on seedling performance during the various growth stages in nurseries:

Establishment Phase. Because of their rapid growth, young seedlings have a high requirement for phosphorus and take it up very rapidly. The stored phosphorus in the endosperm of the seed doesn't last long and so germinants need to quickly find a source of phosphorus to support their high metabolic rates. To complicate things, the restricted root system of young seedlings

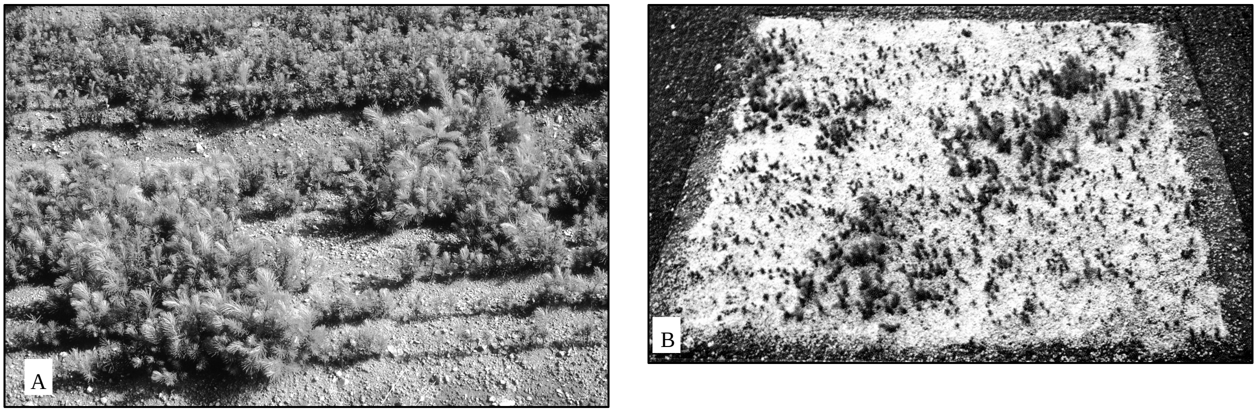

Figure 4 - The strong influence of mycorrhizal fungi on phosphorus nutrition can be seen by this pair of photographs: A) the classic mosaic stunting pattern of mycorrhizal deficiency, B) the "no phosphorus" treatment in a controlled fertilizer study.

Phosphorus and Root Growth

One of the traditional beliefs in nursery fertilization is that phosphorus stimulates root growth. There doesn't seem to be much published research to support this, however. With root crops where much of the photosynthate is channeled to the roots for storage, phosphorus fertilization has been shown to have a beneficial effect. On the other hand, in nursery crops where roots are primarily used for support and absorption, phosphorus does not seem to have any stimulating effect. In fact, adding phosphorus fertilizer to deficient plants has shown to promote top growth rather than root growth.

limits the soil volume that can be accessed. Finally, in bareroot nurseries and open growing compounds, low soil temperatures in the spring has been shown to retard phosphorus uptake.

Rapid Growth Phase. Seedlings in the exponential growth phase continue to have a high demand for phosphorus to support the high metabolism and rapid cell division. Bareroot nursery managers incorporate or band phosphorus fertilizers before sowing to make sure that it is available for uptake and utilization. Container growers keep phosphorus levels high in their fertigation formulas for the same reason.

Hardening Phase. As shoot growth has stopped and cellular metabolic rates slow down, phosphorus uptake has been shown to decline. At the same time, seedling root systems are more extensive and mycorrhizae are becoming established so seedlings are able to access phosphorus much more easily. It has been a traditional practice to increase the amount of phosphorus fertilizers applied to crops during the hardening phase with the objective of promoting root growth. This has not been substantiated by research, however (see sidebar), and may actually inhibit infection by mycorrhizal fungi.

Monitoring Phosphorus

Phosphorus nutrition can be monitored by chemical analysis of soils, growing media, or plant tissue but deficiency symptoms are not diagnostic.

Deficiency Symptoms. The visual symptoms of phosphorus deficiency are neither distinctive nor pronounced enough to be very diagnostic. Because phosphorus is needed for critical processes such as RNA synthesis and energy transfer, a deficiency has a pervasive effect on seedling physiology and growth is restricted. Therefore, the most common phosphorus deficiency symptom is stunted growth, especially in the root system (Figure 4). This is probably the reason why phosphorus is believed to promote root growth but reduced root growth is more a factor of restricted metabolic processes in the shoot rather than a phosphorus deficiency as such. Because it can be caused by so many factors, phosphorus deficiency often goes unnoticed as "hidden hunger".

There is no typical foliar symptom of phosphorus deficiency. The leaves of some crops show a darkish green color and others exhibit a reddish coloration from an enhanced production of anthocyanin pigment. For example, the foliage of western redcedar (*Thuja plicata*) seedlings exhibits a distinctive purpling or bronzing when phosphorus is deficient.

Toxicity Symptoms. High levels of phosphorus are more common in artificial growing media because it is chemically fixed so rapidly in soils. Experience with hydroponic crops relates that, if the phosphorus concentration of seedling foliage exceeds 1.00%, then problems may result. Although high phosphorus levels are not directly toxic, they can cause growth problems because of reduced uptake and utilization of several

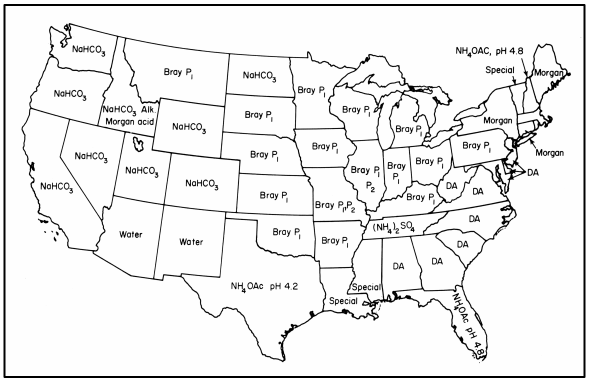

Figure 5 - Soil tests for available phosphorus vary with soil types and so state testing laboratories have adopted different extraction procedures (modified from Donahue and others 1977).

micronutrients including zinc, iron, and copper. These are know as "induced deficiencies" and zinc deficiency is usually the first to occur. A unique situation exists in Australia, New Zealand, and South Africa where plants have adapted to the extremely low soil phosphorus levels and native plants such as *Protea* and *Grevillea* show toxic reactions to even low phosphorus levels.

Soil Tests. Because of the many and varied ways in which phosphorus is bound in soils, creating a reliable test for available phosphorus has proven challenging. Different soils require different chemical extractants that simulate plant availability, and five extraction procedures are currently being used. In the more acidic soils of the northeastern states one of the Bray tests is used whereas, in the more alkaline soils of the western states, the Olson test using a $NaHCO_3$ extractant is preferred (Figure 5). Therefore, bareroot nurseries should use local soil testing labs to make certain that they are getting accurate information. Because soil test results can vary considerably between labs, it is a good idea to chose one lab and stick with them from year to year. A proficiency testing program of soil testing labs in the western US found that soil phosphorus results showed high variability.

Artificial Growing Media Tests. Although there are several techniques available, forest and conservation nurseries do not typically analyze their growing media for phosphorus. Instead, most growers have developed their fertilization regimes based on seedling growth response or foliar tests.

Seedling Tissue Analysis. Because of the difficulty in measuring available phosphorus in soils and growing media, tissue tests are generally considered to be the best way to monitor phosphorus nutrition (Figure 6A). A typical plant contains 0.20% P on a dry weight basis but this can vary 0.10% to 0.50% depending on species and age of tissue. For nursery stock, the adequate level for phosphorus is relatively low for a macronutrient - 0.10 to 0.20% for bareroot seedlings and 0.20 to 0.60 for container stock (Table 1). The phosphorus content of plants is generally considered deficient when it is below 0.10% and this threshold has been confirmed for a wide variety of conifer and broadleafed nursery stock (Figure 6B). For example, the foliage of western redcedar seedlings shows a distinctive purpling or bronzing below

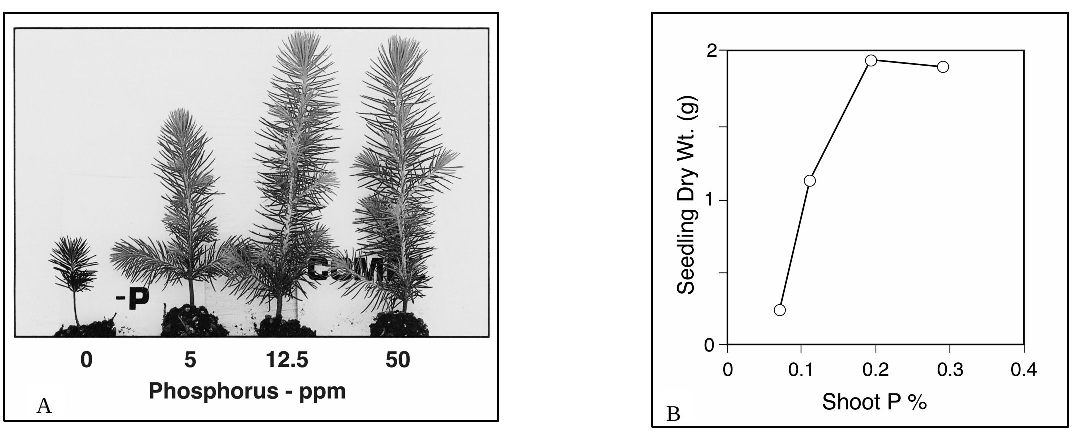

Figure 6 - Seedling growth response is the best way to monitor phosphorus nutrition (A), and nursery stock can be considered phosphorus deficient when foliar concentrations decrease below 0.10 to 20% (B) (modified from van den Driessche 1984).

0.10% but, when foliar concentrations exceed this level, the foliage is a normal green.

Foliar test results can vary from lab to lab so nurseries are encouraged to establish a relationship with one testing facility so that results will be comparable from year to year. Because of the considerable variation that occurs between species and at stages during the growing season, nurseries are encouraged to develop their own standards for tissue analysis.

Phosphorus Management in Nurseries

There are a few cultural practices that will increase phosphorus availability such as keeping soil moisture high and, as show in Figure 4, pH should be in the ideal 5.5 to 6.5 range. In particular, acidifying calcareous soils with sulfur or ammonium sulfate has proven effective. Organic matter contains relatively high levels of phosphorus and so organic amendments are a cheap and easy way to supply phosphorus, although the release rate is too slow to be practical in nurseries. The ratio of nitrogen to phosphorus is important: phosphorus keep the numerous metabolic processes going and nitrogen provides the building blocks for tissue growth and development. Nitrogen-to-phosphorus ratios are often calculated, and a 10:1 ratio is considered optimum.

Fertilization. Much of the phenomenal growth rates that are achieved in nurseries can be attributed to good fertilization practices and this is especially true for phosphorus. Therefore, nursery managers do not rely on reserves in the soil or growing media but add all the required phosphorus as fertilizer. Phosphorus fertilization has some unique considerations, however:

Timing and Method of Fertilization - The restricted root system of young seedlings means that growers must take special care to ensure that phosphorus is readily available early in the season. In bareroot nurseries, presowing incorporation into the seedbed and banding phosphorus fertilizers at the time of sowing have proven effective. Monoammonium phosphate and diammonium phosphate are recommended for banding because the presence of nitrogen is thought to increase phosphorus uptake. Because of its restricted movement in soils, top dressing of phosphorus fertilizers is not recommended.

In artificial growing media, phosphorus remains available but also leaches readily so growers must provide a continual supply. Starter fertilizer formulations and controlled release fertilizers have ample amounts of phosphorus but the challenge is ensuring even distribution of fertilizer between containers. Because of their restricted volume, this is more of a problem in small plug containers. Fertigation is a reliable way to achieve even distribution and provide a steady supply of phosphorus. Recommended phosphorus concentrations in fertigation solutions has traditionally been in the range of 30 to 100 ppm but this is much higher than shown to be necessary. Research trials have demonstrated that healthy seedlings can be grown with as little as 10 to 15 ppm phosphorus (Figure 6A). Growers who lower the pH of their irrigation water with phosphoric acid get the additional benefit of providing a steady supply of phosphorus from the very first irrigation.

Types of Fertilizers - The best phosphorus fertilizer for a given situation depends on many things, but the bottom line is crop response. In bareroot nurseries, you should learn the phosphorus-fixing ability of your soil and install some field trials. Controlled release fertilizers have special appeal for container growers because the can supply a steady supply of phosphorus to plants without the risk of leaching losses.

Due to an established labeling convention, the phosphorus in fertilizers is expressed as phosphate (P_2O_5) and fertilizer labels are required by law to state the N-P-K analysis as % N:% P_2O_5:%K_2O). To convert from % phosphorus to % phosphate multiply by 2.29; to convert from % phosphate to % phosphorus multiply by 0.43. The main sources of phosphorus container fertilizers is given in Table 2.

Eutrophication of Surface Water. Water quality has become one of the most important ecopolitical issues, and all types of agriculture are potential sources of fertilizer pollution. Phosphorus is considered a serious environmental pollutant because it promotes eutrophication of surface waters. Eutrophication can be defined as the excessive nutrient enrichment of water, which results in nuisance production of algae and other microscopic water plants. Because phosphorus is the primary limiting nutrient in freshwater systems, runoff from nurseries can lead to an explosive increase in algal growth called "blooms" on the water surface. Water quality progressively deteriorates as these plants decompose, creating taste and odor problems, and eventually killing fish and other aquatic organisms. To make matters worse, some species of algae release toxins into the water.

In bareroot nurseries, almost all of the fertilizer phosphorus is chemically fixed on soil particles and therefore surface runoff that carries suspended sediment is the primary culprit. With their artificial growing media, container nurseries have inherently high leaching rates of phosphorus. In one study, 16 to 64% of the applied phosphorus fertilizer was recovered in the leachate.

If excess irrigation and fertigation are allowed to run off

Table 2 - Types of Phosphorus Fertilizers Commonly Used in Forest and Conservation Nurseries						
Fertilizer	**Nutrient Analysis**			**Nursery Type**	**Application Method**	**Remarks**
	% N	**% P_2O_5**	**% K_2O**			
Milorganite®	6	2	0	BR	Incorporated	An organic fertilizer made from municipal sludge
Single superphospate	0	16 to 22	0	BR	Incorporated or Banded	Also contains 11 to 12% sulfur
Triple superphospate	0	44 to 53	0	BR	Incorporated or Banded	Also contains 1 to 2% sulfur
Diammonium phosphate (DAP) $(NH_4)_2HP0_4$	18	46	0	BR	Incorporated or Banded	A dry granular or crystalline material
Monoammonium phosphate (MAP) $NH_4H_2PO_4$	11	52	0	BR	Incorporated or Banded	A dry granular material
Potassium phosphates	0	41 to 51	35 to 54	BR or C	Fertigation	Water soluble with low salt index
Phosphoric acid (White or Food grade)	0	54	0	C	Fertigation	Nutrients are a by-product of the acidification of irrigation water
Plant Products 20-20-20	20	20	20	C	Fertigation	Completely soluble, with micronutrients
Scotts Excel Cal-Mag 15-5-15	15	5	15	C	Fertigation	Completely soluble, with calcium, magnesium, sulfur and micronutrients.
Scotts Peters Plant Starter 9-45-15	9	45	15	C	Fertigation	Completely soluble, with high P for young plants.
Scotts Peters Foliar Feed 27-15-12	27	15	12	C	Fertigation	Completely soluble
Controlled-Release Formulations						
Osmocote Fast Start; 8 to 9 month release	18	6	12	C	Incorporation	Polymeric resin-coated prills
Osmocote High N; 8 to 9 month release	24	4	8	C	Incorporation	Polymeric resin-coated prills
Polyon 25-4-12; 8 to 9 month release	25	4	12	C	Incorporation	Polyurethane-coated prills
Nutricote 270; 8 to 9 month release	18	6	8	C	Incorporation	Thermoplastic resin-coated prills

the nursery site, they can be considered point source pollution and subject to more and more legislation. Many container and even some bareroot nurseries are building constructed wetlands which collect all surface runoff and hold it until aquatic plants can remove the excess phosphorus. The surplus phosphorus is contained in the plant tissue and is removed from the system when the plants are harvested.

Conclusions and Recommendations

Phosphorus has critical physiological and structural functions in plants, and so phosphorus management is critical for promoting the rapid growth of nursery seedlings. Phosphorus availability is radically different between field soil and artificial growing media. In soils, the vast majority of phosphorus is chemically bound and unavailable and soil pH level is critical. With artificial growing media, phosphorus is readily available but is also subject to leaching. Phosphorus management is most critical during the establishment phase of seedling growth. Phosphorus nutrition can be monitored by chemical analysis of soils, growing media or plant tissue but diagnosis of phosphorus deficiency or toxicity using foliar symptoms is not recommended. Instead, chemical analysis of foliage has proven useful with 0.10% as the critical level below which growth rates will decline. Much of the phenomenal growth rates that are achieved in nurseries can be attributed to good fertilization practices and this is especially true of phosphorus. To achieve the rapid growth rates of nursery culture, nursery managers should not rely on reserves in the soil or growing media but add all the required phosphorus as fertilizer. In bareroot nurseries, incorporation or banding phosphorus into the seedbed prior to sowing has proven effective. With container crops, providing a low but continuous supply of phosphorus can be achieved by incorporation of controlled release fertilizers or as an added benefit using phosphoric acid to acidify irrigation water.

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Subirrigation: A Better Option for Broad-leaved Container Nursery Crops?

by Thomas D. Landis and Kim Wilkinson

Introduction

Overhead irrigation systems have always been the choice of container nurseries. Fixed overhead sprinklers are relatively cheap and easy to install but have the disadvantage of poor coverage and therefore low water use efficiency. The advent of boom irrigation was a big improvement with much better distribution between individual containers and water use was cut substantially. Traveling booms will probably remain the irrigation system of choice for nurseries growing conifers, but problems develop when broad-leaved plants are the desired crop. Their wide leaf blades combined with the close spacing of most containers create a canopy that intercepts most of the water applied through overhead irrigation systems, reducing water use efficiency and creating variable water distribution between individual cells or containers (Figure 1).

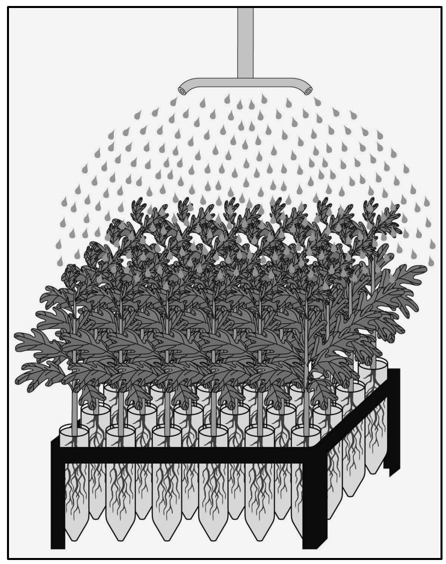

Figure 1 - Overhead irrigation is much less effective for broad-leaved plants like these oaks because so much water is intercepted by the foliage.

Subirrigation systems have been in use in ornamental nurseries and other horticultural applications for many years but this technology has not been adopted for most forest and conservation nursery crops. Native plant nurseries have converted tanks or tubs into propagation units for wetland plants like cattails, sedges, and rushes but this has remained a specialized application.

Types of subirrigation systems

Several different subirrigation systems have been developed:

1. Capillary beds: Containers sit on the floor on a base of sand inside an impermeable perimeter.

2. Capillary mats: Containers sit on benches on a thin permeable mat in a shallow impermeable sheet or tray.

3. Ebb-and-flow or ebb-and-flood: Containers sit on the floor in a shallow structure constructed from pond liner surrounded by a raised border of wood or masonry.

4. Trays, rroughs, or bench liners: Containers sit in plastic or aluminum trays or troughs on a slight incline to allow for water distribution and drainage. Molded plastic or aluminum tops are now available that cover an entire bench.

Capillary beds and mats require good contact between the bottom of the container and so are only useful for containers that have a large bottom surface. Ebb-and-flood, trays, and bench liners should work well with forestry containers and growing medium, however.

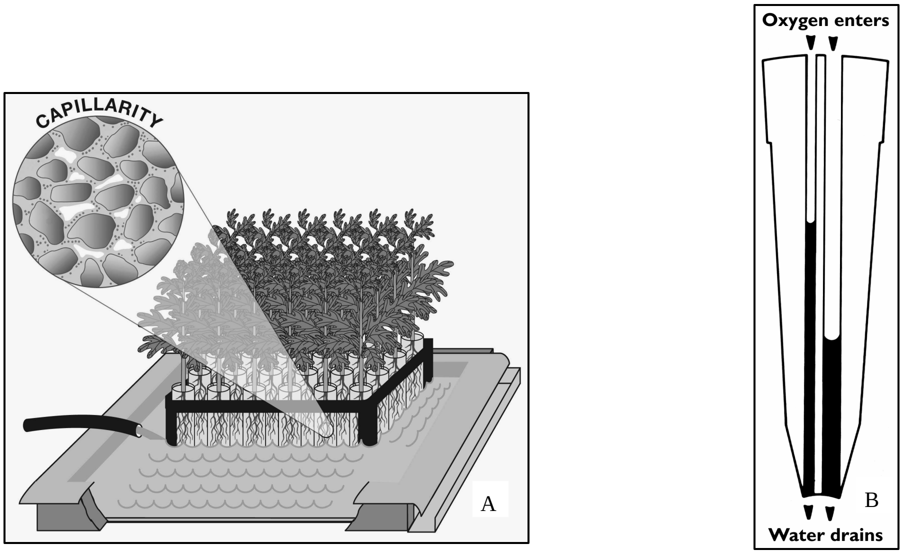

Figure 2 - Subirrigation works because water is drawn upward into the containers by capillarity (A). The amount and speed of water uptake will depend on the porosity of the growing medium, the smaller the pores, the more that will be absorbed (B).

How subirrigation "works"

All subirrigation systems rely on capillary action to move water up through the growing media against gravity. Once the subirrigation tray is flooded, water will begin to move up through the con growing medium in the containers (Figure 2A). In case you don't remember, capillarity is the result of the attraction of water molecules for each other and other surfaces. The height to which water will climb above the water surface under subirrigation will depend on characteristics of the container and the growing medium, mainly the latter. The smaller the pores between the growing medium particles, the higher water will climb (Figure 2B). The growing medium components will also have an effect: Sphagnum peat and vermiculite both have high internal porosity which acts as a sponge. We don't have much experience with forest and conservation nursery crops but, at Tamarac Nurseries in Ontario, it took one hour for the growing medium to be fully saturated when the containers were immersed to a 1 inch (2.54 cm) depth.

Characteristics of subirrigation

The advantages and disadvantages of subirrigation compared to sprinkler irrigation are listed below but several need further explanation. Probably the most serious concern would be with saline irrigation water. Soluble salts will "wick-up" as evaporation occurs and accumulate in the root zone so subirrigation may not be advised in nurseries with even moderately saline water. Leaching of excess fertilizer could also be a problem if not managed properly. At Tamarack Nursery, they were aware of possible salt build-up but never had any problems even at moderate fertigation levels.

Air root pruning would be compromised with subirrigation, but copper-coated mats could be used to promote chemical root pruning. Even though water will fully drain away between irrigations, high humidity could be a problem with our high plant densities so good lateral air circulation would be advisable.

On the positive side, subirrigation has been shown to significantly reduce irrigation water use. Tamarac Nursery experienced an average savings in water and fertilizer of 70%. Irrigation was very efficient with more even crop growth probably due to uniform distribution of water and nutrients. With the increasing concern about fertilizer and pesticide pollution, perhaps the most important benefit of subirrigation is the ability to completely contain and treat all runoff.

Another attractive feature of subirrigation is that different species and containers could be grown together. It should be possible to design "dry", "medium", and "wet" types of growing media by using different components.

Finally, the concern about waterborne pathogens such as *Pythium* and *Phytophthora* is real but serious problems have not been observed.

Advantages:

?? Although commercial products are available, subirrigation systems can be made from affordable, local materials
?? Foliage remains dry, reducing foliar diseases
?? Efficient water use (up to 80% less than overhead)
?? Very uniform application between cells or containers
?? Lower fertilizer rates are possible
?? Reduced leaching of mineral nutrients
?? Drainage water can be recycled or reused
?? No soil splashing
?? Ability to irrigate different size containers and different age plants

Disadvantages:

?? May have to use overhead or hand water until roots reach bottom (usually 2 to 4 weeks)
?? No leaching occurs so cannot be used with poor quality water because salt build-up occurs
?? Less air pruning of roots
?? Risk of spreading water-borne diseases
?? Possibility of high humidity within plant canopy
?? Almost nothing known about response of forest and conservation crops

Commercial subirrigation systems

While prefabricated subirrigation systems are available for purchase, nurseries on a limited budget may consider designing their own systems using available materials. A simple system could be constructed using a raised perimeter of concrete blocks and lumber covered with a pond liner.

The Spencer-Lemaire company of Edmonton, Alberta is well known for their Roottrainer™ containers but they have also developed a couple of subirrigation systems. Both are manufactured in sunlight-resistant ABS plastic so that they will stand-up to the high levels of heat and light in greenhouse environments. FlowTrays™ are smaller units designed to hold a few containers whereas the FlowBench™ sheets come in a range of widths which can be joined together to cover any size bench. Contact them at:

Spencer-Lemaire Industries, Ltd.
11406 - 119 St
Edmonton, AB T5G 2X6
CANADA
TEL: 780.451.4318
FAX: 780.452.0920
E-MAIL: Info@Rootrainers.com
WEBSITE: www.rootrainers.com

If you are only growing a few plants or just want to conduct some trials, Stuewe and Sons is designing subirrigation trays that will hold 1-4 containers. For more information:

Stuewe And Sons, Inc.
2290 SE Kiger Island Drive
Corvallis, OR 97333-9461
USA
TEL: 541.757.7798
FAX: 541.754.6617
E-MAIL: eric@stuewe.com
WEBSITE: www.stuewe.com

Midwest GROmaster custom manufactures ebb-and-flow benches and trays as well as a full line of irrigation and fertigation controls.

TEL: 847.888.3558
FAX: 847.888.3818
E-mail: sales@midgro.com
Website: www.midgro.com

Advanced Greenhouse Technology features aluminum trough and aluminum or plastic ebb-and-flow bench liner systems.

TEL: 800.932.9811
FAX: 905.643.4684
E-mail: carin@zwartsystems.ca
Website: www.zwartsystems.ca

TrueLeaf Technologies designs and sells a complete line of flood floor and flood benches along with control systems.

TEL: 800.438.4328
FAX: 707.794.9663
E-Mail: info@trueleaf.net
Website: www.floodfloors.com

Conclusions and Recommendations

Subirrigation systems offer some real advantages, especially for broad-leaved species where overhead irrigation is ineffective. There is nothing formally published on growing forest and conservation or native crops with subirrigation so interested growers should install trials before going fully-operational. We are going to continue to work on this technology but we would be very interested in hearing about any of your experiences with subirrigation.

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Seedling Quality Tests: Stress resistance

by Gary Ritchie and Tom Landis

In the Winter, 2004 issue of Forest Nursery Notes (FNN) we discussed bud dormancy, how it is measured and why it is important (11). We also emphasized that bud dormancy is closely related to stress resistance (SR) and will now discuss this relationship in more detail. From an operational standpoint, we will introduce some techniques that you can use in your nursery to estimate the relative SR of a crop at any point during the lifting-to-outplanting process. As a review of terminology and concepts, we suggest that you reread our article on dormancy in the Winter 2004 FNN.

The concept of stress resistance

We all know that seedlings are subjected to a variety of stresses from the time they are harvested in the nursery to when they are outplanted: mechanical stresses, root exposure, and desiccation to just name a few. Nursery managers use a variety of cultural techniques, collectively termed "hardening-off", to prepare their stock to tolerate these stresses. Realizing its importance and the practical applications, seedling physiologists have been studying SR for almost 40 years. Hermann found that SR seems to be primarily a property of root systems in bareroot stock (3), and Lavender (5) showed that SR varies seasonally, reaching a mid-winter peak after bud dormancy has begun to decline (Figure 1). The data for this seasonal curve came mainly from outplanting trials and that is why it corresponds exactly with the traditional mid-winter lifting season.

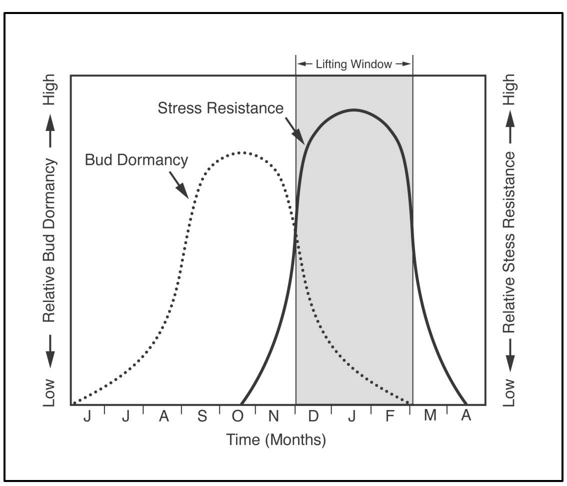

Figure 1 - This classic illustration shows the temporal relationships between bud dormancy, stress resistance and the traditional mid-winter lifting window (modified from 5).

Obviously, nursery managers want to maximize SR in their crops and maintain this condition until they are shipped to their customers for outplanting or transplanted back into the nursery. But how can we measure or estimate SR, and how can we culture our crops to reach this peak?

Measuring stress resistance

A quick and easy way to measure the SR of nursery stock would be an invaluable tool, and there have been many attempts to develop a test to develop this important aspect of seedling quality.

Stress Tests - During the 1970s and 1980s, several attempts were made to develop quick tests of SR. For example, a Stress Test was developed at Oregon State University and consisted of lifting seedlings, potting them, and exposing them to stressful conditions - mainly high temperature, low humidity and low soil moisture (6). After a pre-determined time, the seedlings would then be moved into a greenhouse and assessed for survival, vigor, root growth, bud break and other indicators of vigor. Despite some promising early results, the outcomes of literally hundreds of such tests proved difficult to interpret and not very repeatable. Accordingly, this method was gradually abandoned.

Another more elaborate, but more accurate, method of measuring SR involves a procedure similar to cold hardiness testing (10). It consists of three sequential steps:

1. Exposing plants to a controlled stress treatment. The most commonly used stress treatments employ some sort of controlled trauma to the root systems. This might

involve exposure to high or low temperatures, prolonged drying, or another treatment that simulates rough handling, such as dropping or tumbling (8).

2. Outplanting them into a natural environment where their growth response to the treatment can be expressed. By "natural", we mean the seedlings should be growing in soil and exposed to the ambient outdoor environment but they must be able to express growth potential without confounding effects of browsing, water stress, or weed competition. A nursery bed that is watered regularly and kept weed free is ideal. The test plants are set out in replicated blocks along with unstressed controls of similar initial size from the same seed lots or families.

3. Evaluating the impact of the stress treatment by comparing the performance of the stressed seedlings to that of unstressed controls after a predefined time period - typically one complete growing season. The assessment can be as simple as measuring shoot growth or as complicated as destructively sampling the entire plant and measuring total biomass. We have found that removing the shoots of the seedlings and determining their dry weight is a good basis for comparison. Using this technique, SR is characterized as the difference in growth between the stressed plants and unstressed controls. A helpful way of expressing this difference numerically is by calculating a Stress Injury Index (SII) using the first year shoot growth of the stressed (Gs) and control seedlings (Gc):

$$SII = 100 - (Gs/Gc \times 100)$$

The SII expresses the percent reduction in top growth resulting from stress injury and so, the lower the value, the higher the stress resistance of the test seedlings (12).

Using Cold Hardiness Tests to Estimate Overall Stress Resistance

Decades of nursery experience have shown that, when seedlings are at their maximum state of hardiness, they will show the most resistance to the many stresses of harvesting, handling, storage, shipping, and outplanting. Container nurseries in western Canada are using a "storability test" to determine if seedlings are physiologically ready for lifting, packaging, and cold storage (13). This test is basically a modification of a standard cold hardiness test in which seedlings are placed in a programmable freezer and taken down to the predetermined temperature threshold of 0 °F (-18 °C). After a period of exposure, the seedlings are evaluated for cold injury to the foliage or cambium. A more recent modification uses chlorophyll fluorescence to determine if tissue damage has occurred and produces results up to 6 days earlier than visual evaluation. Because this method tests seedling samples directly, it has proven a reliable predictor of outplanting performance (4).

This storability test shows that cold hardiness testing can also be used to estimate overall stress resistance. Its application should be tested on other species but it only makes sense that, if seedlings are cold hardy, they will be more resistance to other stresses as well. If you will remember from our discussion of Cold Hardiness Testing in the Summer, 2003 issue of FNN, the seasonal stress resistance curve in Figure 1 corresponds very closely to that for cold hardiness. So, cold hardiness tests can give a good indication of overall SR.

Using Chilling Hours to Predict Stress resistance

Research in seedling physiology has revealed that SR is very closely related to dormancy intensity (8, 9, 12). As dormancy intensity weakens through winter in response to chilling, SR gradually increases to a mid-winter high. Then it falls rapidly as dormancy is fully released and spring approaches. This is shown in the gray area of Figure 1. The physiological mechanisms behind this relationship are not fully understood, but it is repeatable from year to year with different crop types (bareroot and container) and species (Douglas-fir, pines, spruces, some hardwoods) and across nurseries (1, 2, 12). This means that if you can track the dormancy status of your crop through winter, you can use this information to estimate SR without measuring it directly.

Calculating Days to Bud Break and Dormancy Release Index - You may recall that in our Winter 2004 FNN article we showed that bud dormancy peaks in fall and is released gradually during winter as plants are exposed to low temperatures (Figure 2). The days to bud break (DBB) can be estimated by accumulating the hours when the air temperature is 41ºF (5 ºC) or below - the "chilling requirement". This relationship is curvilinear so converting it to a linear "Dormancy Release Index" (DRI) makes it much easier to use (Figure 2). The DRI = 0 at peak dormancy in fall, and approaches 1 as dormancy is released in spring.

Research with Douglas-fir has revealed a consistent relationship between DRI and SR (8). In early winter, when DRI is in the range between 0 and about 0.25, SR is low but improving. Between DRI 0.26 and 0.40 (mid-winter) SR is at a seasonal high, but when DRI passes 0.40 (early spring) SR declines and plants become very susceptible to damage. These results lead to the definition of three seedling quality classes based on dormancy intensity and SR (Table 1).

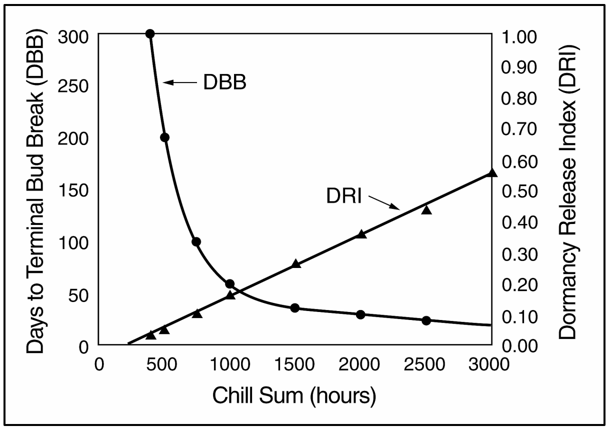

Figure 2 - Because the relationship between chilling hours and days to bud break (DBB) is curvilinear, it is useful to convert to a linear dormancy release index (DRI). In this example, DRI = 10/DBB because Douglas-fir seedlings flushed in 10 days when their full chilling requirement was satisfied (7).

So, once the relationship between chilling and DRI has been established for a given species in a given nursery, it can be used to estimate SR at any point during the winter for subsequent crops at that nursery. Let's say, for example, that it is late December and your nursery chilling sum is about 1,000 hours. Using Figure 2, you would estimate that DRI was approaching 0.2. From Table 1 we see that the stock at this time is in SR class 2 – not yet peaked, but will improve with more chilling. Now, let's say it is February and you have about 2,000 hours of chilling at your nursery. DRI is about 0.38 indicating that SR is in the seasonal high range, but will soon begin to decline.

Adjusting for The Added Effect of Refrigerated Storage - For crops that are "hot planted" without refrigerated storage, this above relationship is very useful. You simply look at your chilling sum at any point and, from it, estimate stress resistance. But many nursery crops are cold or freezer stored from a few weeks to several months before transplanting or outplanting. So, how does that effect SR?

The low temperatures in cold and freezer storage are within the chilling range and contribute to dormancy release. They do so inefficiently, however, because storage temperatures are below the optimum chilling temperature (7,14). Therefore, refrigerated storage *slows the release of dormancy*. This means that seedlings that are lifted and placed into refrigerated storage will pass through SR Classes 2, 1, and 3 more slowly than they would have had they been left in the field or in open container storage. An example: bareroot seedlings that remain in the ground until April will be exhibiting bud swell and will have lost all stress resistance. However, if those seedlings had been lifted in December then placed into storage, when April arrived they would still be dormant and be more resistant to stress.

A summary graph that includes both ambient and storage chilling hours has been developed (Figure 3). The horizontal axis represents the sum of chilling hours to which the seedlings were exposed in the nursery. The vertical axis represents the amount of time the seedlings were held in refrigerated storage (shown in hours on the left and weeks on the right). The roughly parallel curved lines in the graph represent lines of equal DRI, going from about 0 to over 0.50. The three quality classes are shown on the left of the DRI lines and correspond to the values in Table 1.

Here's an example of how to use the graph. Enter the graph on the bottom horizontal axis with total ambient chilling hours from your nursery - for this example, let's use 1,000 hours. At this point, the stock will have a DRI value of about 0.20, placing it in Quality Class 2.

However, if the seedlings are held in refrigerated storage for about 4 weeks, they will enter Class 1 and have even higher SR. However, if these same seedlings had been held in the nursery for several more weeks until they accumulated over 1,300 hours of chilling, they would exceed the DRI limit of 0.25 and enter Class 1 - maximum SR. Then, if they were placed in freezer storage, they could be held for at least 15 weeks (left axis) before their DRI approached 0.40 and their quality dropped to Class 3.

Table 1. Seedling quality classes based on dormancy release index (DRI) and stress resistance (SR) (modified from 9).

Quality class	DRI value	Degree of SR
Class 2	< 0.25	Seedlings are below peak SR, but are improving.
Class 1	0.26 to 0.40	Seedlings are at peak SR.
Class 3	> 0.40	Seedlings are beyond peak - SR is deteriorating.

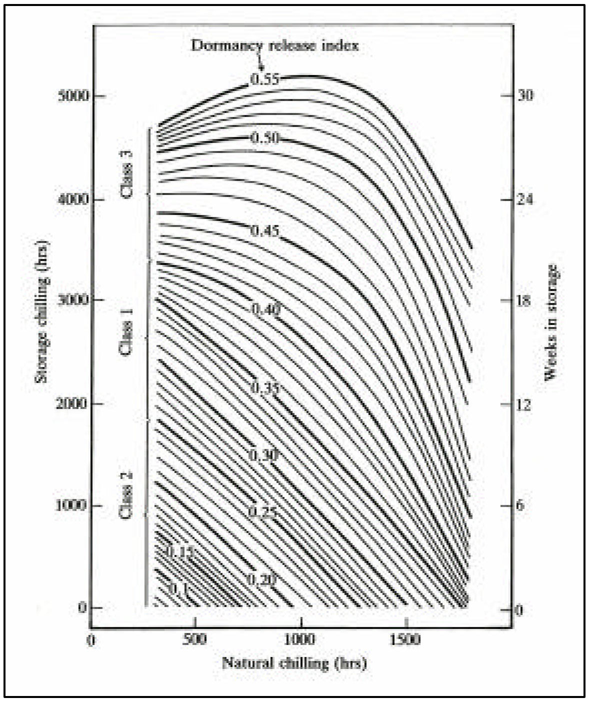

Figure 3. Graph showing how the chill sum at time of lifting, combined with time in cooler or freezer storage, can be used to predict the dormancy intensity (DRI) and stress resistance class (Table 1), of planting stock (9).

So, as you can see, this single graph shows how date of lifting and time in storage interact to control DRI and, hence, stress resistance. If the chill sum at the time of lifting is known, then time in storage can be planned to deliver stock when it is at maximum SR - Class 1. On the other hand, if the outplanting date is known, then lift date and time in storage can be pre-arranged to deliver stock to the outplanting site so it will be in the same Class 1. This graph illustrates the very important point that for late outplanting, early lifting with overwinter storage is preferable to late lifting with no storage.

Application to other species and regions - The data that were used to produce Figure 3 came from coastal Douglas-fir seedlings from four different seed lots (high and low elevations in both Washington and Oregon) that were grown in two different coastal nurseries – one in WA and one in OR. These results have been operationally tested with Douglas-fir crops from other seed lots and during other growing seasons with consistent results. So, for west coast nurseries raising Douglas-fir, Figure 3 is a very handy way of estimating SR from chilling hours.

For interior or northern nurseries, however, the relationship between chilling and DRI may be quite different. This was tested in an interior west Canadian nursery with lodgepole pine and interior spruce (12). The results showed that chilling began to accumulate earlier in the fall and that more chilling accumulated throughout winter. The authors also suggested that these species may have required more chilling hours for full dormancy release than coastal Douglas-fir. Nevertheless, the relationships between DRI and SR and storage were similar to what has been found with Douglas-fir. So, it appears that, before SR can be accurately be predicted from chilling hours, a chilling-DRI "calibration curve" should be developed for other species and nurseries.

Conclusions and Recommendations

Stress resistance (SR) is an important, but elusive, seedling quality attribute that describes a seedling's ability to tolerate the stresses associated with lifting, handling, storing and planting. SR varies seasonally: it is low in fall, high in mid-winter, and low in spring.

SR is very laborious to measure - there is no known "quick test" of SR. However, the seasonal pattern of SR closely coincides with the pattern of cold hardiness (CH). So, CH measurements can be used to estimate SR.

Reminders

1. Seedlings destined for overwinter freezer storage need at least 400 hours of chilling to attain sufficient hardiness before lifting and storing.
2. Seedlings requiring more than 6-8 weeks of storage should be freezer, not cooler, stored.

Studies have shown that SR is related to dormancy intensity expressed as a dormancy release index (DRI). When DRI is in a range between 0 and about 0.25, SR is low but improving. Between DRI 0.25 and 0.40, SR is at a seasonal high. Above DRI 0.40, SR is declining. Importantly, this relation tends to be consistent whether or not seedlings have been stored.

Because cold and freezer storage slow the release of dormancy, they also prolong the period of high stress resistance. These relationships can be used to schedule lifting and storage to deliver stock to the planting site that has very high stress resistance.

To apply these principals in northern or interior nurseries, where winters are longer and colder than in coastal nurseries, it may be necessary to develop calibrations between winter chilling and dormancy intensity for the crop species grown.

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Ramorum blight - Sudden Oak Death Spreads to Nursery Stock

by Thomas D. Landis and Ellen Michaels Goheen

You may have read about a devastating new disease that was discovered in northern California a few years ago. Sudden oak death (SOD) is caused by *Phytophthora ramorum*, which pathologists refer to as "fungus-like organism". At first, it seemed like nurseries had little to be worried about because the disease was only identified on wild trees in the coastal woodlands of northern California and southern Oregon. Things became more interesting, however, when the disease was identified on ornamental nursery stock. Because affected nursery plants are rarely killed, the name Ramorum blight is now used to distinguish the nursery disease from the tree killing cankers of SOD.

The identification of this new disease in nurseries is having serious and wide-ranging consequences, and they are changing week by week. The concern is real because *P. ramorum* had been previously identified in European nurseries and has apparently spread to forests. In March of this year, this disease was identified on camellias in two ornamental nurseries in southern California but not before infected plants had been shipped to 39 states. This prompted government agencies to take quick action. In mid-June, the Oregon Department of Agriculture authorized a temporary rule requiring all nurseries growing potential hosts to enter into "compliance agreements" and be inspected for *P. ramorum* before allowing shipment of host plants. This includes both within and outside of the state of Oregon. *Forest and conservation nurseries are affected because the host list includes Douglas-fir and many other forest and native plant species* (Table 1).

Hosts and Basic Biology

Although it was originally found on native plants in northern California and southern Oregon, pathogen susceptibility tests have shown that *P. ramorum* has an extremely wide host range. Currently, this pathogen has been isolated from over 60 hosts. The Animal and Plant Health Inspection Service (APHIS) of the USDA currently recognizes 28 species in 12 plant families as being *regulated hosts*, and 18 of these are native trees and shrubs (Table 1). Although most are native to northern California, some species are very widespread. For example, Wood's rose (*Rosa woodsii*) is found from Washington state to Texas and California to Wisconsin. Other genera on the list (*Pseudostuga, Quercus, Rhododendron, Rosa*) contain many important plans for reforestation and restoration. This pathogen has also been isolated from other native plant hosts which are known as *associated hosts* until they go through a thorough screening process. This list contains other major genera such as *Abies*, *Fagus* as well as other oaks.

Symptoms and Diagnosis

Identifying Ramorum blight is challenging to say the least because the symptoms caused by *P. ramorum* are different on different hosts. While the characteristic symptom of SOD is a bleeding bark canker on trees, the fungus causes leaf spots and shoot blight on shrubs like *Rhododendron* (Figure 1). Shoot dieback can develop when the disease becomes severe. Unfortunately, these symptoms can be very similar to other *Phytophthora* diseases. Other species exhibit more subtle symptoms such as small lesions on the lower leaves; these infected leaf drop off, making the disease more difficult to diagnose.

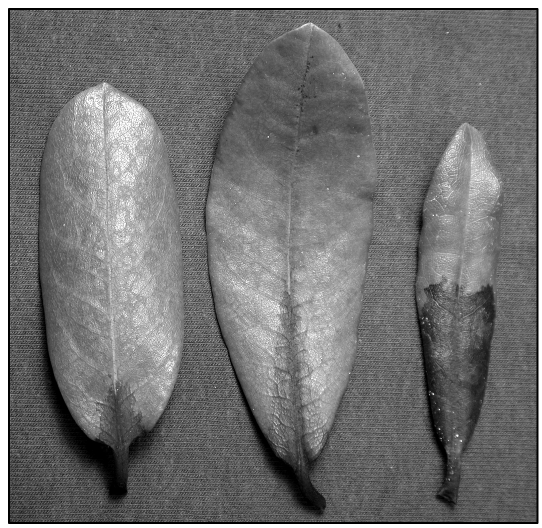

Figure 1 - On broadleaf nursery stock like Rhododendron, Phytophthora ramorum *caused leaf spots and shoot blights which may be indistinguishable from other* Phytophthora *diseases (courtesy of J. Parke).*

Because Ramorum blight is so difficult to diagnose with symptoms, chemical laboratory tests have been developed. Approved testing procedures have been developed by APHIS consist of an initial screening using the ELISA test and plant samples that test positive undergo further DNA testing. To complicate things further, two "mating types" of *P. ramorum* have been identified: Type A1 is found in Europe, while Type A2 occurs in California and Oregon. The concern is that mixing of these two mating types could produce a more potent strain of the fungus. Fortunately, a new rapid diagnostic DNA test has just been developed to distinguish these two mating types.

Table 1 - Natural Hosts for Sudden Oak Death and Ramorum Blight, as Recognized by USDA-APHIS	
Scientific Name	**Common Name**
Acer macrophyllum	Big leaf maple
Aesculus californica	California buckeye
Arbutus menziesii	Pacific madrone
Arctostaphylos manzanita	Roof’s manzanita
Frangula californica ssp. *californica*	California buckthorn
Heteromeles arbutifolia	Toyon
Lithocarpus densiflora	Tanoak
Lonicera hispidula	Pink honeysuckle
Pseudotsuga menziesii var. *menziesii*	Douglas-fir
Quercus agrifolia	Coast live oak
Quercus chrysolepis	Canyon live oak
Quercus kelloggii	California black oak
Quercus parvula var. *shrevei*	Shreve oak
Rhododendron spp.	Azaleas and rhododendrons
Rosa woodsii	Wood’s rose
Sequoia sempervirens	Coast redwood
Trientalis borealis ssp. *latifolia*	Broadleaf starflower
Umbellularia californica	California laurel
Vaccinium ovatum	California huckleberry

In nurseries, the basic biology of *P. ramorum* is different from other *Phytophthora* species because is primarily a foliar pathogen. Although we don’t know much about how this fungus spreads, recent outbreaks have shown that it is very well adapted to the nursery environment. The fungus is capable of producing several different types of spores which allow it to survive harsh environment and still spread (Figure 2).

Quarantines

Quarantine regulations are in place at both the federal and state levels to reduce the risk of spreading *P. ramorum* through infected nursery stock. As an example, let’s look at the comprehensive regulations of the Oregon Department of Agriculture (ODA). This program is mandatory for nurseries that grow host and/or associated host plants, but is only voluntary for growers raising related plant species - within the same genus as a known host or associated host. The ODA program will include three steps:

- Annual survey and inspection of host and associated host nursery stock and/or plant materials at each growing site.
- Annual testing of samples using federally approved laboratory protocols to determine pathogen-free status.
- Participation in a renewable compliance agreement designed to maintain pathogen-free status until the next annual inspection and testing.

These regulations will be changing as new information develops so nursery managers should contact their State Department of Agriculture for the latest.

Conclusions and Recommendations

This article makes no attempt to be comprehensive but is merely a vehicle for awareness. Growers wanting a more complete view on this disease should read the

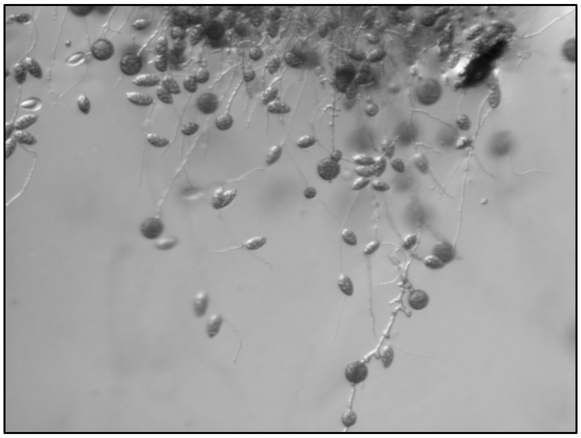

Figure 2 - Phytophthora ramorum *produces several different spores types including round resting spores called chlamydospores and football-shaped sporangia, which release mobile zoospores (Courtesy of J. Parke).*

"Nursery guide for diseases of *Phytophthora ramorum* on ornamentals: diagnosis and management" and "*Phytophthora ramorum*: a guide for Oregon nurseries". Both are available in color as downloadable Adobe PDF publications on the websites listed in the References section.

P. ramorum is an aggressive pathogen that presents a serious threat and so nurseries need to become informed and stay abreast of developments. As already is happening in the Pacific Northwest, nurseries growing potential host plants will be facing legal restrictions on plant shipment. Because things are changing so rapidly, the latest and best information can be found on the following websites, or call the toll free hotline:

TEL: 1.888.703.4457

Websites:

www.suddenoakdeath.org

www.aphis.usda.gov/ppq/ispm/sod/

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Horticultural Humor

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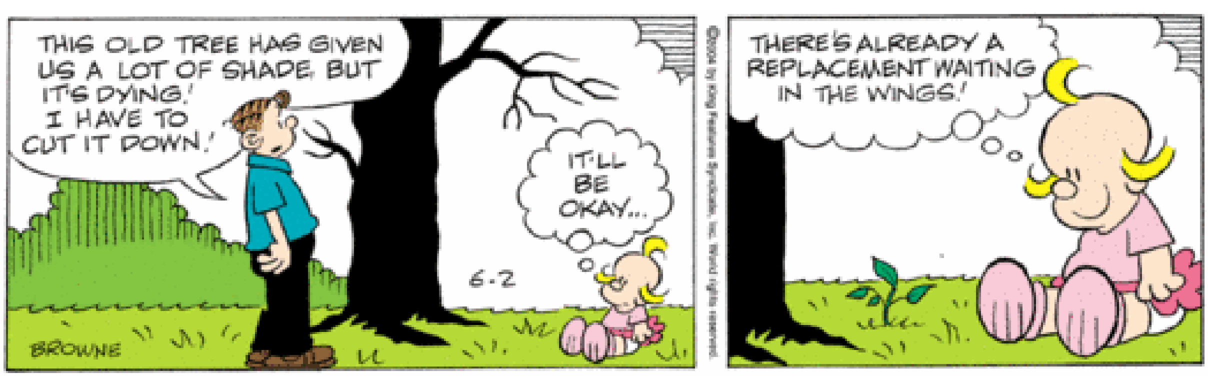

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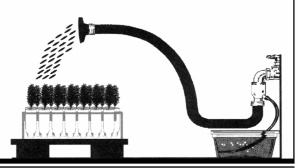

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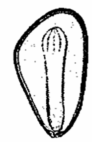
Genetics and Tree Improvement



Genome
Aa
Bb
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Dd

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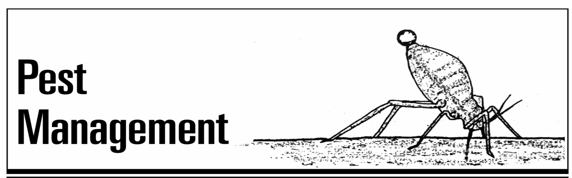

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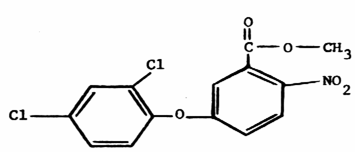

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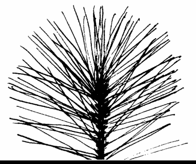

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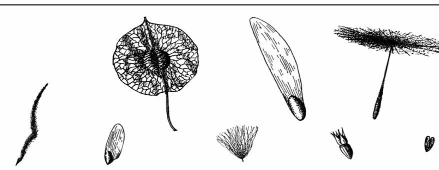

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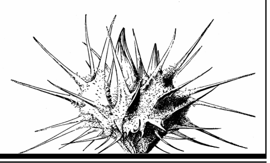

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The Reforestation, Nurseries, and Genetic Resources (RNGR) Home Page (http://www.rngr.net) contains a state-by-state directory of forest and conservation nurseries. There is also a list of nurseries that specialize in native plants in the Native Plant Network section. Use the following form to add your nursery to the directory, or update your listing. Note that we can list your E-mail and WWW home page address so that customers can contact you directly. Send this form back with your literature order form or fax it to: 541.858.6110.

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TEL: 801.571.0900
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Forest Nursery Notes
Container Tree Nursery Manual
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Native Plants Journal</td><td>US and International</td><td>Kas Dumroese
USDA Forest Service
1221 S. Main Street
Moscow, ID 83843
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E-Mail: kdumroese@fs.fed.us</td></tr>
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Technical Assistance about Forest and Conservation Nurseries</td><td>Southeastern US</td><td>George Hernandez
USDA Forest Service
Cooperative Forestry
1720 Peachtree Road NW, Suite 811N
Atlanta, GA 30367
TEL: 404.347.3554
FAX: 404.347.2776
E-Mail: ghernandez@fs.fed.us</td></tr>
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USDA Forest Service, S&PF
Purdue University
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