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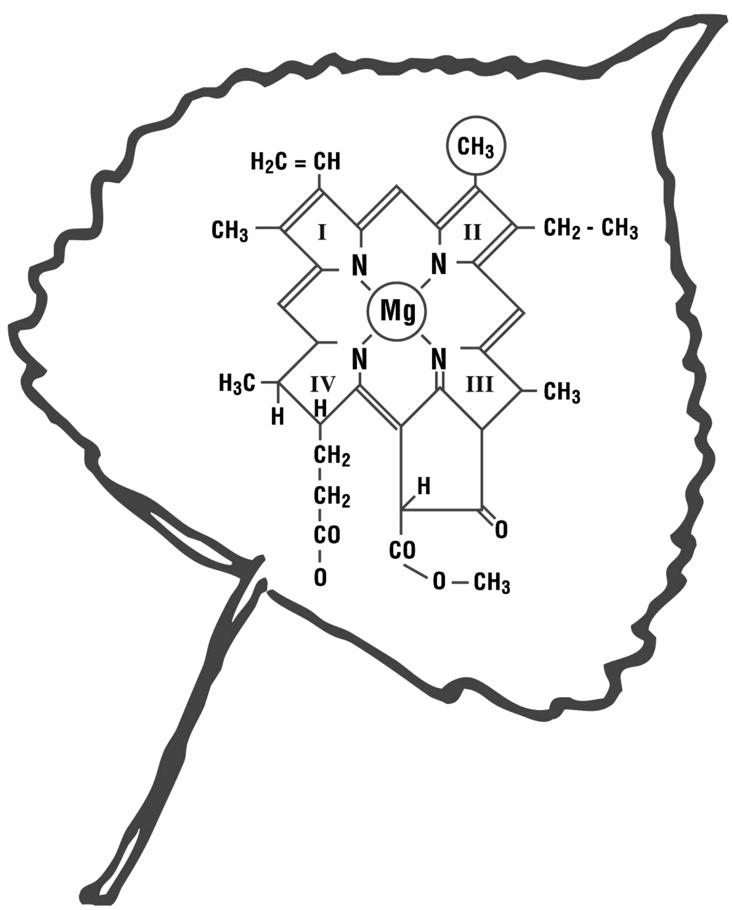
Forest Nursery Notes

Winter 2004



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Forest Nursery Notes
Winter 2004

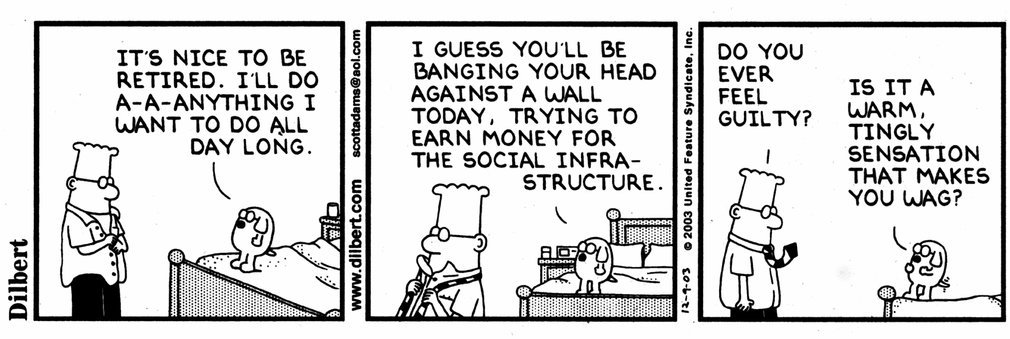
What New in This Issue?

Changes in Management: With my official retirement on January 2, 2004, I am "turning over the reins" to my good friend Kas Dumroese who will also be assuming the role as National Nursery Specialist. I will continue to contribute to FNN as principal author and editor, working on a contract basis. Kas and I have collaborated on many projects and we don't see any major changes in the way FNN issues are produced. The general layout will remain the same: short informational articles on nursery culture and news topics, followed by a New Nursery Literature section. You will still be able to order 25 of the listed articles for free by filling out and returning the Literature Order Forms.

What will change is that I will not be around the office to answer telephone calls, FAXes and E-mail correspondence. It remains to be seen whether my replacement - the new Western Nursery Specialist - will be hired right away. As with most things, it will all depend on funding. The Forest Service still values this position as a valuable technology transfer position so hopefully they will fill it soon.

I am starting a private nursery consulting business and will hopefully have the opportunity to work with many of you in the future. I should be able to keep busy on a part-time basis and have more time for fishing and skiing. Retirement should give me the time to finally do some writing on Volume Seven of the Container Tree Nursery Manual series. Seedling Processing, Storage, and Outplanting will cover the time period from when seedlings are hardened-off and ready for harvest through when they are outplanted.

One thing is sure - I don't want to do as much traveling! So, we'll just have to see how it goes in this new phase of my life. My best wishes to you and yours during this holiday season and throughout the New Year!



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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:

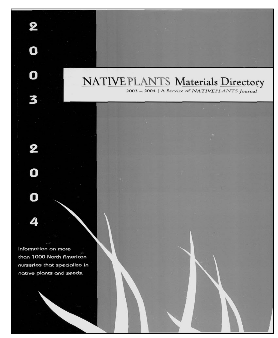
1) Directory of Forest and Conservation Nurseries
2) Commercial Seed Dealers Directory
3) Native Plant Materials Directory.

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:

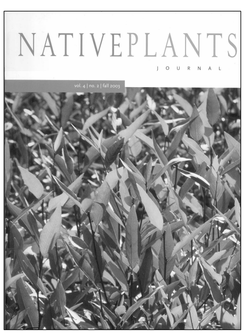
Bryan Jordin
TEL: 706.542.1965
E-Mail: jbjordin@soforext.net

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.

LUSTR Forest Renewal Co-op Presents: Annual General Meeting & Workshop **January 22 and 23, 2004** in Thunder Bay, Ontario. Registration for the workshop is available to any interested groups or individuals, but the AGM is for Co-op members only. Some of the topics include Tree Improvement Activities in Ontario, Federal and Provincial Afforestation Initiatives and Herbicide use. block of rooms are reserved at Valhalla Inn until January 8, 2004. All information is available online at: <www.lustr.ca>

For reservations contact:
Valhalla Inn
800.964.1121 or 807.577.1121
Reservations@valhallainn.com
Confirmation #1725

For more information and registration contact:
LUSTR Forest Renewal Co-op
Lakehead University
Faculty of Forestry and the Forest Environment
955 Oliver Road
Thunder Bay, ON P7B 5E1
TEL: 807.343.8313
FAX: 807.343.8116
E-Mail:lustr@lakeheadu.ca

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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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 Nursery Technology Cooperative at Oregon State University will be hosting two conferences in 2004 in **Eugene, OR.**

May 12-13, 2004: Forest Seedling Root Development from the Nursery to the Field.

December 15-16, 2004: Forest Plant Propagation and Restoration

For more information please contact:

Diane Haase
Nursery Technology Cooperative
OSU Forest Science
321 Richardson Hall
Corvallis, OR 97331
TEL: 541.737.6576
E-MAIL: diane.haase@orst.edu

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 Q-Plug: A One Year Transplant

By David Steinfeld

For years, nursery managers have looked for ways to produce a transplant seedling in one season. Not only would this drastically reduce costs, it would also make planning and ordering seedlings easier for clients. One approach that has been investigated is to 1) sow into small containers in early winter, 2) grow for three to four months under greenhouse conditions, 3) extract and transplant in spring, 4) grow in bareroot beds for nine months and 5) lift the following winter. At Stone Nursery we have tried this method over several years using Styroblock®2, [2.9 in^3 (39 cm^3)] and Styroblock®4, [3.7 in^3 (70 cm^3)] containers. We learned that seedlings sown in mid winter did not have a firm root plug that would tolerate transplanting until late May to mid June. Unfortunately seedlings planted at this late date are not only subjected to hot, dry environmental conditions but, they also don't have enough time to develop the target size requested by our clients.

We realized that the key to producing a one-year transplant is to work with a plug that would hold together without the support of a developed root system. This would allow us the flexibility to extract and transplant at any time during seedling development, opening the transplant window to as early as mid March at our nursery. Concurrently, we were also looking for a stabilized plug that would work well in a carousel type transplanter - a transplanter that we believed would give us higher transplant production, better density control and better planting quality. When it really came down to it, we were looking at modifying our entire transplanting system if we could find the right plug. That plug is called the "Q-plug".

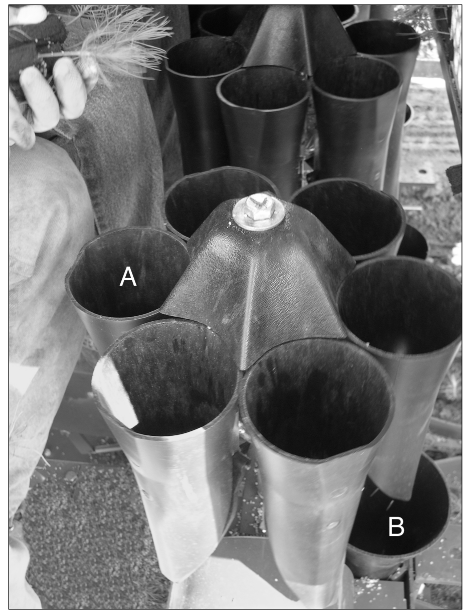

Figure 2. Carousel transplanter – Q-plug is placed in chamber (A) which rotates the plug 180 degrees and drops it into tube (B) which delivers it to the soil.

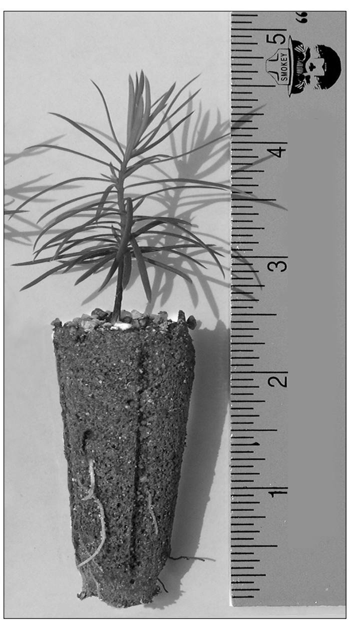

Figure 1. 10 week old Doulgas-fir seedling in Q-plug ready for transplanting.

The Container Seedling

A Q-Plug is like a fine textured sponge that when thrown against a wall will bounce. A bag of them could very well be wrapped and placed under a Christmas tree to a young child's delight. Q-Plugs are produced by International Horticulture Technologies (www.ihort.com) who describes their product as a "stabilized rooting media™". The technology is proprietary but basically the media is composed of composted bark and peat, held together with a binding agent. The media can be molded into any shape and size and the company has molds for a variety of growing containers. For our needs, we chose a Hortiblock®200 container which is a styrofoam block container with 200 cells, tapered for easier extraction. Plug volume is 1.2 in^3 (20cc) and length is 2.4 in (5.8 cm) (Figure 1).

The Transplanter

Having found the right plug, we turned our attention to selecting a transplanter. Up until this point, our production transplanting had been done with a clip/wheel transplanter. Since clips cannot hold the stem of a very small Q-Plug seedling, we became interested in the carousel type transplanter. With this technology, a seedling is simply placed into a rotating chamber (Figure 2) which drops the seedling through a tube that delivers it to a furrow in the soil where it is packed into place (Figure 3).

We settled on the Mechanical Transplanter 5000®, a carousel transplanter produced by the Mechanical Transplanter Company. We purchased nine carousel units and fabricated a transplanter that could plant nine rows in a bareroot bed at a density of 11 seedlings per square foot (118/m^2).

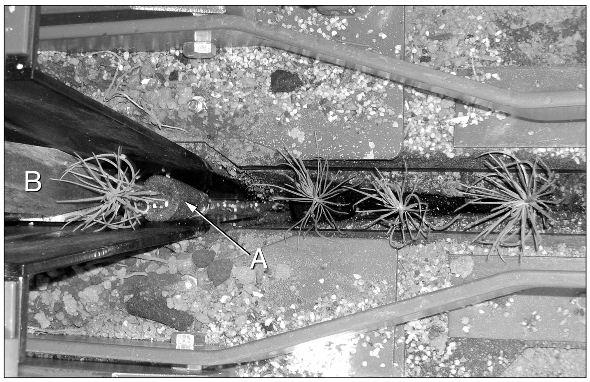

Figure 3. As transplanter moves to the left, a Q-plug drops into the soil (A) and is placed into an upright position with a moving paddle (B). The soil furrow is immediately closed.

Container Culture

Last fall, we contracted with the IFA Nursery in Klamath Falls, Oregon to grow several million ponderosa pine, Douglas-fir and incense cedar seedlings in Q-Plugs. The nursery was within an hour and a half drive from us, which was close enough to give us flexibility in ordering seedling shipments on short notice.   Their nursery management saw this as a great opportunity to fill greenhouses that were typically empty in the winter months. They could have a Q-Plug crop grown and shipped to us by the time they needed to fill their greenhouses with the normal spring production crop. So, in late January we sent them stratified seed, which they sowed over the next several weeks. Since the volume of the Hortiblock®200 plugs are very small, attention to the moisture status of the plug was critical and irrigation schedules were adjusted accordingly. In addition to frequent irrigation, seedling culturing involved light fertilization and several applications of mycorrhyzal spores. By late March, the crop was ready to ship back to our nursery for transplanting.

Transplanting

As luck would have it, the weather last spring was the worst we had experienced in decades. We were uncertain from day to day if we were going to be able to transplant so flexibility in seedling shipments was important. When a shipment of seedlings arrived, we would store them outside for several days until we were ready to transplant them. Because of the small size of the seedlings and lack of many roots, plugs could not easily be extracted from the containers without a little help. We had to fabricate a pin-type block extractor to loosen the Q-Plugs from the styrofoam blocks. As soon as they were loosened, the styrofoam blocks were placed on the transplanter (Figure 4). We designed the transplanter to store enough containers to transplant an 800 foot (244 m) bed. At the beginning of each bed, our crews would position several styrofoam blocks in vertical frames in front of each carousel. Crew members would then gently pull Q-Plugs from their containers and place them in the carousel chambers. Once our crews got the hang of it, we were planting between 130 to 170 thousand seedlings a day per transplanter.

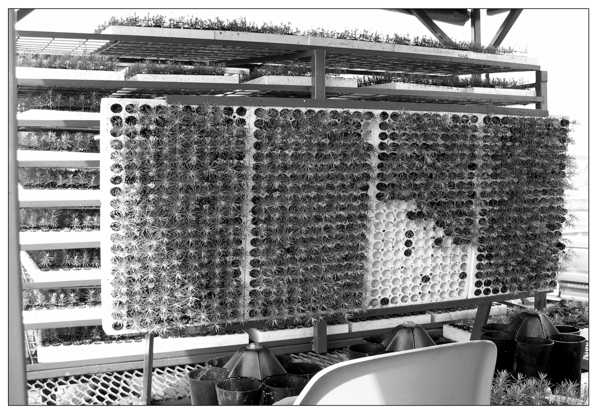

Figure 4. Several styroblocks (Hortiblock 200) are placed vertically in front of each carousel for easy extraction and placement in chambers.

Bareroot Culture

Culturing a seedling crop started in Q-Plugs presented us with some initial challenges. We learned that transplanting into less than ideal soil conditions becomes even more critical with the small Q-Plug. Since the soil conditions last spring were often very moist during transplanted, the soil around the Q-Plugs was often compacted, resulting in poor aeration and drainage immediately around the plug. To increase soil friability, we wrenched the seedling beds in late June. The Douglas-fir and incense cedar seedlings were not affected by the stress of this operation and they kept growing through the summer but the ponderosa pine set

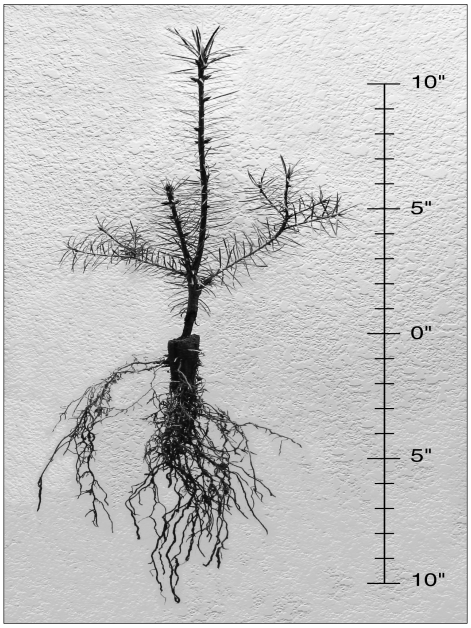

Figure 5. Douglas-fir seedling started in Q-plug in February 2003 and lifted in January 2004.

a bud and stopped height growth. All seedlings however continued to put on root and caliper growth into the late fall (Figure 5). Transplanting with drier and more friable soils will improve future crops.

Summary

We see many advantages to this new one-year transplant stocktype. Most of our clients are located in areas where summer precipitation is extremely low. Their target seedling has a small top, high root volume and large stem diameter. While our 2+0 or 1+1 seedlings have large stems and good root volumes, they also typically have corresponding large shoots since they have been grown for two years in a nursery that has an extremely favorable growing environment. While the Q-Plug transplant has a smaller root volume and stem caliper than a 2+0 or 1+1, it has a much higher root to shoot ratio, giving it an advantage on droughty sites. Our departure from standard bareroot transplanting methods has resulted in many benefits including:

?? Eliminating the 1+0 year in a bareroot bed
?? Eliminating seedling extraction and cold storage
?? Increasing worker productivity on the transplanter
?? Increasing seedling bed density
?? Reducing poorly planted seedlings (reducing culls)
?? Decreasing the time in a greenhouse (10 weeks vs. up to 9 months)
?? Reducing seedling costs, while producing a stocktype that meets the needs of many of our clients.

We are receiving good orders for one-year transplants for this coming year. Of course, the final test for any new stock type is survival and growth on the outplanting site. Several land management agencies (including Medford BLM and the Umpqua, Winema and Wenatchee National Forests) will be outplanting our transplant stock this coming spring and we will monitor seedling performance for several years.

Macronutrients - Nitrogen: Part 2
by Thomas D. Landis and Eric van Steenis

This article is the second part of a look at the importance of nitrogen in nursery management. Part One can be found in the Summer, 2003 issue of FNN and covered the role of nitrogen in plant nutrition and influences on seedling growth and development. Figure 2 was inadvertently omitted from that article and so we are including it here:

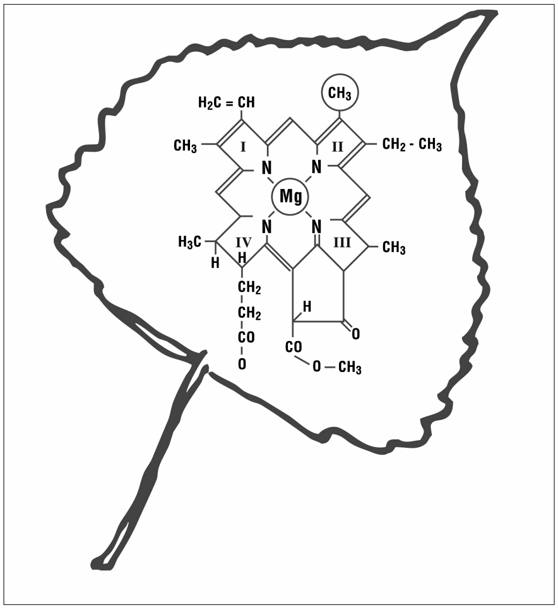

Figure 2 **-** *Nitrogen is critical to photosynthesis because each chlorophyll molecule contains four nitrogen atoms at its very heart.*

Influences on Plant Growth and Development

Because nitrogen is so critical to nursery production and has so many different affects on seedling physiology, you can occasionally see deficiency symptoms in forest and conservation nurseries.

Deficiency Symptoms.

The initial stages of nitrogen deficiency are difficult to diagnose because nitrogen is very mobile within the plant and minor deficiencies will first be expressed as slower growth rates ("hidden hunger"). In individual seedlings, nitrogen is translocated from older to younger tissues resulting in a color change in the older leaves or needles. First, they turn a light green, then yellow as the chlorophyll is broken down. Severely deficient foliage will appear scorched on the margins. In bareroot nursery seedbeds, competition for nitrogen can be severe between adjacent seedlings and results in a characteristic "scalloped" growth pattern (Figure 5). This symptom occurs because the larger green seedlings in the outside rows have access to fertilizer in the tractor paths while the stunted and chlorotic seedlings in the center rows must compete with each other.

Chlorosis is a poor diagnostic symptom for nitrogen deficiency, however, because yellowing can be caused by many other mineral nutrient deficiencies. Nevertheless, the symptom pattern of chlorosis beginning in the older (lower) foliage of seedlings can be diagnostic to distinguish nitrogen from magnesium, sulfur, or iron deficiencies.

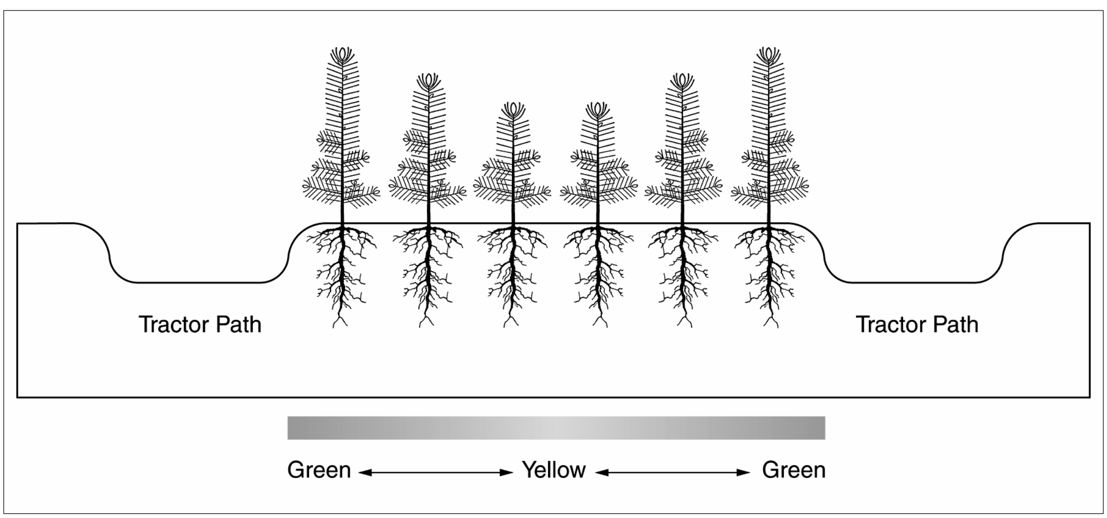

Figure 5. "Scalloped" nursery beds are a common nitrogen deficiency symptom in bareroot nurseries.

Toxicity Symptoms.

Because nursery plants can take-up so much nitrogen fertilizer as luxury consumption, there are no specific nitrogen toxicity symptoms. However, over application of nitrogen fertilizer can cause typical salt damage symptoms such as scorching and curling of needle tips or leaf margins. Toxicity can also be caused by high levels of ammonium-based nitrogen fertilizers, resulting in the death of root tips. These damaged root systems are expressed as drought stress and reduced nutrient uptake ability, and so wilting of succulent seedling tissue when water is not limiting and evapotranspiration is low should be investigated.

Oversupply of nitrogen fertilizers can also be expressed in deficiencies of other nutrient elements. These “induced deficiencies” may be due to ion competition in the root zone such as ammonium competing with calcium, or they may be the result of internal nutrient imbalances. Induced deficiencies result because mineral elements are utilized in varied proportions according to need. For example, sulphur atoms are needed for protein synthesis at approximately one-tenth the rate of nitrogen atoms. Oversupplying nitrogen causes a relative depletion of sulphur, resulting in a “nitrogen-induced sulphur deficiency”. The plant responds by preferentially constructing proteins that require less sulphur atoms, which sacrifices processes and structures that require high-S-proportion proteins.

Monitoring Nitrogen

Nitrogen can be monitored by chemical analysis of soils, growing media or plant tissue.

Soil Tests.

The many organic and inorganic forms of nitrogen in the soil make it extremely difficult to use soil tests as a diagnostic tool. Therefore, many nurseries apply nitrogen fertilizer based on crop response rather than soil test results. Some nurseries do monitor nitrate concentrations in soils as a rough indication of nitrogen availability or as an indication of the need to leach high nitrate levels from the root zone.

Artificial Growing Media Tests.

Chemical tests for nitrogen availability are not common in container nurseries either. Because of their high organic matter content, artificial growing media have large reserves of nitrogen in the peat moss, compost or other organic components. Therefore, most container growers have developed their fertilization regimes based on seedling growth response rather than media tests.

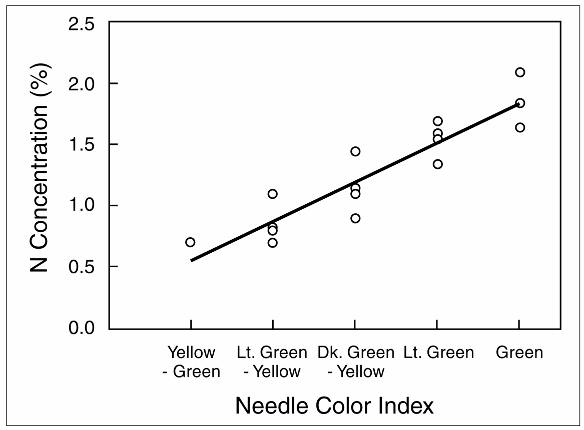

Figure 6. Nitrogen concentration in relation to color of Norway spruce needles (modified from 5).

Seedling Tissue Analysis.

Chemical analysis of plant tissue has been done more for nitrogen than for any other mineral nutrient. However, because of its high mobility in the plant and growth

Table 3 - Nitrogen Concentration (%) in Conifer Seedling Tissue During the Growing Season For Conifers in Eastern Canada

Species Group	Seedling Age of Production Stage			
	3 to 10 weeks	10 to 16 weeks	Hardening	Storage
Pine	2.8 to 3.0	2.5 to 2.8	2.2 to 2.5	1.9 to 2.2
Spruce	3.2 to 3.6	2.5 to 3.0	2.5 to 2.8	1.9 to 2.2
Modified from 4				

dilution effects during the season, good standards have been hard to develop for many forest and conservation crops. Nevertheless, experienced nursery managers frequently test foliage samples to fine-tune crop development or test the effectiveness of a particular fertilizer regime. Some growers do analyze foliar samples during the growing season to develop their own standards (Table 3). More commonly, foliar samples are collected from seedlings in the fall or during the hardening phase eliminate the growth dilution effect.

The nitrogen adequacy range for conifer foliage is generally considered to be between 1.5% and 3.5%. Below 1.5% seedling growth will be retarded - this is the "hidden hunger" symptom that is so difficult to diagnose. Towards the lower end of the adequate range (1.5 - 1.8% nitrogen) most species will grow slower and display lighter green foliage. Seedlings being grown at levels between 2.5 and 3.5% nitrogen generally display lush green color and can produce very soft, succulent tissue under optimum growing conditions (Figure 6). Under operational conditions, growers generally maintain seedling foliage nitrogen levels between 2 and 3% during active growth and allow it to ramp down to about 2% prior to lifting or winter storage (Table 3). When monitoring crops for nitrogen status, it is important to base decisions on solid data trends rather than "snapshots in time". Having a series of foliar nutrient analyses done over several seasons and graphing the results is easy with computer software. Tracking the status of several nutrients on the same graph can be valuable in exposing mineral nutrient interactions.

Nitrogen Management

Managing nitrogen in forest and conservation nurseries is critical, not only because large amounts of nitrogen fertilizers are used to force growth but because nitrogen pollution is an increasingly serious problem in all forms of agriculture.

Fertilizers, Application Methods and Rates in Bareroot Nurseries.

A wide variety of nitrogen fertilizers are being used in forest and conservation nurseries (Table 4). In bareroot nurseries, recommendations are often given as "actual nitrogen" instead of bulk fertilizer which allows growers to convert easily to whatever fertilizer they are using. For example, 40 lbs (18.1 kg) of actual nitrogen would convert to an application of 190 lbs (6.2 kg) of ammonium sulfate (21-0-0), or 121 lbs (54.9 kg) of ammonium nitrate (33-0-0).

Organic Nitrogen Fertilizers **-** In the early days, manure was the most common nitrogen fertilizer but it is not widely used today because of its volume and weight, variable quality, and contamination with weed seeds. All organic fertilizers are slow-release and contain a full complement of mineral nutrients compared with many synthetic brands. Today, only a few organic fertilizers such as Milorganite® have been used in bareroot nurseries because of their lower analysis and consequently higher application costs (Table 4). One of the underappreciated benefits of organic fertilizers is the large amount of organic matter that they add to the soil. For example, applying Milorganite® at an annual rate of 200 lbs of N/acre (224 kg/ha) will supply almost 2 tons (1.8 mt) of organic matter to the soil as a by-product of fertilization.

Synthetic Nitrogen Fertilizers **-** Most contemporary fertilizers used in forest and conservation nurseries are synthetically produced and are inorganic salts (Table 4). The choice of fertilizer is dependent on the application method. Applying granular fertilizer to the soil surface ("top dressing") is the most common application method for nitrogen fertilizers in bareroot nurseries although incorporation and banding are sometimes used. For example, monammonium or diammonium phosphate are banded at the time of sowing to ensure uniform placement in the root zone. After seedling emergence, ammonium sulfate and ammonium nitrate are commonly top-dressed and their choice depends on their effect on soil pH, the former lowering it and the latter raising it.

The newest option for applying nitrogen fertilizers is through sprayers. A stock solution of soluble fertilizer is diluted with water in a spray tank and then sprayed over the crop. An exciting feature is that new computer-controlled sprayers can change application rates for different crops or soil types without stopping. Spray application is also much more uniform than other fertilizer application equipment (15).

Application Rates and Timing **-** Nitrogen applications for bareroot nurseries are generally applied based on estimates of crop use because there is no acceptable soil test for determining total available nitrogen. The actual amount of nitrogen that a seedling crop requires is dependent on species, seedling density, climate, and soil type. Fertilizer nutrient recovery is also relatively low ranging from 13 to 16% nitrogen for a 1+0 crop to perhaps 50% during the 2+0 year. Therefore, most nursery managers apply from 50 to 250 (56 to 280 kg/ac) of nitrogen during a rotation (16).

One of the most scientific ways of determining the proper time for nitrogen applications is the degree day

Table 4 - Types of 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	Top-Dressed or Incorporated	An organic fertilizer made from municipal sludge
Urea (NH_2-CO-NH_2)	46	0	0	BR	Top-Dressed or Incorporated	A dry material in dry or prilled form
Ammonium nitrate NH_4NO_3	33-34	0	0	BR & C	Top-Dressed or Fertigation	A dry material in dry or prilled form
Ammonium sulfate $(NH_4)_2SO_4$	21	0	0	BR	Top-Dressed	A dry crystalline material. Contains 24% sulfur.
Diammonium phosphate (DAP) $(NH_4)_2HPO_4$	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 nitrate KNO_3	13	0	45	C	Fertigation	Dry crystalline material.
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 with high urea for quick "green-up."
Controlled-Release Formulations						
Osmocote Fast Start; 8 to 9 month release	18	6	12	C	Incorporation	Polymeric resin-coated prills; 10.4% Ammonium, 7.6% Nitrate
Osmocote High N; 8 to 9 month release	24	4	8	C	Incorporation	Polymeric resin-coated prills; 18.5% Urea/ Ammonium, 5.5% Nitrate
Polyon 25-4-12; 8 to 9 month release	25	4	12	C	Incorporation	Polyurethane-coated prills; 22.4% Urea/ Ammonium, 2.6% Nitrate
Nutricote 270; 8 to 9 month release	18	6	8	C	Incorporation	Thermoplastic resin-coated prills 8.6% Ammonium, 9.4% Nitrate

system which uses accumulated heat units. The degree day approach is attractive because the fertilizer applications are synchronized with seedling growth which, of course, is closely controlled by temperature. Either ambient or soil temperature can be used as a degree-day basis although soil temperatures are more stable and more accurately reflect the environment where the nutrient uptake is actually occurring. Because of climatic and edaphic variation, each nursery must develop its own degree day system.

Another effective procedure is to schedule nitrogen fertilizer applications in bareroot nurseries based on seedling growth curves. Plots of growth increments show the times when shoot growth generally occurs and so fertilizer applications can be scheduled at regular intervals during this period (Figure 7). This approach ensures that the fertilizer is available during the time of maximum seedling growth rather than later in the year when the fertilizer would he wasted or could adversely affect the onset of dormancy or frost hardiness.

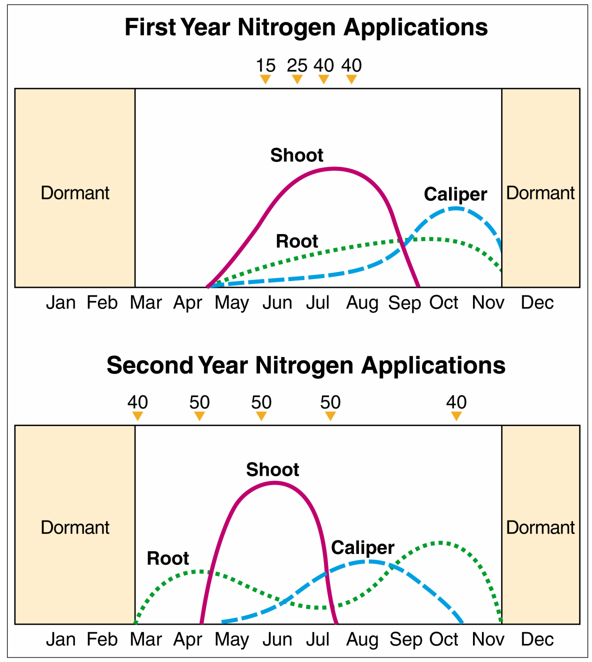

*Figure 7. Nitrogen fertilizer should be scheduled in 4 to 5 applications per season, the majority applied early in the growing season to promote shoot growth. In this example, the fertilizer applications are given as amount of actual nitrogen in pounds per acre (*1 lb/ac = 1.12 kg/ha).

Fertilizers, Application Methods and Rates in Container Nurseries.

With regards to nitrogen fertilizers, there are two options for container nursery managers: 1) incorporate controlled-release fertilizers (CRF) into the growing media prior to sowing, or 2) apply liquid fertilizer through the irrigation system ("fertigation"). With larger containers, it is possible to top-dress with soluble or CRF fertilizers but this is not common in forest and conservation nurseries.

Incorporation of Controlled Release Fertilizers - Some nurseries traditionally mixed a "starter dose" of soluble fertilizer in their growing media but the newest trend is to incorporate controlled release fertilizers. Although Osmocote® and some other products have been around for decades, the newest brands and formulations offer better nutrient release patterns lasting up to 12 to 14 months (Table 4). These longer release formulations are designed to promote some growth in the nursery but also give a boost to seedlings after outplanting. To supplement the incorporated CRF, growers add enough additional nitrogen through fertigation to achieve desired growth rates and seedling quality.

One thing to notice about CRF is that the ammonium to nitrate ratio is different from brand to brand and between formulations of the same brand. Polyon® 25-4-12 contains a much higher percentage of urea/ammonium than nitrate nitrogen compared to Nutricote® 18-6-8, which contains an almost even balance of the nitrogen ions. Likewise, Osmocote High N® contains much more urea/ammonium than nitrate compared to Osmocote Fast Start®, which is much closer to equal proportions (Table 4).

Fertigation with Soluble Fertilizers - Fertigation is a quick, easy, and cheap application method and so most nurseries inject soluble nitrogen fertilizer through the irrigation system. Of course, the rate and uniformity of nitrogen applied to each container is completely dependent on the efficiency of the irrigation system. Regulating the amount of nitrogen fertilizer is used to control seedling growth rate and plant succulence, and container growers typically apply from 50 to 250 ppm nitrogen, depending on species and growth stage. Formulations should generally contain a mixture of ammonium and nitrate, favoring more nitrate during low light conditions in the winter and early spring, and adding more ammonium as light increases. For examples of typical fertigation regimes, see Volume Four of the Container Tree Nursery Manual (9).

Exponential fertilization is a relatively new fertigation technique which applies nitrogen fertilizer at an increasing rate over the growing season. This corresponds more closely to the exponential growth rate of seedlings, providing more nutrient gradually as the crop increases in size. This technique has been advocated by Timmer (14) and is being done operationally in eastern Canada. Although the theory is attractive, exponential fertilization has yet to find widespread use in container nurseries in the rest of the country.

Nutrient Loading.

Some nurseries in Eastern Canada have used high nitrogen fertilizer rates (up to 6X normal rates) to buildup nutrient reserves prior to harvesting. This "nutrient loading" involves forcing foliar nitrogen levels into the luxury consumption range without causing bud break or other detrimental changes in morphology. When combined with exponential fertilization, these exponentially loaded seedlings have exhibited greater growth after outplanting compared to conventionally fertilized stock. This practice is particularly recommended for outplanting sites with severe vegetative competition where rapid height growth is advantageous (11). So far, nutrient loading has only been proven in specific situations and it remains to be seen whether it will achieve widespread use in other outplanting environments.

Effects of Overfertilization.

Over-application of nitrogen fertilizers can create several problems including:

1) Poor shoot-to-root balance **-** High nitrogen fertilization rates, especially with ammonium, can produce excess shoot growth at the expense of root growth (Figure 8A). This can cause problems both in the nursery and after outplanting. Top-heavy seedlings are often culled because customers know that they will be at a disadvantage on the outplanting site.

2) Delayed dormancy or hardiness **-** High levels of nitrogen fertilizer have been shown to prolong tissue succulence, stimulate growth of lammas shoots, and increase the possibility of cold injury in the Fall (Figure 9). Because nitrogen fertilization has such an overriding control on both the seedling growth rate and hardening, it is intuitive to make this association. Several specific research studies are documented in Volumes Four and Six of the Container Tree Nursery Manual (8 & 9).

3) Water pollution **-** It is hard for nursery managers not to be tempted to overfertilize with nitrogen fertilizer, considering the tremendous growth boost that it provides (Figure 8A). After all, fertilizer is still relatively cheap. However, a combination of a rising environmental consciousness and fear of restrictive legislation has made nurseries take another look at their fertilization practices. Plants are only able to uptake and utilize a given amount of nitrogen at a time which is known at their "nitrogen use efficiency". This efficiency has been shown to decrease with increasing fertilization rates (Figure 8B), increasing the pollution potential. For example a study at the Forest Research Greenhouse at

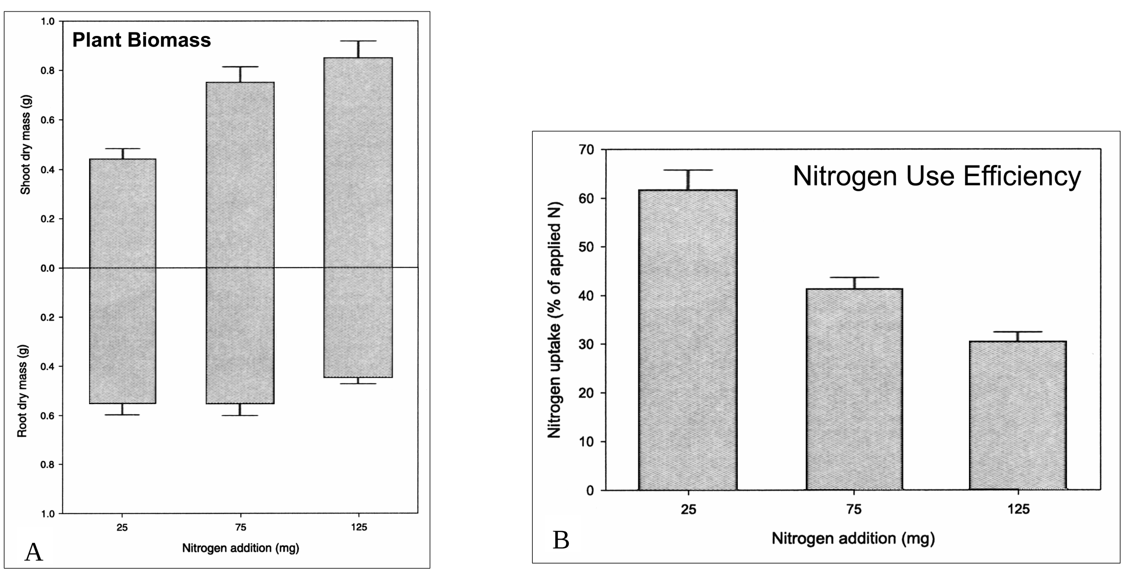

*Figure 8. Increasing nitrogen fertilization stimulated both shoot and root growth of container seedlings of interior spruce (*Picea glauca x engelmannii*) but, at the highest level, root growth was depressed (A). As the nitrogen fertilizer rate increased, the ability of the seedlings to utilize the fertilizer decreased (B) and the potential for nitrogen runoff increased (modified from 13).*

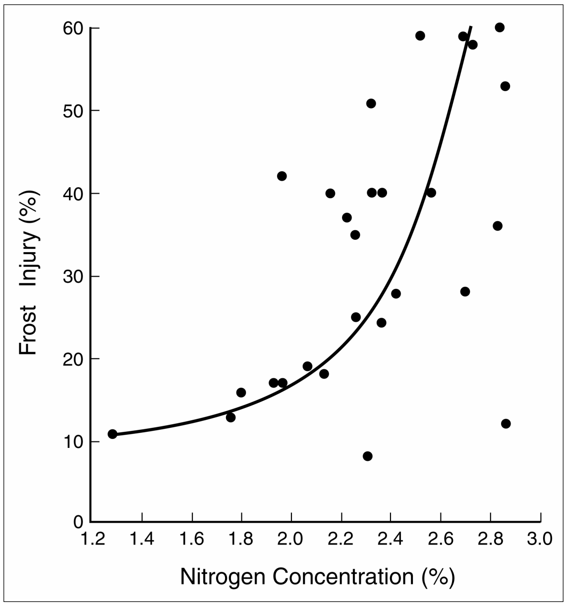

Figure 9. Cold injury was found to increase with foliar nitrogen concentration in these balsam fir transplants (modified from 4).

the University of Idaho showed between 32 and 60% of all nitrogen applied in fertigation was discharged in the wastewater (2).

Nitrates are very mobile in water and can easily escape from nurseries in surface runoff or leach to groundwater. This nitrate pollution can adversely affect human health, especially in babies, and nitrates also pose a significant threat to water quality through eutrophication. Eutrophication refers to the excessive nutrient enrichment of water, which results in nuisance production of algae and other water plants (12).

4) Reduced Outplanting Performance - High nitrogen fertilization has been shown to adversely affect seedling survival and growth after outplanting. The exact reason for this varies but has been attributed to non-hardy stock, seedlings with disproportionately small root systems, and an increased amount of animal damage. Although many of these reports are anecdotal, several research studies have linked high foliar nitrogen levels and poor outplanting performance.

Note that this is apparently in direct conflict with the practice of exponential nutrient loading as discussed earlier. The reasons for this apparent contradiction are unclear but can most likely be related to conditions on the outplanting site. As has been found to be true for fertilization at time of outplanting, nutrient-loaded seedlings have performed best on mesic sites with high levels of vegetative competition (14). The added nutrient boost apparently helps seedlings outgrow the surrounding vegetation and the presence of other vegetation reduces the animal damage. On drier outplanting sites, however, the nutrient-loaded seedlings are more exposed to animals and the higher salts levels in the foliage is thought to actually attract herbivores.

Conclusions and Recommendations - Part 2

Nitrogen is by far the most important mineral nutrient in forest and conservation nurseries but managing nitrogen fertilization has environmental as well as economic effects. Nitrogen deficiency rarely occurs in nurseries due to the high levels of fertilization, and toxicity is not seen because plants can uptake large amounts of nitrogen as luxury consumption. Monitoring nitrogen is primarily done by observing seedling growth rates and through chemical analysis of foliage. In bareroot nurseries, synthetic nitrogen fertilizers are sometimes applied by incorporation or banding but top-dressing is still most common. Injecting soluble fertilizers through the irrigation system is the most widespread technique for applying nitrogen in container nurseries. Some container growers incorporate controlled-release fertilizers into their growing media and supplement it with soluble fertilizers. Because of growing concern about the serious consequences of overfertilization with nitrogen, both bareroot and container growers are monitoring fertilization more closely. The benefits of nutrient loading seedlings on outplanting performance is currently being tested on outplanting sites across the country.

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Seedling Quality Tests: Bud Dormancy

by Gary Ritchie and Tom Landis

In the Winter 2002 issue of Forest Nursery Notes, we initiated a series of articles on seeding quality testing with a discussion of the popular root growth potential test. In the Summer 2003 issue we reviewed aspects of the cold hardiness test. In this third installment, we will discuss dormancy - what it means, how it can be measured, and how it can be practically used in forest and conservation nurseries.

The Concept of Dormancy

Dormancy is one of the oldest concepts in nursery science. Foresters learned by observation and trial and error that plants could be transplanted and outplanted most successfully when they were not actively growing. In the temperate zone, this occurs in winter so nurseries have traditionally harvested their stock during this period. The concept of the "lifting window" was developed by harvesting and outplanting seedlings from late fall through early spring and measuring survival and growth. These trials supported the traditional practice of harvesting during mid-winter, and people interpreted these results to mean that seedlings were most "dormant" during this period. However, as we will show, the concept of a mid-winter dormancy peak is not correct.

Defining dormancy. Okay then, what do we mean by dormancy in forest and conservation nurseries? Dormancy has a couple of common definitions: a state of minimal metabolic activity; or any time that a plant tissue is predisposed to grow, but does not (6). In other words, dormancy is that condition in which plant growth – cell division and enlargement – is not occurring. In horticulture, dormancy can refer to either seed dormancy or plant dormancy. In the published literature, seed dormancy has been much more studied than plant dormancy but it is the latter that we are concerned with here.

Two kinds of plant dormancy are recognized: 1) imposed dormancy, also known as "quiescence", occurs when environmental conditions (*e.g.* severe water stress) will not support growth (6). Plants exhibiting imposed dormancy will resume growth when these unfavorable conditions are relaxed (*e.g.* it rains). 2) Internal or deep dormancy is a condition in which plants will not resume growth until they have experienced a long period of exposure to low temperatures (8). This article will focus on deep dormancy and how this physiological condition affects nursery culture.

Dormancy Refers to Tissues, Not Plants - In everyday nursery jargon we talk about seedlings, or even entire crops, being dormant. While this is common terminology, it is important to understand that plant dormancy refers to a specific meristematic tissue –

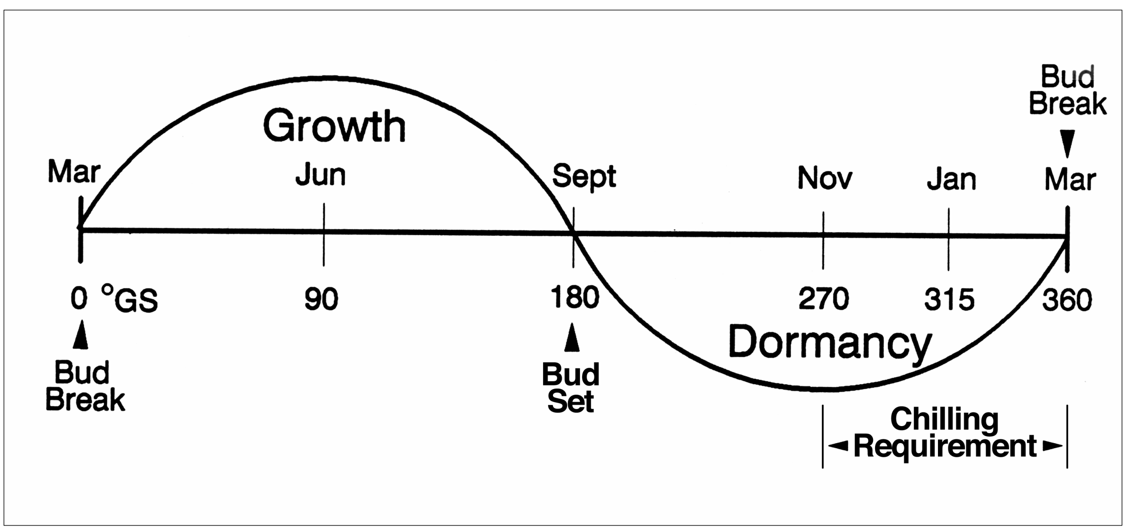

Figure 1. The shoots of all perennial plants, including forest and conservation nursery stock, undergo a seasonal cycle of shoot growth and dormancy. Note that peak dormancy occurs in late fall instead of mid-winter as is popularly believed. Bud dormancy is released by cumulative exposure to cold temperatures - the chilling requirement (modified from 2).

usually buds. In the same seedling, buds may be dormant while the lateral meristem may not. Root meristems never truly go dormant and will grow anytime that environmental conditions, especially temperature, are favorable. So, since we are concerned with seedling quality testing, we will be discussing bud dormancy, which is most clearly observed in the behavior of terminal buds.

The Dormancy Cycle - Perennial plants that grow in temperate regions exhibit a pronounced seasonal "cycle of dormancy" (Figure 1). In spring, as day length and temperature increase, plant buds begin to exhibit dimensional increases reflecting both cell division and expansion - in other words, they begin to grow. Shoot growth persists through spring and into summer. In early summer, as the day length (photoperiod) begins to shorten, the increasing length of the dark period is perceived by the phytochrome system in the leaves as a signal to begin preparing for winter. At this point shoot growth slows, and winter bud development proceeds (2, 3).

The Chilling Requirement - Through late summer, plant shoots enter the condition of imposed dormancy. As summer surrenders to autumn, imposed dormancy gradually gives way to deep dormancy and buds reach maximum dormancy in late fall (270 degrees in Figure 1). As we just discussed, the only way this dormant condition can be released is by exposure of the plants to an extended period of low temperature (this is known as a "chilling requirement") that is sensed by the buds. This evolutionary adaptation ensures that plants will not break bud during a mid-winter warm spell only to be killed by a return of cold weather. Once this chilling requirement is satisfied, warm spring temperatures and, to a lesser extent, lengthening photoperiod, will trigger and sustain a resumption of shoot growth (4). Although temperatures in the range of about 3°C to 5°C (37°F to 41°F) are most efficient at releasing bud dormancy (1), temperatures above and below this range also are effective to a lesser degree (Figure 2).

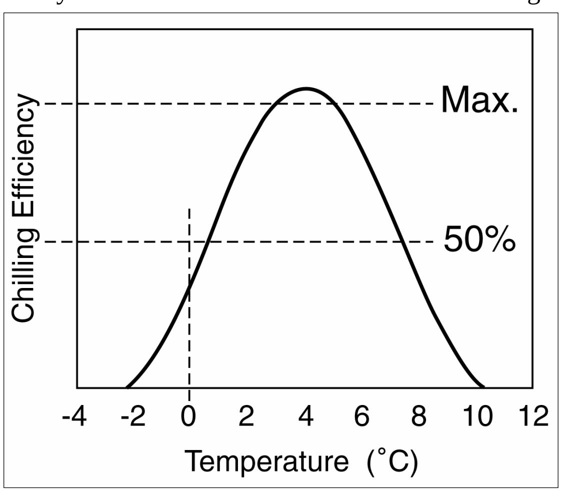

Figure 2. A range of chilling temperatures is effective at breaking bud dormancy (modified from 1). Note that temperatures in the range of refrigerated storage [30 to 33°F (-1°C to +1°C)] are relatively inefficient at releasing dormancy (modified from 1).

Orchardists, and other horticulturalists, have developed elaborate models to predict the date of flower bud opening in cold sensitive crops such as peaches (9). These models take into account the efficiency of chilling and the fact that warm interruptions during late fall can negate some chilling that has occurred up to that time. In forest nurseries, however, this level of precision is not warranted, and a simplified process involving calculating chill sums or chilling hours has been effective. The details are given in the following section.

Measuring Dormancy

Because of its tremendous importance to nursery management, there have been many attempts to develop a simple way to measure dormancy. As we will now discuss, this objective has been elusive:

1. Dormancy meters. In the 1970s, researchers observed that changes in electrical resistance of plants provided a useful way to determine whether tissues were injured or dead. Building on these observations, they constructed a "dormancy meter" (Figure 3) with the objectives of measuring dormancy in the fall and telling nursery managers when it was safe to lift their stock. Unfortunately, subsequent tests showed that these meters were not reliable (13). The idea of a simple "black box" is still attractive but it is doubtful that any equipment or technique will be able to instantaneously measure bud dormancy.

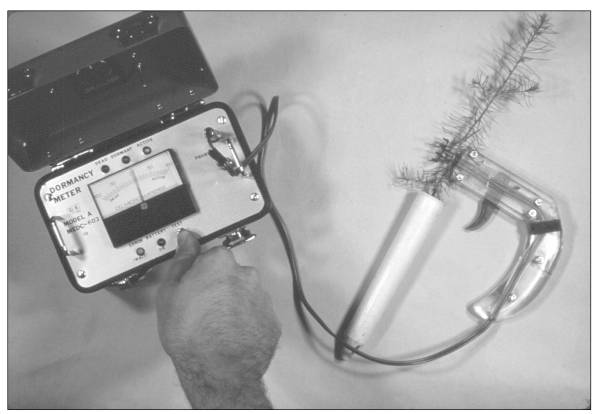

Figure 3. The "dormancy meter" was an attempt to find a simple and easy way to measure dormancy and determine when seedlings were ready for harvest. It didn't work, perhaps because they weren't even measuring bud tissue!

Table 1—An Example of How to Calculate Chilling Sums Using Degree Days, Calculated from an Average of Daily Maximum and Minimum Temperatures and a 40 ºF (4.5 ºC) Base Temperature

Day	Base Temp. (ºF)	Daily Temperatures (ºF)			Degree Days	Chilling Sum (Days)
		Maximum	Minimum	Average		
One	40	40	20	30	10	10
Two	40	45	35	40	0	10
Three	40	50	40	45	0	10
Four	40	40	30	35	5	15

2. Chilling Sums. The easiest and most practical method for estimating the intensity of bud dormancy as it weakens during winter is based on the chilling requirement that we just discussed. The concept is logical enough - the cumulative exposure of seedlings to cold temperatures controls the release of dormancy. So, by measuring the duration of this exposure, it is possible to estimate the intensity of dormancy indirectly. In practice, chilling hours, or degree-hardening-days (DHD) have been used.

The process involves measuring the temperature each day and calculating the amount of time below some reference temperature. There are several different formulas for calculating chilling sums. One short cut method is to record the daily maximum and minimum temperatures, average them, and subtract this average from the base temperature. Note that, when calculating chilling sums, only negative values are recorded (Table 1).

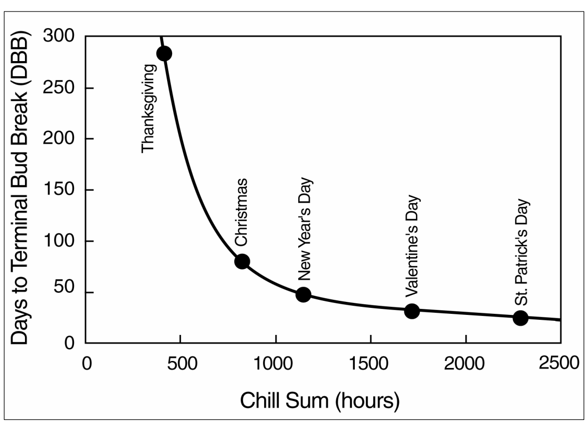

Figure 4. The only reliable test for bud dormancy intensity is a bud break test which can be performed by bringing seedlings into a greenhouse at various times during winter. As they break bud, the number of days to bud break (DBB) is plotted against the chilling sum for each lift date.

3. Bud Break Test. The deeper their dormancy, the slower the terminal buds will break. This phenomenon forms the basis of the only direct way of measuring dormancy intensity – the bud break test. If you have access to a greenhouse or other growth-promoting structure where you can maintain ideal growing environment through the winter, then you can measure intensity of dormancy in your nursery stock by observing days to bud break (DBB).

The procedure is relatively simple. Grow your plants to shippable size in seedbeds or containers and harden them to the fully dormant condition. Container stock should be kept outside or fully exposed to ambient conditions. At this point, it will be fall and your seedlings should have formed a winter bud and exhibit the other morphological changes such as increased needle waxes in conifers and leaf color change and abscission in hardwood stock. Place your temperature-recording device at seedling height in the bareroot seedbeds or within the containers. Check temperatures at least weekly and record them to compute your chilling sums (Table 1).

Set the environmental controls in the greenhouse to maintain spring “forcing” conditions with warm days, cool nights, and long photoperiods using lights. Then, beginning around Halloween, harvest a sample of seedlings and bring them into the greenhouse at regular intervals through the winter. With each sample group, pot them if they are bareroot stock and label them. Then, keep the sample seedlings watered, and count the number of days required for the terminal buds to break (Figure 4). Repeat this process at every major holiday: Thanksgiving (late November), Christmas (late December), New Years Day (early January), Valentine Day (mid-February) and St. Patrick’s Day (late March). When you have finished, plot the DBB values over the chilling sums. The number of days required for the terminal buds to break is a direct measure of dormancy intensity. (Note: the Halloween seedlings may never break bud). You will likely obtain results similar to those shown in Figure 4, which came from coastal Douglas-fir in western Washington and Oregon (10) and are in agreement with the general curve proposed by Lavender (6). As the chilling sum accumulates during winter, the number of days to bud break will shorten dramatically. Similar experiments have been done with many tree species, always yielding similar results (12). Once this curve has been developed for a species or response group, it can be used subsequently to estimate the dormancy intensity from chilling sums.

From this experiment, it is clear that bud dormancy intensity is very high in the fall and drops sharply in early winter, in contrast to the common misconception that deepest dormancy occurs in mid-winter. In addition, this test illustrates that there is no simple "chilling requirement" for any species. Rather, there is a curvilinear relationship between chilling and dormancy in which more chilling will result in more rapid bud break. For example, seedlings with only 800 hours of chilling will eventually break bud, but not nearly as rapidly as those exposed to 2,000 hours of chilling (Figure 4).

4. Calculating The Dormancy Release Index. Now that the days to bud break for your crop have been estimated, how can you use this information? If you were to measure bud break rate on a group of seedlings that were fully released from dormancy (*i.e.*, the chilling requirement was completely fulfilled) you would find that buds would break in about ten days. Taking this number as the denominator, you can then calculate an

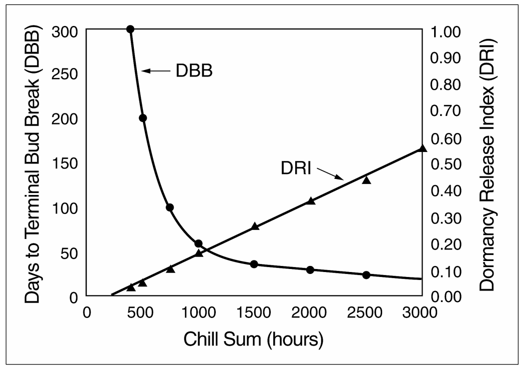

Figure 5 - Because days to bud break (DBB) is a curvilinear relationship, it is useful to convert to a linear dormancy release index (DRI). In this example, DRI = 10/DBB because Douglas-fir seedlings flushed in 10 days when their full chilling requirement was satisfied (10).

index that expresses the dormancy intensity on a linear scale:

$$\text{Dormancy release index (DRI)} = 10/\text{DBB} \qquad (1)$$

where DBB is the days to bud break of a test group of seedlings as described in the experiment above.

Seedling buds at peak dormancy have a DRI value near zero (e.g., DRI = 10/300 = 0.03). As dormancy weakens, DRI approaches one (e.g., DRI = 10/15 = 0.67). This relationship is shown in Figure 5. DRI is useful because it linearizes the response of dormancy intensity to the chilling sum. Hence it can be used to provide a benchmark and for normalizing the response of stock lots to chilling.

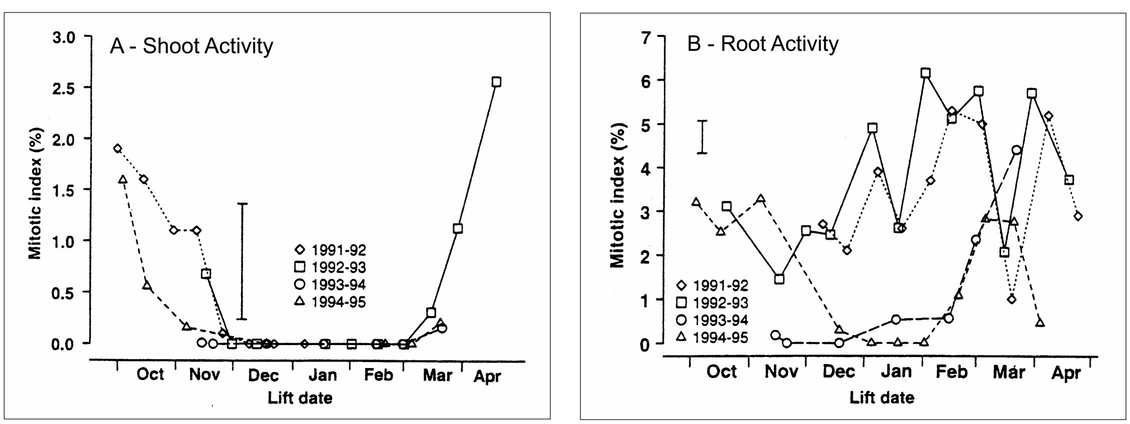

Figure 6. Measuring cell division rates is a laboratory measure of dormancy. Shoot activity over four years shows a characteristic pattern of inactivity during winter (A), but roots (B) continue to grow whenever conditions are favorable (7).

The Dormancy Release Index has been particularly useful as an indicator of seedlings stress resistance – a key seedling quality attribute. In a sequel to this article we will discuss this relationship and how it is used.

5. Measuring Mitotic Index. In our definition of dormancy, we stressed that dormancy could refer only to buds or other plant meristems. A technique has been developed to determine the percentage of bud cells that are dividing at any given time. This is a laboratory test and has been used only for research purposes, but the results help illustrate dormancy patterns. For example, the tips of terminal shoots and long roots of bareroot Douglas-fir seedlings were excised and a mitotic index was calculated under microscopes at 400X for four successive winters (7). The results indicate that terminal bud activity shows a definite seasonal pattern - cell division slows gradually in the fall and stops completely during the winter. With the warmer temperatures and longer days of late winter and early spring, cell division begins to increase rapidly (Figure 6A). This is in direct contrast to the patterns of root meristem activity over the same four seasons, showing that roots never do go truly dormant but will grow whenever soil temperatures permit (Figure 6B). So, although measuring the mitotic index in buds can mark the beginning and end of deep dormancy, this technique has little practical value for tracking dormancy release through winter.

6. Bud Size and Development. While bud size and development are not, in themselves, indicative of the intensity of bud dormancy, they have traditionally been viewed by nursery managers as a measure of seedling quality. As part of their seedling quality testing, the Ontario Ministry of Natural Resources developed a bud dissection and evaluation service. The process involves cutting the buds in half and counting the needle primordia. At the end of the hardening phase, low numbers of primordia were interpreted to indicate stressful conditions and increased susceptibility of overwinter damage. On the other hand, seedlots having buds with large numbers of needle primordia were rated as being of higher quality (5). The Ontario Ministry of Natural Resources has terminated their seedling quality testing program but KBM Forestry Consultant Laboratories in Thunder Bay, ON now offer bud assessment on a fee basis:

SQA Coordinator
349 Mooney Avenue
Thunder Bay, ON
CANADA P7B 5L5
TEL: 807.345.5445 ex. 34
FAX: 807.345.3440
E-mail: sgellert@kbm.on.ca

Conclusions and Recommendations

Although the term "dormant plants" is common in nursery jargon, dormancy refers only to meristematic tissues - buds, lateral cambium, and root tips. Of these, bud dormancy has been studied most often and is of major interest to nurseries.

Forest and conservation nursery seedlings, like all perennial plants, undergo an annual cycle of activity. In late summer, shortening photoperiods trigger plants to begin the bud dormancy process, which culminates in late fall. This condition is known as deep dormancy and can be broken by gradual exposure to low temperatures. This process is known as satisfying the chilling requirement, and temperatures in the range of about 37° F to 41°F (3°C to 5°C) are most efficient. By late winter, the chilling requirement has been met and buds will break whenever temperatures permit.

Unfortunately, there is no quick and easy way to measure bud dormancy. The only reliable method is to conduct a bud break test by bringing samples of seedlings into a forcing greenhouse at regular intervals throughout the winter, and recording the days required for the buds to break (DBB). Once the relationship between DBB and chilling has been established, it can be used to estimate the dormancy intensity during subsequent winters.

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Nursery Seedlings Increase Genetic Diversity

by Thomas D. Landis

Several years ago, while perusing the published literature for FNN, I came across an article that really caught my eye because it shows that using nursery stock in reforestation has advantages from a biodiversity standpoint. It was written by some research foresters in Canada who collected needle tissue from lodgepole pine (*Pinus contorta* var. *contorta*) in 12 stands in Alberta. Their objective was to use two biochemical tests to examine the impact of reforestation method on genetic diversity of stands in the foothill region of Alberta, and sampled three stand classes and one batch of nursery seedlings:

1. Unharvested, mature stands
2. Harvested stands which were left for natural regeneration
3. Harvested stands which were planted with nursery stock
4. Nursery seedlings from the same region

The procedure consisted of collecting current-year needle tissue and analyzing these samples using two DNA-based markers: RAPD (randomly amplified polymorphic DNA) and microsatellite SSR (simple sequence repeat). With my limited understanding of genetics, I'm not even going to try and explain what these tests actually measure. If you are interested, let me know and I'll send you a copy of the article and you can explain it to me!

The results are reported in terms of the "Expected Heterozygosity" which I'm interpreting as "More Genetic Variation". Using either the RAPD test (Figure 1A) or the SSR test (Figure 1B), the planted seedlings had as much genetic variation as the unharvested stands and more variation than the natural seedlings. The nursery seedlings in the RAPD test had the most genetic variation of all the samples (Figure 1A).

One of the things that has always bothered me is that some people just assume that natural regeneration is better than artificial regeneration. This viewpoint is particularly true of the environmental community which believe that "nature always knows best" and that the less interference by man the better. I've always believed just the opposite - that by managing forests and other plant communities we can actually improve on nature. To me, it's intuitively obvious that, because seeds are collected from a variety of trees in a seed zone, the nursery stock grown from these seeds would be more genetically diverse than natural seedlings. The same situation should apply to fire restoration. It would be better to plant the burned area with source-identified, locally-adapted stock than wait for natural regeneration to occur.

So, it's nice to finally see some hard evidence that this actually occurs. My hunch is that if more of these sorts of tests were done, we could further prove that planting nursery stock after timber harvest, forest fire, or other type of disturbance improves the genetic diversity of the resulting plant community.

Source:

Thomas BR, Macdonald SE, Hicks M, Adams DL, Hodgetts RB. 1999. Effects of reforestation methods on genetic diversity of lodgepole pine: an assessment using microsatellite and randomly amplified polymorphic DNA markers. Theoretical and Applied Genetics 98: 793-801.

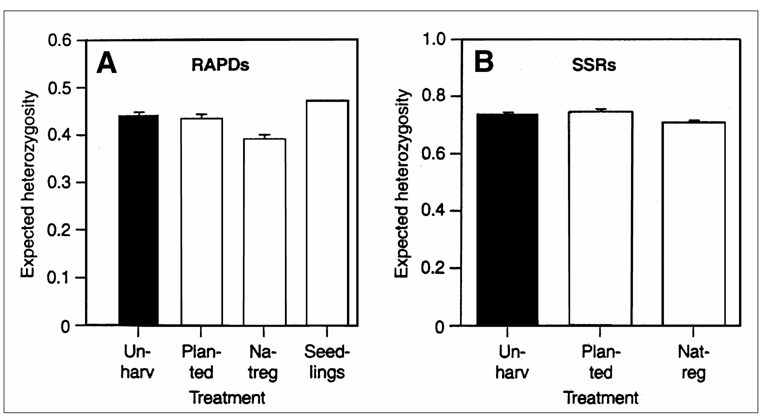
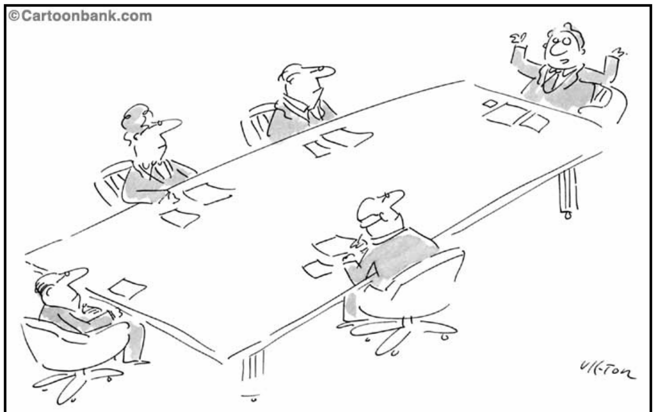
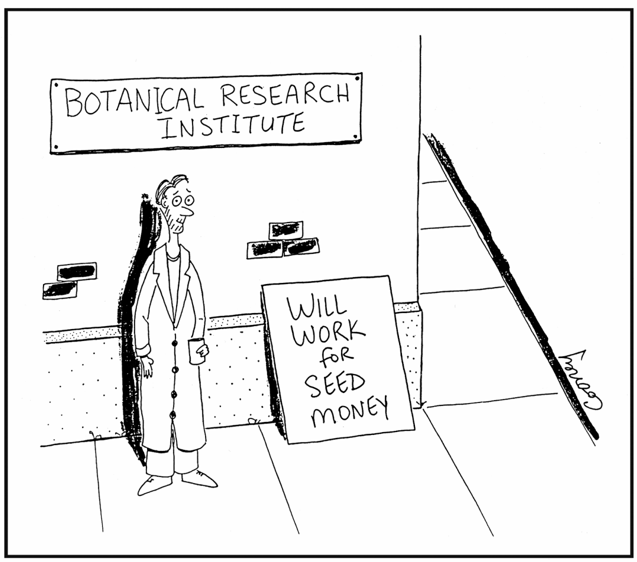


Figure 1. Two Measures of Genetic Diversity on Lodgepole Pine Reforestation Sites. "Unharv" = Unharvested stands, "Planted" = Harvested stands with nursery stock, "Natreg" = Harvested stands with natural regeneration, and "Seedlings" - Nursery stock from Same Region.

Horticultual Humor



"This might not be ethical. Is that a problem for anybody?"



New Nursery Literature

Copies of the following journal articles or publications are free and can be ordered using the Literature Order Form on the last page of this section. Just write in the appropriate number or letter on the form and return it to us. Note that there are three restrictions:

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Bareroot Production

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Container Production

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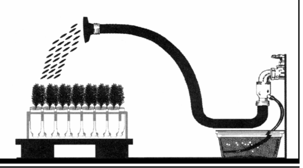

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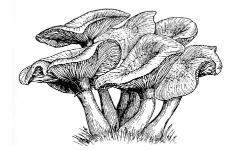
General and Miscellaneous



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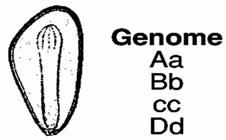

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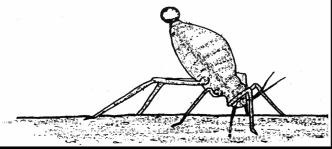

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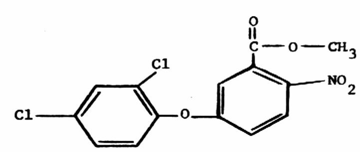

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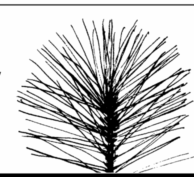

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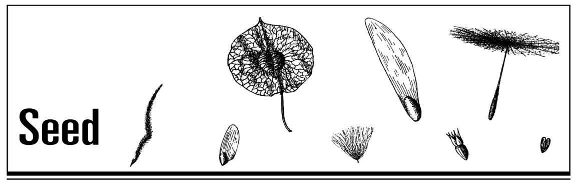

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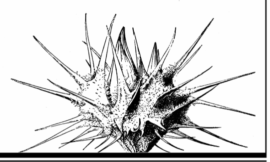

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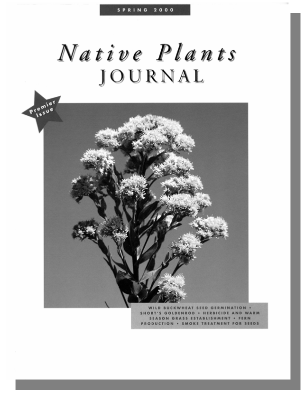

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Technical Assistance about Tree Improvement and Genetic Resources Technical Assistance about Forest and Conservation Nurseries	Southeastern US	George Hernandez USDA Forest Service Cooperative Forestry 1720 Peachtree Road NW, Suite 811N Atlanta, GA 30367 TEL: 404.347.3554 FAX: 404.347.2776 E-Mail: ghernandez@fs.fed.us
Technical Assistance about Forest and Conservation Nurseries	Northeastern US	Ron Overton Regeneration Specialist USDA Forest Service, S&PF Purdue University 1159 Forestry Building West Lafayette, IN 47907-1159 TEL: 765.496.6417 FAX: 765.496.2422 E-Mail: roverton@fs.fed.us
Technical Assistance about Tree Improvement and Genetic Resources Editor - Tree Planters' Notes	US and International	
Technical Assistance about Tree and Shrub Seed	US and International	Bob Karrfalt Purdue University 1159 Forestry Building West Lafayette, IN 47907-1159 TEL: 765.494.3607 FAX: 765.496.2422 E-Mail: rkarrfalt@fs.fed.us

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