United States
Department of
Agriculture

Forest Service

**Pacific
Northwest
Region**

State and Private
Forestry

**Cooperative
Programs**

R6-CP-TP-03-98

January 1998

Forest Nursery Notes

Integrated Pest Management

Biocontrol of Lygus Bugs

National and International Issues

"Sister" Nurseries

Cultural Perspectives:

Role of Water in Nurseries

Forest Nursery Notes

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

Holiday Reflections

While looking through some old issues of FNN, I found the following holiday greeting which still applies and so decided to use it again this year: I hope that you all had a happy and healthy holiday season. Regardless of your religious beliefs, this is a special time of year. Unfortunately, the media hype and crass commercialism during the Christmas season can generate unrealistic expectations. So, take time to appreciate the really important things in life-friends and family. Give thanks that we work in a profession where we can each have a positive effect on the fate of the world. In our nurseries, we observe the changing of the seasons and can even measure the physiological process of dormancy in our seedlings. Take a cue from nature and use winter as a time of personal reflection, and an opportunity to plan for the future. Reserve some private time to reflect on the promise of renewal that underlies the winter season, and to anticipate the rebirth that we know will soon come.

Thanks, and Goodbye

Long-time readers probably noticed a major change in the appearance of FNN issues starting back in July, 1992. The reason for this sudden improvement was the assistance of a very nice and talented lady named Aleta Barthell who came to work for us at that time. Aleta used her artistic and layout skills to transform my rather pedestrian writings into the handsome publication that FNN is today. Initially, she helped convert to a double-column format and added scanned graphics which certainly improved the readability of the articles. In the last several issues, she improved the appearance of the FNN cover with innovative designs and different colors of card stock. Last month, Aleta decided to move to Southern California and return to graduate school to pursue her true profession of theater arts. We miss her already, especially that charming laugh, and wish her well!

We're not sure whether we will be able to fill Aleta's position and so Kent Giard, a student intern, will be filling in for the next two issues. After that, we'll just have to see what happens.

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Nursery Meetings and Workshops

The 13th **High Elevation Revegetation Workshop** will be held on **March 4-5,1998** at the University Park Holiday Inn in Ft. Collins, CO. The final agenda is still being developed, but the meeting will include a tour of the Colorado State University nursery. For more information, contact:

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The **Southern Nursery Association** will be meeting in Lafayette, LA on **July 13-16,1998.** The agenda is still being developed but, in the meantime, you can contact:

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The **Northeastern Forest Nursery Conference and Workshop** will be held at the Wyndham Hotel in Annapolis, MD on **July 27-30, 1998.** We are still working on the agenda but, if you have a paper that you would like to present, give Dick Garrett a call:

Richard Garrett
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The **Forest Nursery Association of British Columbia (FNABC)** will host a joint meeting with the **Western Forest and Conservation Nursery Association (WFCNA) on August 10-13,1998** at the Dunsmuir Lodge which is near Victoria, BC in CANADA. Dunsmuir Lodge is a wonderful conference facility with beautiful views of the North Saanich peninsula and the surrounding bays. The Program Chair, Drew Brazier, is looking for people wishing to present papers or posters and so contact him soon if you are interested. Registration packets will be mailed out in the next month but call the Lodge directly for room reservations:

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The **Western Region of the International Plant Propagators' Society** will be meeting at the Ontario Airport Marriott Hotel in Ontario, California on October 28-31, 1998. These IPPS meetings always cover a wide range of basic plant propagation concepts, techniques, and technologies, and are an excellent opportunity to expand your horticultural horizons. The final agenda is still being developed but additional information can be obtained from:

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A **Native Plants: Propagation and Planting** conference will be held at the LaSells Stewart Center at Oregon State University in Corvallis, OR on **Dec. 9-10, 1998.** The conference will be jointly sponsored by the Nursery Technology Cooperative at OSU and the USDA Forest Service. The technical sessions will focus on seed collecting, processing, and propagation; vegetative propagation techniques; and an entire section devoted to types of outplanting projects that utilize native plants. The main presentations will be by invitation but there will be room for some contributed papers and plenty of room for posters. To get the latest information, contact me or:

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The **1998 Methyl Bromide Alternatives Research Conference** will probably be held next December in Orlando, FL. Stan Barras is on the Program Committee and is soliciting papers, posters or just ideas for the 1998 conference from anyone who is interested. He may be reached at:

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Role of Water in Nurseries

"Water is the driver of nature" - Leonardo da Vinci

Organisms have evolved either around or in or around water, and life as we know it would be impossible without it. The importance of water has been known since ancient times. The Greek philosopher Aristotle recognized water as one of the four basic elements along with earth, air, and fire. Almost every plant process is affected either directly or indirectly by water, and so nursery managers and growers must have a good understanding of the physical, chemical, and biological properties of water.

Fascinating Facts about Water. The chemical structure of water (two hydrogens and one oxygen atom) is structurally simple yet biologically profound. The lack of symmetry in the water molecule produces polarity - a positive charge at one end of the molecule and negative at the other (Figure 1). The bipolar electrical charge creates an intense attraction between the hydrogen and oxygen atoms in adjacent water molecules, and these hydrogen bonds are responsible for most of water's amazing properties. Someone once calculated the force of hydrogen bonds as 21 billion times that of gravity, which explains why water is one of nature's most stable compounds. A substance with the low molecular weight of water should exist as a gas at the normal temperatures but, due to strong hydrogen bonding, it is a liquid. Water has the most anomalous properties of any common substance. The strong polarity of the water molecule causes them to surround dissolved ions and molecules and weakens the forces between them. This strong **dielectric constant** makes water an excellent solvent **(Table 1)**. In fact, water is so effective at dissolving other compounds that it is almost impossible to find chemically pure water in nature. The high dielectric constant is biologically important because water carries mineral nutrients, and organic products of photosynthesis as well as dissolved oxygen and carbon dioxide. Water also has remarkable softening properties, reducing the hardness and strength of soils so that it can be tilled. On the negative side, the high dielectric constant of water causes it to absorb ions and leach them from soils, growing media, and even from seedling foliage. Novice growers might think that irrigating with pure distilled water would be beneficial but the opposite is true. Excessive leaching of nitrates, phosphates, and pesticides can cause environmental pollution if they leave the nursery as surface runoff or leach to groundwater.

Another amazing property of water is its **anomalous expansion**. Water is unique in having its maximum density at 4 °C (39 °F) and so ice floats, which has important implications for life as we know it **(Table 1)**. This property also has some negative consequence for nurseries. Because liquid water expands when it freezes, succulent seedling tissues can be instantaneously killed by a relatively minor radiation frost. Irrigation pipes and pumps also can be ruined if they are not properly drained or filled with antifreeze before winter. Finally, volume expansion on freezing contributes to frost heaving which can kill young seedlings in bareroot seedbeds or after outplanting. Water also has a very **high latent heat of vaporization** which means that 540 calories of heat are required to evaporate 1 gram of water. This property is responsible for energy distribution and the hydrologic cycle on a global basis, as well as evaporative cooling at the seedling level **(Table 1)**. The latent heat of fusion—80 calories of heat are released when 1 gram of water freezes—is also unusually high and explains why seedlings can be protected from frost with irrigation. Water's **high specific heat and thermal conductivity** cause its temperature to rise or lower more slowly than other materials which gives water its great temperature buffering properties. On a practical basis, these properties dampen rapid temperature change in bodies of water as well as plant tissues. Water also has a **high surface tension** for liquids, which is again caused by the strong hydrogen bonding between water molecules **(Table 1)**. This slows evaporation and also creates strong capillary retention in soil pores and plant cells. Thus, high surface tension is responsible for the large reservoir of available water in soils and growing media.

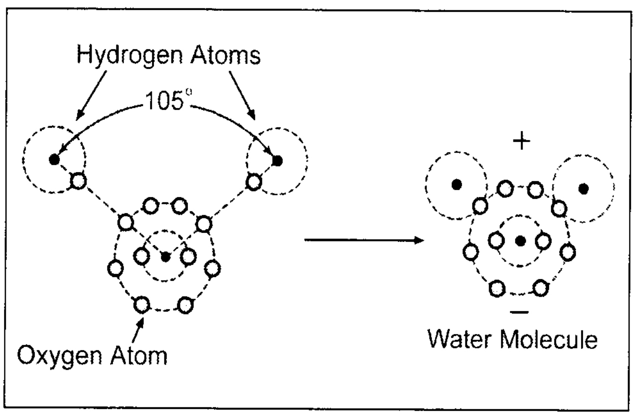

Figure 1. The bipolar charge of the water molecule causes hydrogen bonding which is resposible for most of water's remarkable properties (Hartman and others, 1981)

Effects of Water on Seedling Growth. Water has four major influences on the growth of seedlings in forest and conservation nurseries:

1. Constituent - Water composes 80 to 90 % of the fresh weight of plants and is an important part of the protoplasm that fills every living cell. Dehydration first slows metabolic processes and eventually leads to a state of dormancy and, at extreme levels, to death.

2. Solvent - This "Universal Solvent" distributes gases, ions, and other solutes throughout the plant. Water carries mineral nutrient ions into the roots and then through the xylem to the foliage where they are used in photosynthesis. Then, photosynthate and other organic compounds are then carried back throughout the plant by way of the phloem to fuel the cell metabolism and provide the organic building blocks of all plant tissue.

Table 1 - Exceptional properties of water that affect nurseries

Property	**Biological Significance**	**Practical Use in Nurseries**
Specific Heat and Thermal Conductivity	One of the highest values of temperature regulation in water and organisms.	The high water content in plants buffers extreme changes in temperature.
Latent Heat of Vaporization	Highest of common liquids. A relatively large amount of heat is needed to convert liquid water to water vapor. This property is responsible for evaporational cooling.	Allows photosynthesis to occur in strong light without high temperatures which would damage leaf tissues. Another practical application is that light irrigation or misting lowers potentially damaging temperatures.
Latent Heat of Fusion	Highest of common liquids. A surprisingly large amount of heat is released when water freezes.	This property is practically used in nurseries during freeze protection with irrigation.
Dielectric Constant	The ability of water to neutralize attraction between charged particles is very high, and so it is known as the "universal solvent".	Water can dissolve mineral nutrients and transport them into roots and through plants, as well as carry dissolved oxygen and carbon dioxide. Water also "softens" soils.
Surface Tension	Very high for common liquids. Reduces evaporative losses, and causes capillary tension.	Explains why water can be carried upwards in xylem tissues, and is responsible for retaining water reserves in soils and growing media.
Volume Expansion on Freezing	Nearly all liquids contract as they freeze, but water has a maximum density at 4 °C (39 °F) and so ice floats.	Irrigation water is available during winter because surface layers of ice keep ponds from freezing solid. On the negative side, this is why irrigation pipes burst if not properly drained.

3. Reactant - Water is a biochemical reactant for many plant processes, but most importantly, photosynthesis, which has been rightly called the most important chemical reaction in the world:

$$CO_2 + H_2O + Sunlight = C_6H_{12}O_6$$

Water also serves as a substrate or ligand for many other important chemical reactions. More specifically in nurseries, water is necessary to bring seeds out of dormancy and stimulate the hydrolysis of the stored starches to sugars to feed the developing embryo. The young germinant requires a steady supply of water to fuel the photosynthetic process which produces the energy needed for rapid growth.

4. Maintenance of turgidity - Plants are "leaky", however. To capture the very low amount of CO_2 in the atmosphere, 500 kg. (I ,102 lbs) of water is lost to produce 1 kg. (2.21 lbs) of dry matter. Therefore, the vast majority of water that we apply during irrigation is used just to keep the stomata open so that CO z can easily enter the leaf. If seedlings are allowed to lose turgidity the stomata begin to close photosynthesis slows, and eventually stops all together.

Like all things, however, you can have too much of a good thing and an excess of water affects seedling growth in negative ways. Very fine-textured soils or growing media will hold too much water and not allow adequate exchange of oxygen and carbon dioxide, eventually suffocating the roots. Many pathogens thrive

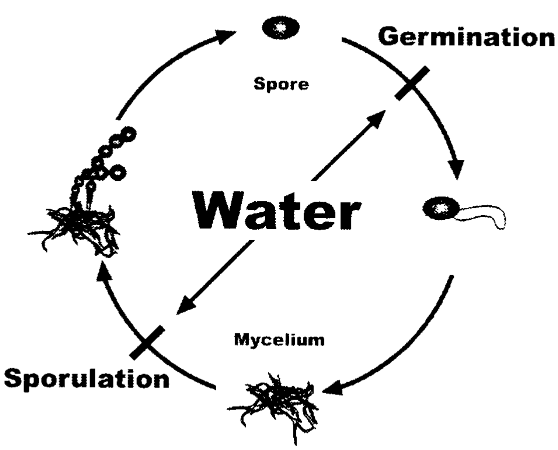

Figure 2. High humidity stimulates sporulation of dormant fungi like Botytis cinerea, and free surface water promotes spore germination and penetration of plant tissues.

in overly wet conditions including damping-off fungi (see section in Integrated Pest Management in this issue). One of the best examples of how excess water can harm a seedling crop is with fungi like *Botrytis cineria.* The body of the fungus is the mycelium which remains dormant under low humidity conditions and can remain in this dormant state almost indefinitely. If the humidity is allowed to remain at high levels, however, the Botrytis fungus quickly produces fruiting bodies which release airborne spores into the air. If the spores happen to land on plant tissue with free water, they can germinate and penetrate the epidermis and initiate an infection **(Figure 2)**

So, you can see that water is a truly remarkable substance that is the most important limiting factor affecting seedling growth and nursery management. Growers must learn to provide enough water at the right time to minimize water stress and stimulate seedling growth and development. Over-irrigation leaches fertilizers or pesticides which can cause environmental pollution, and also promotes excessively high humidity which favors pathogens.

Dick Tinus and John Mexal reviewed this article and contributed greatly to its technical accuracy and readability. Their contributions are gratefully acknowledged.

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Micronutrients - Manganese

Of all the micronutrients, manganese is second only to iron in the amount required by seedlings **(Table 2)** but it wasn't until the early 1900's that manganese was proven to be essential for plant growth. Manganese has some metabolic functions that are similar to other micronutrient metals, so manganese deficiency is often confused with iron or zinc deficiency.

Role in Plant Nutrition.

Physiologically, one of the most important functions of manganese is its involvement in the "Hill Reaction" during photosynthesis, which the process responsible for the splitting of water and evolution of oxygen. Manganese also acts to protect the photosynthetic system against photo-oxidation, thereby maintaining the integrity of the lamellar system of chloroplasts. When manganese becomes deficient, the lamellar system becomes disorganized, resulting in lowered chlorophyll production, reduced photosynthesis, and resulting in the characteristic deficiency symptom of chlorosis **(Figure 3).** Manganese is also a catalyst in a variety of other enzyme systems where it plays a role in carbohydrate synthesis, and lipid metabolism. As a structural component of ribosomes, manganese is involved in nucleic acid synthesis.

Manganese is important for root development since it influences the supply of soluble carbohydrates: Low manganese levels impact carbohydrate reserves in roots more than in shoots, reducing root elongation and particularly lateral development. For this reason, manganese deficiency weakens the root system in a similar fashion to when seedlings are grown under low light levels. Since soluble carbohydrates are needed for synthesis of organic nitrogen compounds such as amino acids, manganese indirectly exerts an influence of nitrogen metabolism (especially ammonium). Thus, it is conceivable that a manganese deficiency can lead to increased susceptibility to ammonium toxicity because the carbon skeletons needed to detoxify ammonium would be in short supply. It has also been noted that manganese-deficient plants are more susceptible to cold injury. This may in part be due to this same shortage of soluble carbohydrates which act like anti-freeze in plant cells.

Manganese also has a role in protecting seedlings against pathogens as it is involved in phenol and other plant defense systems. Adequate manganese levels help the plant resist fungal invasion by inhibiting the pectolytic and proteolytic enzymes produced by pathogens to attack roots. When roots are well supplied with carbohydrates, they can easily outgrow pathogens and have lower levels of free amino acids which provide food for soil pathogens.

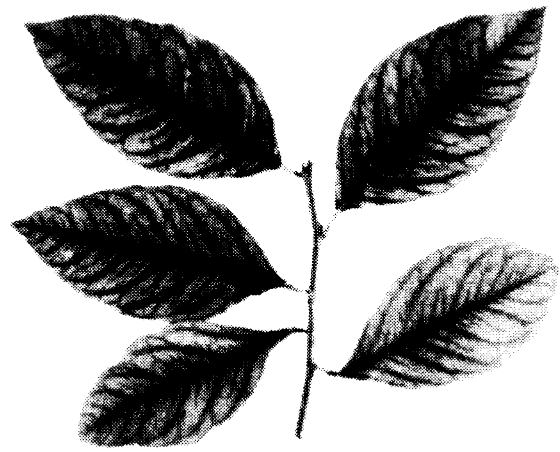

Figure 3. Interveinal chlorosis is the first visible indication of manganese deficiency although this sympton can also be caused by other micronutrient deficiencies (Labanaukas, 1965).

Availability and Uptake.

Manganese is widely distributed in nature, similar to iron, but is found in smaller quantities in agricultural soils. It has been found to be completely absent in sandy soils in high rainfall areas. The balance of iron to manganese is particularly important and a 2:1 ratio, on a parts per million (ppm) basis, is recommended. The available form of manganese is the divalent cation (Mn^{2+}) which is taken up by roots roughly in proportion to its availability in the soil solution. In soils, pH strongly affects manganese availability **(Figure 4)** and this is why over-liming is a common cause of deficiencies. High organic matter

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

Element	Symbol	Average Concentration in Plant Tissue (%)	Adequate Range in Seedling Tissue (ppm): Bareroot	Adequate Range in Seedling Tissue (ppm): Container
Iron	Fe	0.01	50 to 100	40 to 200
Manganese	**Mn**	**0.005**	**100 to 5,000**	**100 to 250**
Zinc	Zn	0.002	10 to 125	30 to 150
Copper	Cu	0.0006	4 to 12	4 to 20
Molybdenum	Mo	0.00001	0.05 to 0.25	0.25 to 5.00
Boron	B	0.002	10 to 100	20 to 100
Chloride	Cl	0.01	10 to 3,000	--------

increases canon exchange capacity and thereby insures good manganese availability. The Mn^{+4} ion is the oxidized, unavailable form of manganese. Plants under stress have manganese oxidizers present and so a biologically-induced deficiency is theoretically possible.

The range between manganese deficiency and toxicity is relatively narrow and is strongly influenced by competing canons, especially calcium, magnesium, and iron. In soils, manganese toxicity is possible if the proper conditions exist but this is relatively rare. Toxicity should not be a problem in artificial growing media because *Sphagnum* peat moss and vermiculite contain so little manganese. Container growers have complete control over manganese levels through fertilization. Nursery managers should consult a specialist if manganese toxicity is suspected because of the sensitive balance of micronutrient interactions.

Diagnosis of Deficiencies and Toxicities.

Deficiency Symptoms—Manganese deficiency symptoms are very similar to those of iron with interveinal chlorosis of young leaves **(Figure 3).** The major difference is that, with manganese deficiency, the chlorosis usually progresses to necrosis whereas foliage with severe iron deficiency will eventually change in color from yellow to almost white. Foliar symptoms do vary between species, however. For example, manganese deficient white spruce *(Picea glauca)* seedlings exhibited chlorosis and browning of apical needles whereas Douglas-fir *(Pseudotsuga menziesii)* seedlings showed no foliar symptoms, only reduced growth. Proper diagnosis is important because adding iron fertilizer to a plant deficient in manganese can make the problem worse because iron competes with manganese for uptake. Therefore, it is advisable to perform seedling nutrient analysis on symptomatic tissue before deciding to apply fertilizer.

Toxicity Symptoms—Manganese toxicity is relatively common in agriculture although the critical concentrations vary widely between crop species. Manganese toxicity has not been documented on commercial conifer seedlings such as Douglas-fir and white spruce and, in fact, both species exhibited luxury consumption without apparent adverse effects. The principal foliar symptom is brown spots surrounded by bands of chlorotic tissue. Manganese toxicity also induce deficiencies of other mineral nutrients, especially calcium and magnesium. Under waterlogged conditions, high concentrations of manganese can develop and lead to toxicity and high temperatures can accelerate the condition.

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

Chemical analyses of soils or growing media only determine total manganese and therefore are relatively useless for determining its real availability to seedlings. Because of the major effect of pH on manganese availability **(Figure 4),** growers should monitor soil and water pH on a weekly basis and watch for any trends. The general target pH of 5.5 is appropriate for most conifer crops but other broadleaved seedlings and noncommercial natives may have different requirements.

Manganese becomes unavailable if irrigation water is alkaline. Most good nursery sites typically have irrigation water that is neutral or slightly acidic, but it may exceed pH 7.0 when other dissolved salts are present, especially bicarbonate ions. It is relatively easy to lower water pH with the injection of phosphoric acid because the excess hydrogen ions bond with the hydroxyl ions to form water. Other acids can also be used but are more dangerous and caustic. The need for acid injection and the amount of acid to use per volume of water must be determined with a laboratory titration.

Seedling nutrient analysis can be used to diagnose manganese deficiency and interpretation is much more straight-forward than with iron. However, because of the variability that can exist, paired samples of normal and healthy plants should always be taken.

Manganese Management. There are basically two options for managing manganese in nurseries: maintain a

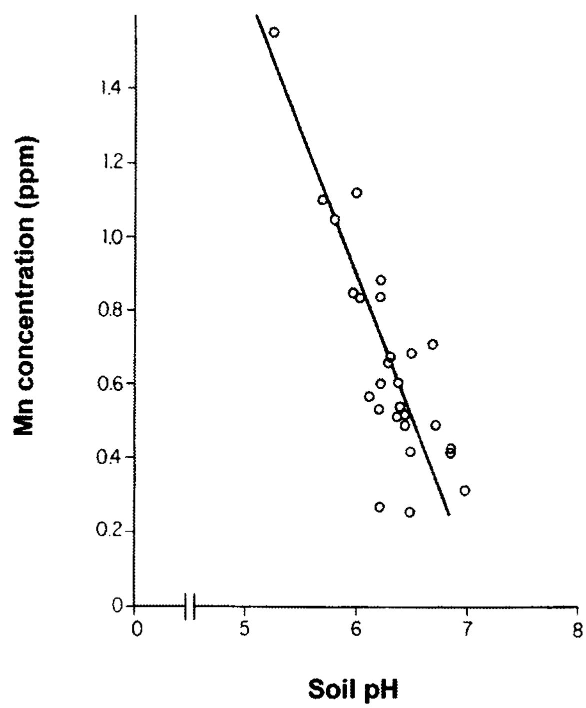

Figure 4. Manganese availability in soils is strongly affected by pH and so overliming can lead to deficiencies (Tisdale and Nelson 1975)

slightly acid pH and, if warranted, insure a steady supply of fertilizer:

pH Maintenance—The pH of the rhizosphere that affects nutrient uptake is determined by both the soil or growing medium and the irrigation water. In bareroot nurseries, high pH can be a problem if the site has either alkaline or calcareous soils or irrigation water, and lime-induced manganese deficiencies have been documented. Water is much easier to treat and acid injection is commonly recommended for container nurseries, but treating the water has not solved the problem in bareroot nurseries. In particular, calcareous soils are highly buffered and the excess calcium ions can still cause problems after the pH has been lowered. The pH of alkaline or over-limed soils can be lowered with sulfur applications although this can take many years with calcareous soils.

The situation is completely different with artificial growing media as they only contain very small amounts of manganese or other micronutrients, and most of these are organically bound so they are released slowly. The pH of the growing medium has a very minor effect on manganese availability unless there are problems with alkaline irrigation water, as noted above. Therefore, container growers should maintain a target pH of 5.5 to 6.5 and provide a continuous supply of manganese through fertilization.

Fertilization—Manganese can be supplied from inorganic fertilizer salts or organic compounds known as chelates **(Table 3).** Manganese sulfate is very soluble and is effective as either a soil or foliar application. Frits are slow-release fertilizers that consist of micronutrients impregnated in a glass powder which have release rates for up to one year. Manganese chelate consists of Mn^{2+} ions surrounded by an organic shell that maintains availability under adverse soil conditions, such as high pH, and is more effective as a foliar spray than for soil incorporation. Chelation also helps protect against over-fertilization because the nutrient is slowly released from the organic complex. Unlike iron, which comes in several types of chelates, manganese is not as affected by pH so the EDTA form works well under all conditions.

Manganese sulfate and chelate is also available in a variety of micronutrient mixes **(Table 3).** Although the actual manganese concentration can vary by two-fold between the various products, all supply adequate levels. Some soluble mixes can be injected through the irrigation system whereas others can be incorporated into the growing medium. Fertigation is recommended whenever possible because it insures that a uniform amount of manganese will be available throughout the growing season. The most comprehensive list of manganese fertilizers and their US suppliers can be found in the Farm Chemicals Handbook. In Canada, Plant Products Co. Ltd. offers a wide variety of chelated fertilizers.

Table 3 - Some common fertilizers containing manganese

Fertilizer	Chemical Notation	Manganese (%)	Use in Nurseries
	Single Nutrient Fertilizers		
Manganese sulfate	$MnSO_4 \cdot 3H_2O$	26 to 28	Only for foliar applications
Manganous oxide	MnO	41 to 68	Foliar or soil applications*
Manganese oxide	MnO_2	63	Foliar or soil applications*
Manganese frits	MnO_2	10 to 25	Only for soil applications
Manganese chelate	MnEDTA	13	Foliar or soil applications*
	Multinutrient Fertilizers		
Soluble Trace Element Element Mix – STEM®	Manganese as $MnSO_4$	8.0%	Foliar or soil applications *
Micromax®	Manganese as $MnSO_4$	2.5 %	Incorporation in growing media
Plant-Prod® Chelated Micronutrient Mix	Manganese as EDTA	2.0 %	Foliar or soil applications*
Osmocote Plus®	Manganese as $MnSO_4$	0.07%	Incorporation in growing media

In conclusion, manganese availability is usually not a problem in bareroot nurseries with good quality soil and irrigation water. If a deficiency is diagnosed, then either manganese sulfate or chelate can be applied to correct the problem. In container nurseries, a steady supply of manganese should be supplied as soluble fertilizer. Chelates are recommended because there is less chance of over-fertilization.

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

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Whitcomb, D.E. 1988. Plant production in containers. Stillwater, OK: Lacebark Publications, Inc. 633 p.

Biological Seed Treatments for Damping-off

Damping-off has the distinction of being the oldest nursery disease that I can find in the literature. It was originally named back in 1874 and, interestingly enough, conifer seedlings were one of the crops mentioned. In a classic 1921 paper, Hartley described the three different diseases that comprise damping-off: 1) pre-emergence seed decay, 2) post-emergence root and hypocotyl decay, and 3) root root of established seedlings. It is important to remember that damping-off is a disease symptom and so can have several different causes. Many native soil fungi have been implicated including *Pythiurrc spp., Phytophthora spp., Fusarium* spp., and *Rhizoctonia spp.* but damping-off also can be caused by some normally saprophytic fungi such as *Alternaria* spp. under stressful conditions. Damping-off symptoms also can be attributed to abiotic stresses such as heat and pesticides. Besides being carried in soil, spores of pathogenic fungi that cause damping-off can be introduced into the nursery environment in irrigation water; on seed; and on used containers, tools, or equipment **(Table 4).** Typically, losses become significant when some abiotic stress tips the scale of crop vigor and predisposes seedlings to attack. Mortality in excess of 50% has been reported in a bareroot seedbeds after an extended period of cool, wet Spring weather. These conditions favor the water mold pathogens *(Pythium* and *Phytophthora* spp.) which have mobile zoospores and so can quickly spread. Container nurseries are not immune either; one greenhouse reported a complete crop failure of Douglas-fir seedlings due to damping-off after the seedlings were predisposed with high surface temperatures. Managing damping-off should focus on prevention rather than on a cure because, once the symptoms are noticed, most of the damage has been done and it is too late to save many seedlings anyway. The standard preventative recommendations of selecting a well-drained soil or growing media, maintaining a low pH, and sowing at low densities will not help if the fungus is seedborne. In fact, spores which are carried on the seed is one of the primary ways in which damping-off fungi enter the normally sterile container nursery environment **(Table 4).**

Because seedborne fungi are a primary cause of damping-off in both bareroot and container nurseries, it is logical to try and remove this source of inoculum. Chemical seed treatments have been used to control pathogens on seed for centuries. The fungicide Captan has been a traditional presowing seed treatment for almost 50 years, and Thiram is still used to prevent damping-off in many Southern nurseries. The extent of phytotoxicity due to these fungicide treatments is unknown because most of the injury takes place before seedling emergence and could easily be attributed to other causes. Another limitation of chemical seed treatments is that they only work on pathogens on the seed itself, and have little if any effect on soilborne pests. An ideal treatment would be to apply beneficial microbes directly to seed becuase they could either inhibit the germination of the spores, or physically eliminate pathogens from microsites on the seedcoat. Sporeforming soil bacteria, including *Bacillus* spp. and *Pseudomonas spp.,* are commonly applied as seed treatments to several agricultural crops and have resulted in significant yield increases. The fungus *Trichoderma* spp. has been used as a soil-applied biocontrol agent for years but also is a promising seed treatment. *Trichoderma harzianum* is native saprophytic fungus that thrives in acidic soils and therefore would be ideal for forest and conservation nursery crops. Unfortunately, this fungus is less effective in sandy soils and so much higher concentrations of spores are needed for soil applications. Luckily, *Trichoderma* spp. has been shown to readily infest agricultural seeds and protect them against damping-off. In addition to its ability to colonize and persist on the seed, a successful biological control agent must be able to exhibit "rhizosphere competence" -

Table 4. Damping-off pathogens can enter the nursery environment in several different ways but fungi frequently are carried into both container and bareroot nurseries on seeds.

Source of Fungal Inoculum	Container Nurseries	Bareroot Nurseries
Seed	Common	Common
Irrigation Water	Common	Common
Soil/Growing Media	Infrequent	Common
Containers/Equipment	Common	Infrequent

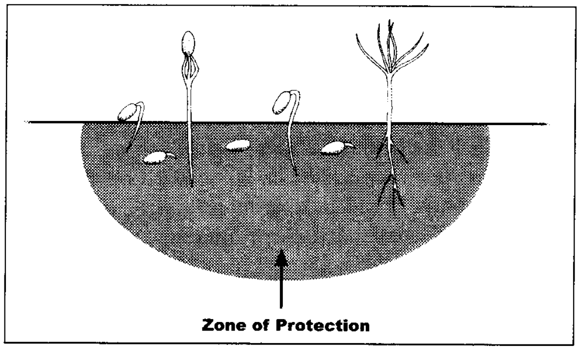


Figure 5. Spores of special strains of *Trichoderma harzianum* have been shown to protect germinating seedlings from fungal damping-off by creating a zone of protection in the rhizosphere.

the ability to spread to the radicle and thrive in the competitive environment surrounding a germinating seed **(Figure 5).** Many wild strains of *Trichoderma* are unable to demonstrate this ability but the T-35 strain of *T. harzianum* successfully colonized the rhizosphere around melon, cotton, and tomato roots to a distance of 12 cm (4.7 in.). This beneficial fungus was shown to compete with *Fusarium* spp. at the germinating root tip and significantly reduce populations of this damping-off pathogen. The T-22 strain of *T. harzianum* has been registered with the EPA for use as a seed treatment and is compatible with many synthetic pesticides used for damping-off. It also can be mass produced by fermentation to yield high quality propagules that are tolerant to desiccation, and can be applied to bulk seed with existing technology.

In conclusion, microbials are more effective than chemical seed treatments because work two ways:

1) they deal with pathogens on the seed itself
2) they spread into the rhizosphere to create a zone of protection around the germinating seedling

Research with agricultural crops has proven that strains of T. *harzianum* show considerable promise as seed treatments against damping-off. New research is developing mass production and seed application methods which will lead to more effective and less expensive products. Now, specific operational trials must be established in both container and bareroot nursery systems before their true biocontrol potential can be determined for forest and conservation crops.

Sources:

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

Quarles, W. 1996. Alternatives to methyl bromide: *Trichoderma* seed treatments. IN: Quarles, W.; Daar, S. eds. IPM alternatives to methyl bromide. Berkeley. CA: Bio-Integral Resource Center :51-57.

Sutherland, J.R.; Shrimptom, G.M.; Sturrock. R.N. 1989. Diseases and insects in British Columbia forest seedlings nurseries. FRDA Report 065. Victoria, BC: Crown Publications, Inc. 85 p.

Taylor, A.G.; Harman, G.E.; Nielsen, P.A. 1994. Biological seed treatments using *Trichoderma harzianum* for horticultural crops. HortTechnology 4(2): 105-109.

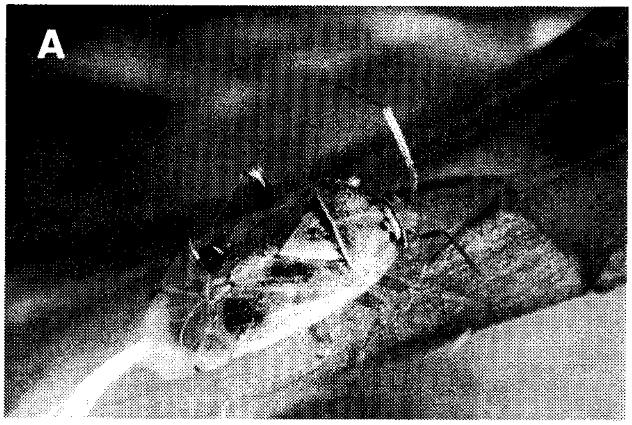
Biocontrol of Lygus bugs

Lygus bugs have been known to injure seedlings for at least 50 years but they were not recognized as a serious pests of conifer nursery crops until recently. Now that it has been properly diagnosed, damage due to Lygus spp. has been found in the US, Canada, and Europe. Because there are species of the Lygus complex found around the world, the actual extent of their damage is probably even more widespread.

The reason Lygus damage was not recognized earlier is that the symptoms were usually misdiagnosed. Both nymphs and adults **(Figure 6A)** feed by sucking the juices from succulent plant tissue, often near the expanding shoot. While feeding, they inject a toxic saliva into the tissue which causes stem lesions, distorted needles, bud abortions, and eventually multi-leadered shoots **(Figure 6B).** It is difficult to directly observe Lygus feeding because they are not active during the middle of the day and also fly readily when disturbed. The multi-leader symptoms that are the most common in conifer seedlings have been attributed to many causes including: frost, herbicide injury, viruses, nutrient deficiencies or other insects such as thrips. The extent of Lygus damage can be considerable - in a recent survey, the percentage of conifer seedlings with multiple leaders ranged from 4 to 65%. This translates directly into economic loss as seedlings with multiple tops usually end-up on the grading room floor. David South has estimated a loss of $36,000 if only 4% of a crop of 30 million southern pine seedlings had to be culled.

One of the problems with trying to control Lygus is that the insects have a wide host range including common cover crops and weeds. In many nurseries, it appears that they build-up their populations on these other hosts and then move into the succulent, well-irrigated tree seedlings later in the season. Although monitoring with sticky traps can give a general idea of when Lygus populations begin to increase, this is usually too late to avoid significant injury. Therefore, most nursery managers apply preventative applications of common insecticides.

Until now, there have been few Integrated Pest Management (IPM) options for managing Lygus bugs. Back in the July, 1991 issue of FNN, I mentioned that the J. Herbert Stone nursery was testing "bug suckers" -large, tractor-drawn field vacuums that had been used to control Lygus in strawberry fields. This cultural control is still being used but is not completely effective, and so insecticides are still required as part of their IPM program.



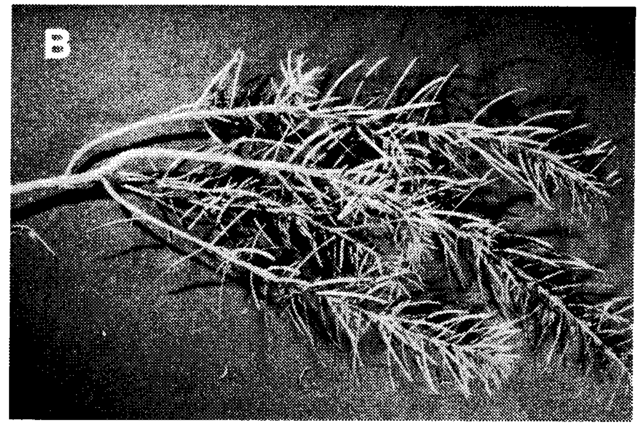


Figure 6. The feeding of adult Lygus bugs (A) and their nymphs causes distorted growth and terminal bud abortion, and often results in multi-topped seedlings (B)

Entomologists at the Beneficial Insects Research Laboratory, which is run by the USDA-Agricultural Research Service, have reported success with introducing a parasitic wasp as a biocontrol agent. *Peristenus digoneutis* is a small [6.5 mm (0.25 in.)] parasite of two native Lygus bugs *(L. lineolaris* and *L. hesperus*), which have been implicated in conifer seedling damage in the South and Pacific Northwest. The female wasp attacks the relatively immobile Lygus nymphs by laying eggs in them **(Figure 7).** In a few days, the wasp larva hatches and feeds on the host, providing a safe and effective control. The Peristenus wasps are native to Europe and have been raised at the Beneficial Insects Research Lab. They were originally released in New Jersey but have since been found in five surrounding States. Researchers think their range is probably even greater. Because Peristenus wasps only attack the target pests, they are unlikely to affect other beneficial insects. One serious problem, however, is that these wasps don't tolerate warm weather and so potential control will be limited to the northern US and Canada. Further research is now underway in the Northwest on alfalfa, strawberries, and other fruits and vegetables but it would be interesting to see how they would work in tree seedling nurseries. Anyone wanting more specifics should contact:

William H. Day
USDA-ARS
Beneficial Insects Research
Laboratory
501 So. Chapel St.
Newark, DE 19713
Tel: 302/731-7330
Fax:3021737-6780
E-mail: trop@udel.edu

Sources:

Becker, H. 1997. Imported wasps work well as biological controls. Agricultural Research 45 (12): 14-15.

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

South, D. B. 1991. Lygus bugs: a worldwide problem in conifer nurseries. IN: Sutherland, J.R.; Glover, S.G. eds. Proceedings of the first meeting of IUFRO Working Party S2.07-09: Diseases and insects in forest nurseries. Forestry Canada, Pacific Forestry Centre. Information Report BC-X-331: 215-222.

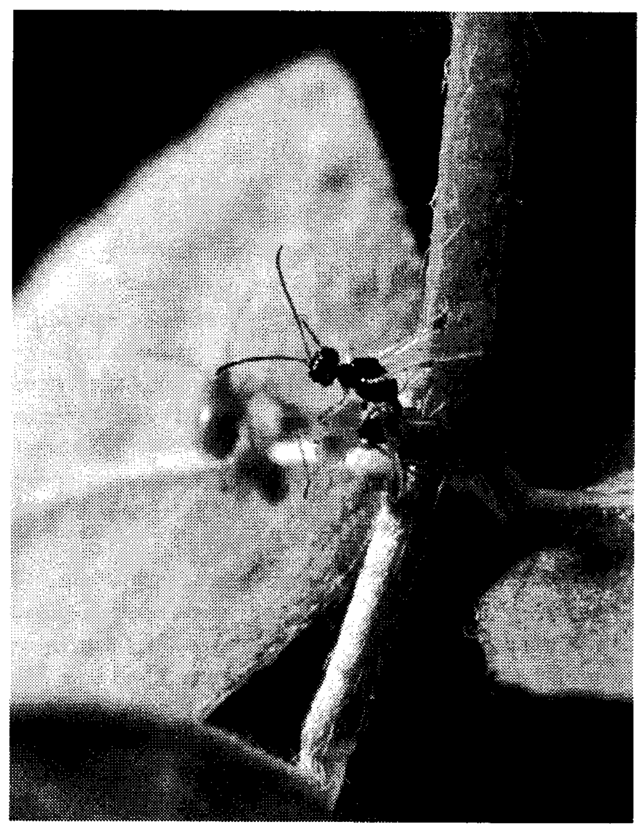


Figure 7. A parasitic wasp (*Peristenus digoneutis*) laying eggs in the nymph of a Lygus bug (*Lygus lineolaris*) (Courtesy of W. Day and S. Baeur).

The purpose of this section is to make readers aware of new nursery equipment, products, or services that will help them in their work. All trade names mentioned are used for the information and convenience of the reader, and do not imply endorsement or preferential treatment by the author or the USDA Forest Service.

As you all know, water is one of the most important factors that limit plant growth (see "The Role of Water in Nurseries" in this issue) and so I thought that it might be a good idea to review some of the equipment and techniques for monitoring moisture in the nursery.

Measuring Moisture in Seeds, Seedlings, Soils or Growing Media

Controlling seed moisture content is the most important factor in maintaining seed viability during storage. Although temperature is also important, poorly-controlled moisture content can lead to measurable viability losses in as little as 24 hours. Therefore, nurseries should have a quick and accurate way to assess seed moisture.

Seed Moisture Meters. Electronic testers are the most economical and practical way of measuring seed moisture content in the nursery. These portable testers work best for moisture contents in the range of 6 to 8 % which is ideal for seed storage. Although some models will work at higher moisture contents of 15 to 45 %, such as those used in the stratification-redry or incubation-drying-separation procedures, the variability has been found to be too high. For this reason, the standard oven drying method of determining seed moisture is recommended for these high moisture situations.

There are several different seed moisture meters available at prices that range from a few hundred to several thousand dollars. For example, the Dole/Baton Model 400 has been around for over 40 years, and can be used with a wide variety of seeds **(Figure 8).** Dickey-John moisture testers also work well with most tree and shrub seed, but have not been as reliable for certain seed types such as true firs *(Abies* spp*).*

Operating seed moisture meters is very simple. With the Dole/Eaton meter, a sample of seed is collected and a test sample is weighed out using the meter's own internal weight scale. This test sample is then poured into the test chamber, front dial adjustments are made, and the moisture reading is read from the dial. With the Dickey-John meter, the test chamber also serves as the weighing chamber and the reading can be read without any dial adjustment. Because seed moisture meters were developed for agricultural seeds, the meter readings for forest and conservation seeds require a conversion

Figure 8. Because it is so critical to maintaining viability during storage, nurseries should monitor seed moisture with electronic meters, such as this Dole/Eaton Model 400 (Courtesy of Agri-Tronix Corporation.

factor. Each species needs its own conversion chart based on the oven drying standard, and any seed laboratory should be able to develop these charts. The National Tree Seed Laboratory has developed charts for a number of tree and shrub species and will work with new species upon request:

USDA Forest Service
National Tree Seed
Laboratory
Route 1,Box 182B
Dry Branch, GA 31020-9696,
USA
TEL: 912/751-3552
FAX: 912/751-3554

Besides selling new seed moisture meters, the Agri-Tronix Corporation supplies parts and service for older models. Contact them at:

Agri-Tronix Corporation
2001 N. US 31
Franklin, IN 46131,
USA
TEL: 800/445-5058
FAX: 317/738-9877
E-mail: agritron@aol.com
WWW: www.agritron.com

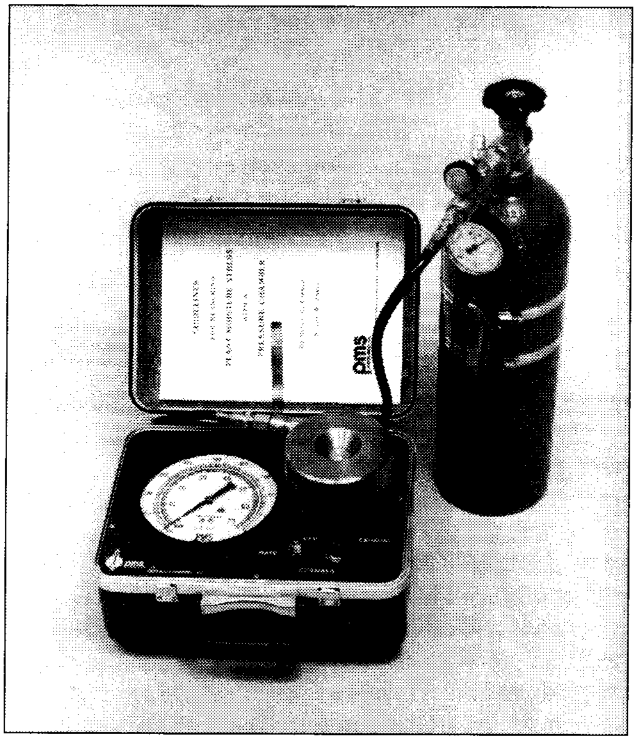
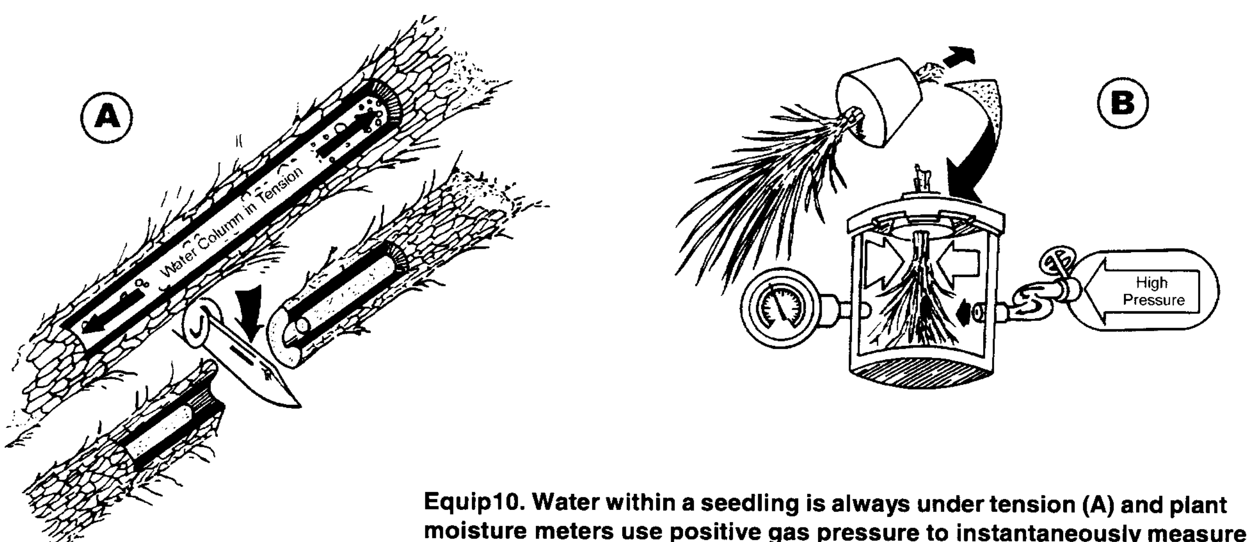


Figure 9. Plant moisture meters allow an instantaneous measure of seedling moisture stress (Courtesy of PMS Instrument Company)

Plant Moisture Meter. The "pressure bomb" or "pressure chamber" measures plant moisture stress (PMS), and the basic equipment hasn't changed appreciably since my college days. What has changed, however, is that plant moisture meters are now available commercially in several different models which feature innovative new improvements that make monitoring the internal moisture status of your seedlings easier and safer **(Figure 9).**

To understand how plant moisture meters work, you need to have a basic knowledge of seedling water relations. Water moves through plants in a continuous stream - it is absorbed by the roots, travels through the stem and is lost through the foliage during transpiration. During the day, this stream of water is always under tension or stress because leaves transpire faster than roots can absorb water. For the purposes of measurement, it is useful to think of the water inside a plant as a rubber band. The moisture stress is lowest (less tension on the rubber band) just before sunrise because the roots have had all night to replenish the water lost during the previous day. As the heat of the sun becomes more intense, however, transpiration gradually increases and the moisture stress within the seedling becomes greater (more tension on the rubber band). The amount of moisture stress in a nursery seedling at any given moment is a function of the availability of water in the soil or growing medium, irrigation practices, and atmospheric demand - primarily solar intensity and wind speed. In the nursery, seedling moisture stress increases with time since the last irrigation, and is greatest during hot, windy weather.

The basic operation of the pressure chamber is relatively simple. A sample consisting of a shoot or fascicle of needles is prepared by making a clean cut with a knife or razor blade **(Figure 10A).** Remember, the internal water column is like a taut rubber band and so this break causes the water to recede back into the stem of the cut sample. The sample is then inserted into a rubber gasket in the lid of the chamber which is attached so that the cut surface of the sample protrudes from the top **(Figure 10B).** Positive pressure is slowly applied to the chamber from a tank filled with nitrogen gas while the cut surface is observed. This gas pressure forces the water column back to its original position at the cut surface of the sample. The pressure reading when the cut



Equip10. Water within a seedling is always under tension (A) and plant moisture meters use positive gas pressure to instantaneously measure this stress (B) (Courtesy of PMS instrument Company)

Table 5. Some general plant moisture stress (PMS) guidelines for nurseries and reforestation

PMS Reading (bars)	Relative Stress	Seedlings Response	Cultural Implications
0 to 5	Slight	Rapid Growth	Irrigation Not Needed
5 to 10	Low	Good Growth	Irrigation Required
10 to 15	Moderate	Growth Reduced	Use for Hardening
15 to 25	Severe	Growth Stops	Permanent Injury Potential
Over 25	Extreme	No Growth	Injury or even mortality

surface becomes moist is recorded and essentially equals the internal moisture stress of the seedling.

Plant moisture meters can have several uses in the nursery. PMS measurements taken before the heat of the day can give an excellent indication of when to irrigate because they integrate soil moisture availability and atmospheric demand **(Table 5).** Some bareroot nurseries monitor seedling moisture stress during lifting and packing and use the measurements to know when the seedlings need to be sprayed down. Plant moisture meters also have been used to give an accurate picture of the internal moisture stress of seedlings during storage and shipment. The biggest drawbacks of the technique is that the measurements require destructive sampling and that early morning readings are inconvenient.

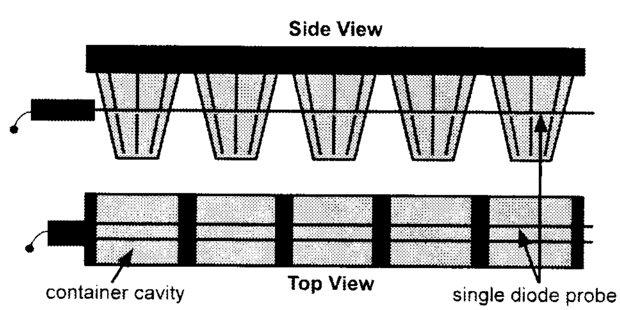
The PMS Instrument Company offers several models of plant moisture meters from portable models that can be used out in seedbeds or greenhouses to laboratory models with digital readout and data storage . For the latest information, you can contact them at:

PMS Instrument Company
480 SW Airport Avenue
Corvallis, OR 97333,
USA
TEL: 541n52-7926
FAX: 541/752-7929
E-mail: pms@proaxis.com
WWW: www.proaxis.com/~pms

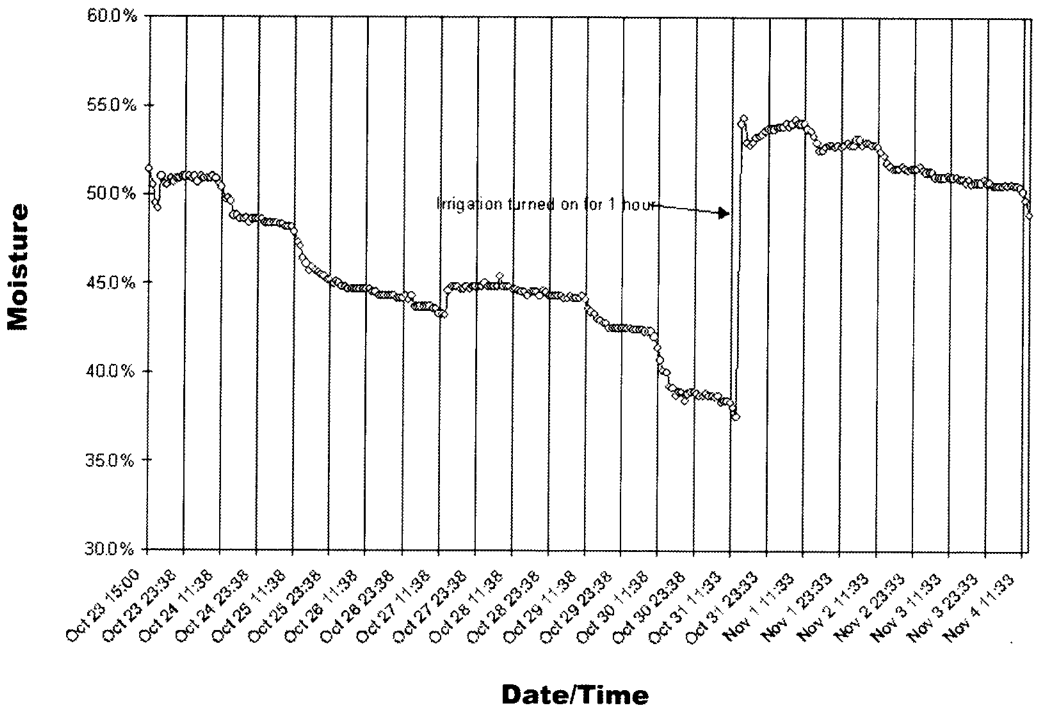
Moisture Meter for Soils and Growing Media. Measuring water in soils or growing media is always a challenge because there just never has been a quick and easy way to do it. Equipment such as tensiometers and gypsum blocks have been around for decades but both have limitations in nursery applications. There haven't been any new innovations for the past 20 years, until recently, when I was shown a new technique that offers some real advantages for monitoring moisture in soils or growing media.

Time Domain Reflectometry (TDR) is a relatively recent technique which utilizes water's unusually large dielectric constant. TDR has been used for other applications, but the Moisture-Point TDR™ equipment is the first to use this technique to measure moisture in bareroot nursery soils and container growing media. The process consists of inserting specially designed probe sensors into the soil or growing media and then reading the % moisture on a portable meter which features digital readout **(Figure 11A).** For containers, the probes must be designed and calibrated for each different type and size. One probe is designed to be horizontally inserted into predrilled holes in block containers **(Figure 11B)** and left there for the growing season. The media moisture content can either be monitored manually by hooking the probe to a portable meter or can be permanently wired

Equip 11A. Moisture•Point TDR™ meters give a digital readout of % moisture using probes that are designed for bareroot nursery soils. (Courtesy of Environmental Sensors, Inc.)



Equip 11B. Moisture•Point™ also makes special single diode probes that can measure % moisture in the growing media in multi-celled containers (Modified from Lambany and others, 1996-95 in New Nursery Literature Section)



Equip 11C The Moisture•Point™ readings can be graphed to show the rate of moisture depletion and indicate when it is time to irrigate (Courtesy of Environmental Sensors, Inc.)

into a data logger system which can monitor up to 64 different probes. The resultant graphical data clearly illustrates when it is time to irrigate **(Figure 11C).** The readings can even be transmitted by way of a modem to the nursery office where the moisture content of the media can be input into an environmental control computer. Operational research in a Canadian nursery has shown that TDR readings taken in peat-vermiculite growing media are very precise and reproducible. The readings had immediate practical application because they showed that air-slit containers dry more quickly at the edge than in the center of the cells (see article #185 in the New Nursery Literature section).

For bareroot nurseries, a portable probe can be inserted vertically into the seedbeds to instantaneously measure moisture content in the top 30 cm (12 inches) of soil **(Figure 11A).** The meter is housed in a waterproof, lightweight case and completes a reading in around 30 seconds. Other soil probes can measure moisture in vertical soil layers as thin as 15 cm (6 in.).

Although % moisture is good for relative comparisons, the matric potential of soils or growing media as measured in bars would be even more informative in terms of seedling physiology. This conversion could be done using soil moisture retention curves which can be made by any soil testing laboratory. These curves are a function of the type and size of soil particles and so are unique to each soil or growing medium. Since soil moisture retention curves measure % moisture on a weight basis, these readings would have to be converted to % by volume to correspond to the TDR measurements (Soil moisture curves for a peat-vermiculite medium and a silty loam soil are given in Figure 4.2.8 of Volume Four of the Container Tree Nursery Manual).

I think that this technology has tremendous potential but, as we all know, "the proof is in the pudding". Several bareroot and container nurseries in the Pacific Northwest have purchased Moisture Point TDR equipment and will be using it operationally during the coming growing season. The Moisture Point meters also will be demonstrated at regional nursery meetings this coming year but, if you would like more specifics now, contact:

Pierre Ballester
Environmental Sensors, Inc.
100-4243 Glanford Avenue
Victoria, BC V8Z4B9,
CANADA
TEL: 800/799-6324 or 250/479-6588
Fax: 250/479-1412
E-mail: admin@esica.com
WWW: http://www.esica.com

Fleshy Seed Macerators

The "Dybvig Seed Cleaner" has been a standard piece of equipment at many nurseries and seed processing facilities for the past 45 years. Melvin Dybvig's father developed the machine at their family nursery in South Dakota for the purpose of depulping berries and other fruity seeds. A similar macerator is the Model #193 Seed Cleaner which is available from Bouldin and Lawson. Although both machines work on the same principle, they are not alike and parts are not interchangeable.

Both macerators consist of a cylindrical hopper with a spinning plate in the bottom which is powered by a variable speed electric motor **(Figure 12).** For depulping seeds, the flanged plate is adjusted so that the gap between it and the bottom of the hopper is just smaller than the width of the seed. Then, the hopper is filled with fruits and irrigated with a intermittent stream of water from a hose. The vertical ridges on the rotating cleaning plate agitate the contents of the hopper, breaking-up the fruits. The pulp and other debris are washed out of the hopper through the gap around the plate in the bottom. When the separation is complete, the cleaned seed is washed out the sliding door on the side of the hopper into a bucket. Randy Moench at the Colorado State Forest Service Nursery uses their Dybvig cleaner for processing *Juniperus scopulorum, J. virginiana, Prunus americana, P. virginiana,* and *Cotoneaster* spp. It has also been used for dewinging a variety of hardwood and conifer seeds including *Fraxinus* spp., *Ulmus* spp., and *Syringa* spp.

For more information or replacement parts, contact either:

Dybvig Seed Cleaner:	**Melvin R. Dybvig** PO Box 372 Brightwood, OR 97011, USA **TEL:** 503/622-5242
Model 193 Seed Cleaner	**Bouldin & Lawson, Inc.** PO Box 7177 McMinnville, TN 37110-7177, USA **TEL:** 800/443-6398 or 931/668-4090 **FAX:** 931/668-3209

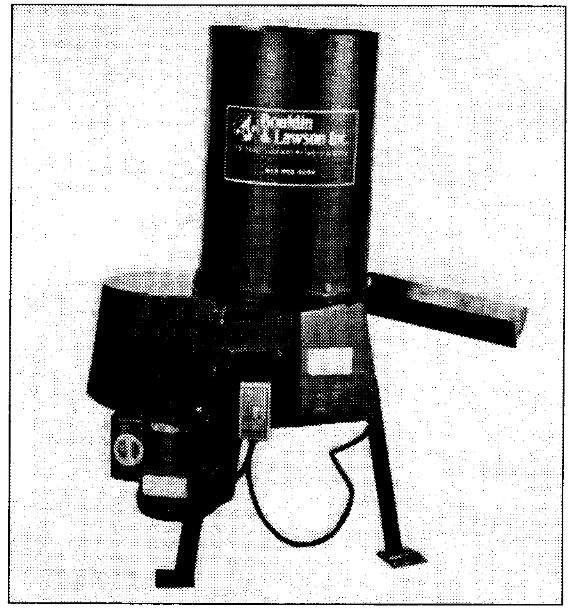


Figure 12. Macerators, like this Model #193 Seed Cleaner, are used to depulp fleshy fruits and berries (Courtesy of Boulding and Lawson, Inc)

Anti - transpirants

Now that we have discussed how to measure plant moisture stress, how about a way to prevent it? A number of different anti-transpirant chemicals have been developed over the years, but there has always been a basic problem - how to stop water loss through the foliage without interfering with photosynthesis or respiration **(Figure 13).** There have been several research projects that have studied the efficacy of anti-transpirants but the results have been mixed. Many of these studies have been flawed, however, by problems with proper concentration or method of application. I recently learned, however, that some Southern bareroot nurseries have been using one product (Vapor Gard®) for the past 15 years and so thought that I would pass along this information.

Vapor Gard is an anti-transpirant concentrate whose active ingredient is pinolene® - a derivative of pine resin. Wilt-Pruf® is another pinolene-based anti-transpirant that comes in a pre-emulsified formulation that is easier to use in small sprayers. When sprayed on foliage, Vapor Gard

Table 6. A foliar spray of Vapor Gard® increased both survival and growth of two sources of loblolly pine seedlings when outplanted on droughty sites (Rowan 1988)

	Vapor Gard Treated		Control	
Bareroot loblolly pine seedlings	**Survival (%)**	**Height Growth (cm)**	**Survival (%)**	**Height Growth (cm)**
- Georgia source	66.0 c	93.3 a	63.4 b	77.3 a
- Texas source	47.0 b	85.0 a	29.1 a	90.7 a

Survival and height means followed by a common letter are not significantly different at the 95 % level

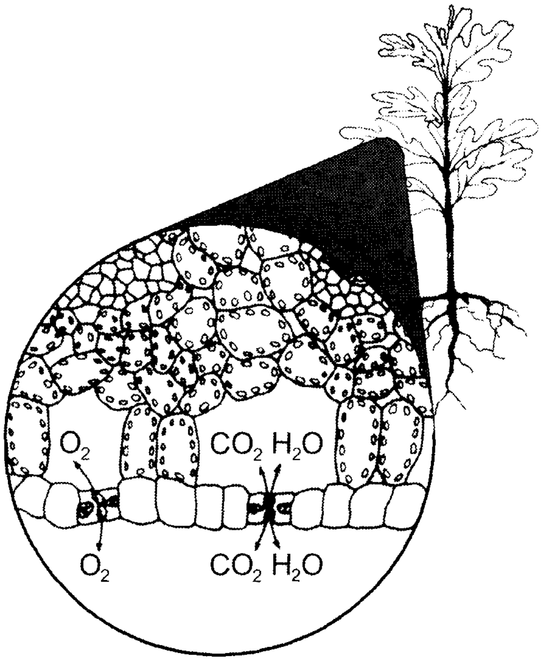


Figure 13. Anti-transpirants must reduce water loss through stomata while not completely restricting the exchange of carbon dioxide for photosynthesis and oxygen which is needed for respiration (Modified from Hartmann, Flocker, & Kofranek, 1981)

and Wilt-Pruf form a soft flexible film which partially blocks the stomata and thereby retards transpirational water loss, apparently without adverse effects on growth. The spray film is weather resistant and observations with a scanning electron microscope have shown that Vapor Gard can persist on citrus leaves for 6 months. Because Vapor Gard and Wilt Pruf do not alter seedling physiology, they are not considered growth regulators and so do not require Environmental Protection Agency (EPA) registration. They also are safe to handle with an LD_{50} in excess of 20,000. Wilt-Pruf Products, Inc. has a very informational home page (see URL at end of this article) which contains a wealth of technical specifications as well as a Material Safety Data Sheet.

Anti -transpirants have several applications in forest and conservation nurseries as well as after outplanting. One obvious use would be to prevent winter desiccation in conifers stored outside or under other high moisture loss conditions. Several studies have shown that when applied to southern pines prior to harvest, Vapor Gard prevented moisture stress after outplanting and even increased growth during the first season **(Table 6).** The benefits are particularly significant on droughty sites. Currently, Vapor Gard is applied operationally to all species of bareroot pine stock in nurseries of the Georgia Forestry Commission. The method of applying Vapor Gard or Wilt Pruf is important and growers should heed the label directions. For example, there are two rates given on the Vapor Gard label: the desired rated for transplanting, and a heavier rate for established plants.

For both post-harvesting and pre-outplanting applications, foliar sprays have been effective on both bareroot and container conifers whereas foliar dips have shown some adverse effects. Dips are not recommended because the viscous solution does not cover as well and also needs time to dry evenly. Spraying gives more even coverage and Vapor Gard or Wilt Pruf can be applied several days prior to harvesting. As with all chemicals, however, growers should conduct small scale trials with their own species to test for possible phytotoxicity before beginning full operational use. Although it is mentioned on the label, Vapor Gard should not be used at a "Water Saving Tool" or as a substitute for good nursery irrigation practices. Rapidly growing seedlings require full exchange of carbon dioxide and oxygen for rapid growth and even partial blockage of the stomata cannot be beneficial. For more information, contact:

Vapor-Gard:
Gary Wakefield
Miller Chemical & Fertilizer Corp.
327 Center St.
Slippery Rock, PA 16057
USA
Tel: 412-794-3530
Fax: 717-63211581
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or 860/767-7033
Fax: 860/767-7265
E-mail: wiltpruf@wiltpruf.com
WWW: http://www.wiltpruf.com

Sources:

Harmann, H.T.; Flocker, W.J.; Kofranek, A.M. 1981. Plant Science: Growth, Development, and Utilization of Cultivated Plants. Englewood Cliffs, NJ: Prentice-Hall, Inc. 676p.

Rowan, S.J. 1988. Vapor-Gard affects survival and growth of outplanted pine seedlings. IN: Proceedings. Southern Forest Nursery Association; July 25-28, 1988; Charleston, SC. Columbia, SC: South Carolina Forestry Commission: 27-32.

South, D. 1996. Personal communication. Auburn University, AL: Southern Forest Nursery Management Cooperative.

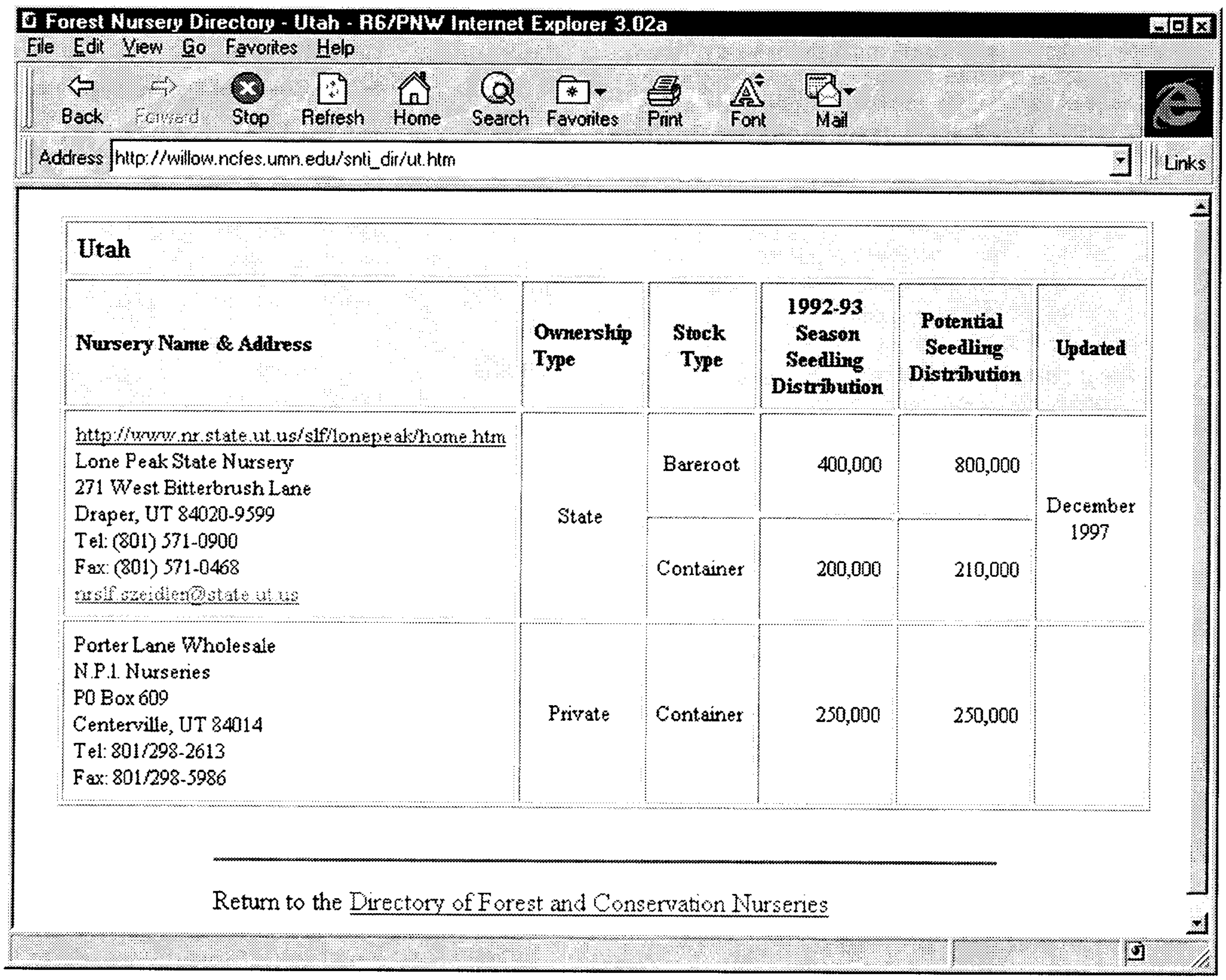
National Nursery Directory Update

In the last issue of FNN, I mentioned that we are updating the *Directory of Forest and Conservation Tree Nurseries in the United States* on our WWW home page:

http://wfllow.ncfes.umn.edu/snti/snti.htm

Our intent was to have readers send us their updated addresses, including E-mail and home page URL's, along with their current seedling distribution statistics. The information is easy to access - just go to the Directory listing and you'll find a US Map. Click on your State or its postal abbreviation and you will go to a table with nurseries listed in alphabetical order. In addition to the Nursery Name and Address, you will find Ownership Type, Stock Type, and Current and Potential Seedling Distribution (Figure 14). For those nurseries with E-mail addresses and Home Pages, these appear in blue lettering which means that people can link to them directly on-line.

We know that many of you still don't have easy access to the Internet but we have a responsibility to keep our directory accurate. So, we are going to make copies of the current nursery listings and mail them out to everyone on the 1994 edition of the Directory with a one-page survey letter. If we don't get a response within 4 weeks, we'll remove the listing from our home page. If you have any questions, you can contact me at the telephone, FAX, or E-mail addresses listed on the inside front cover of this issue.



Utah

Nursery Name & Address	Ownership Type	Stock Type	1992-93 Season Seedling Distribution	Potential Seedling Distribution	Updated
http://www.nr.state.ut.us/slf/lonepeak/home.htm Lone Peak State Nursery 271 West Bitterbrush Lane Draper, UT 84020-9599 Tel: (801) 571-0900 Fax: (801) 571-0468 nrslf.szeidler@state.ut.us	State	Bareroot	400,000	800,000	December 1997
		Container	200,000	210,000	
Porter Lane Wholesale N.P.I. Nurseries PO Box 609 Centerville, UT 84014 Tel: 801/298-2613 Fax: 801/298-5986	Private	Container	250,000	250,000	

Return to the Directory of Forest and Conservation Nurseries

Figure 14. Nurseries are listed by state on the Seedlings, Nurseries and Tree Improvement (SNTI) home page where readers can electronically link to the nurseries who have home pages or E-mail addresses.

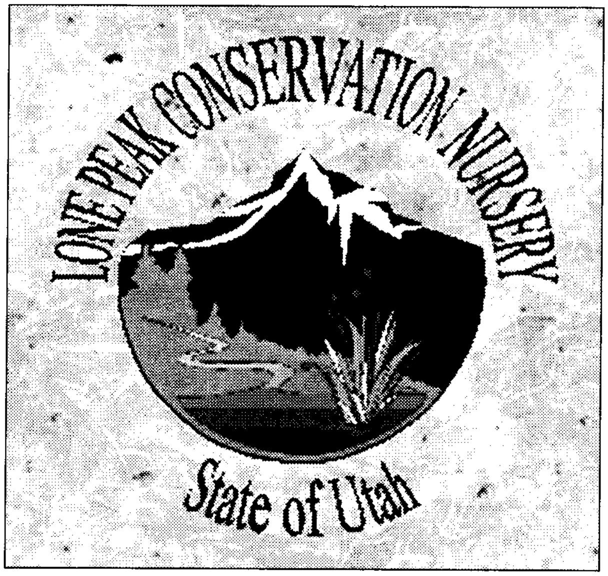


Figure 15. The Lone Peak Conservation Nursery attracts potential customers and provides technical information on their products and services through their home page on the World Wide Web:
http://www.nr.state.ut.us/slf/lonepeak/home.htm

Lone Peak Conservation Center

Many nurseries are developing their own WWW home pages as a way to market their seedlings as well as encourage information exchange. Most people, including me, don't have the technical expertise to design their own web pages. So, to give you an idea of what's possible, I'd like to feature one excellent home page that contains all the basic elements: easy-to-use instructions, good illustrations, and helpful information.

The home page of the Lone Peak Conservation Center (Figure 15) contains three basic elements:

1) Provides information on who they are. The first panel informs the reader that their nursery is part of the Division of Forestry, Fire and State Lands of the Utah Department of Natural Resources. It also lists their nursery goal - "Growing native plant seedlings for ecosystem based, multiple use management of resources"

2) Describes what products and services they provide. Of course, the main objective of any nursery is to sell seedlings. On their home page, the reader can link directly to their Plant Species Brochure which lists the

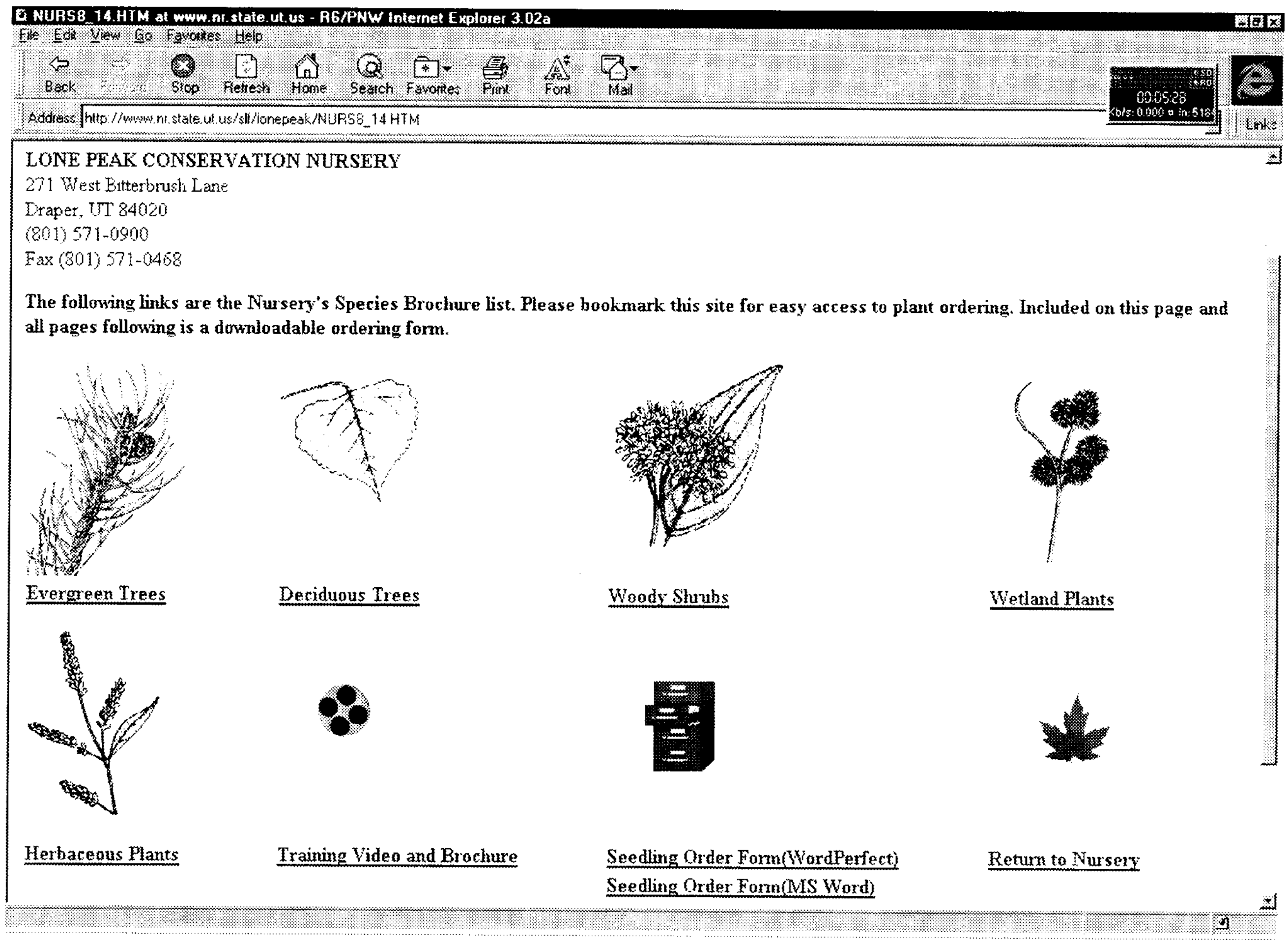
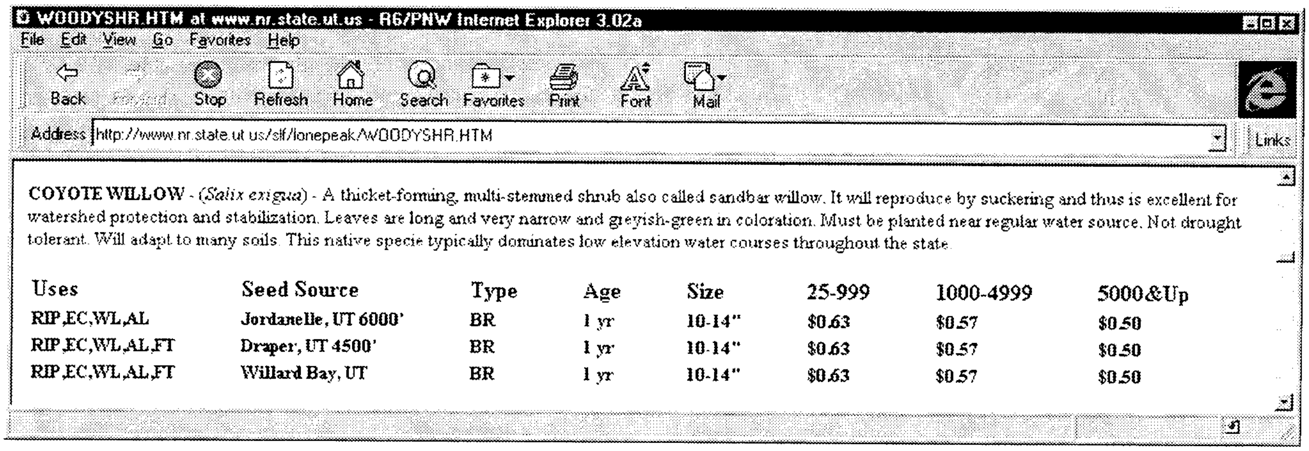


Figure 16. These visual links on the Lone Peak Conservation Center home page direct customers to plant species descriptions and prices, training aids, and order forms


WOODYSHR.HTM at www.nr.state.ut.us - R6/PNW Internet Explorer 3.02a

File Edit View Go Favorites Help

Back Forward Stop Refresh Home Search Favorites Print Font Mail

Address http://www.nr.state.ut.us/slf/lonepeak/WOODYSHR.HTM Links

COYOTE WILLOW - (*Salix exigua*) - A thicket-forming, multi-stemmed shrub also called sandbar willow. It will reproduce by suckering and thus is excellent for watershed protection and stabilization. Leaves are long and very narrow and greyish-green in coloration. Must be planted near regular water source. Not drought tolerant. Will adapt to many soils. This native specie typically dominates low elevation water courses throughout the state.

Uses	Seed Source	Type	Age	Size	25-999	1000-4999	5000&Up
RIP,EC,WL,AL	Jordanelle, UT 6000'	BR	1 yr	10-14"	$0.63	$0.57	$0.50
RIP,EC,WL,AL,FT	Draper, UT 4500'	BR	1 yr	10-14"	$0.63	$0.57	$0.50
RIP,EC,WL,AL,FT	Willard Bay, UT	BR	1 yr	10-14"	$0.63	$0.57	$0.50

Figure 17. A typical descriptive listing for plants on the home page of the Lone Peak Conservation Center

more than 90 native and adapted plants that the nursery grows. By going to the next panel, you have access to other links for several plant categories: Evergreen Trees, Deciduous Trees, Woody Shrubs, Wetland Plants, and Herbaceous Plants **(Figure 16).** Within each of these categories, the reader is informed of brief descriptions of the characteristics of each species, uses, seed source, stock type, age, size and prices. For example, **Figure 17** gives the listing for a native willow.

Some species listings contain links to color pictures of what the plant will eventually look like. If the reader would like to order plants, they can either view an order form or download it in one of the principal software formats **(Figure 16).** Another real benefit of their home page is that the nursery can inform prospective customers if a species is sold out.

3) Makes it easy to communicate. The home page not only lists the mailing address and telephone and FAX numbers at several locations, but also provides office hours and seedling ordering and delivery information. One thing that is missing is a map on how to find the nursery. Of course, one of the real advantages of a home page is that they contain direct links to the nursery staff. When readers click on the highlighted E-mail address a pre-addressed memo is generated.

So, if you are interested in designing a home page or simply want to see what one looks like, I would recommend visiting the Lone Peak Conservation Nursery on the Worldwide Web.

FNN Issues Available On-Line

Many of you have asked for back issues of FNN but, unfortunately, all except the past few are out of stock. The cost of reprinting hard copies is prohibitory and so we decided to lay them out in HTML format and upload them on our Seedlings, Nurseries, and Tree Improvement (SNTI) home page. The specific address for FNN is: willow. ncfes.umn.edu/snti/fnn_list.htm

Currently, we have the January and July issues from July, 1994 to the present. The layout of each issue was done by sections so that you can download individual articles quickly if you like. Readers can even order copies of technical articles listed in the New Nursery Literature section with a easy pre-addressed electronic order form. Our intent is to co-publish future FNN issues both in hard copy and over the Internet. Because of the relatively slow printing process, the version on the home page should be available even before you could receive the hard copy in the mail. This will be especially true for foreign subscribers. As always, we are open to suggestions so let us know if you have any ideas for improvement.

Government Nursery Services

In the July, 1997 issue of FNN, I presented an editorial on "The Role of Government Nurseries" in which I listed developing and sharing information as one of their traditional missions. I decided that it might be helpful if I actually followed-up that article with some examples. So, in the next several issues, I am going to feature some federal and state government nurseries and discuss their technology transfer offerings.

The J. Herbert Stone Nursery in Southern Oregon **(Figure 18)** has been operated by the USDA Forest Service since 1979 with the primary purpose of growing seedlings for federal forest lands. Production at the Stone nursery peaked in 1990 when almost 27 million seedlings were shipped, but since then, demand has steadily decreased due to the reduced federal timber harvest. During the same period, the nursery began to get requests to grow a wide variety of noncommercial native plants.

Developing Propagation Techniques for Riparian Plants. There has been an increased demand for riparian and wetland plants all over the US but, in the Pacific Northwest, the "salmon crisis" is one of the driving forces. This issue developed in the past 5 years or so because populations of many species and ecotypes of salmon, steelhead, and native trout are in serious decline, and some even have been proposed for endangered species listing. Like most wildlife management problems, loss of suitable habitat is at least partially to blame and so the Forest Service and other land management agencies have initiated projects to restore riparian areas across the Northwest. These projects are fueling the need for a variety of plant materials such as willows and other riparian trees and shrubs. Larger stock types are particularly in demand both to stop soil erosion along the banks as well as provide instant shade for cooling the water temperature in salmon spawning areas **(Figure 19).** The Stone nursery has responded by growing a wide

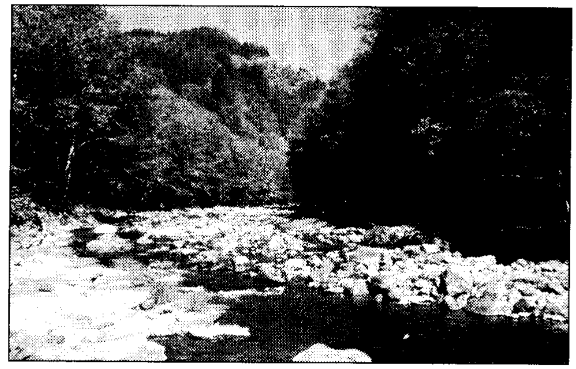


Figure 19. The salmon crisis in the Pacific Northwest has generated a demand for large riparian stock to provide shade in spawning areas and retard streamside erosion.

variety of trees, shrubs, forbs, grasses, and sedges as both bareroot and container stock. Since little is known about how to propagate many of these native species, the nursery is working to develop propagation protocols while producing seedlings for the projects themselves. For example, one National Forest requested seedlings of Oregon boxwood *(Pachistima myrsinites)* but reported that they were having trouble finding and collecting the very small seed. A little research by the nursery staff revealed that ornamental species of boxwood were normally produced by cuttings, and so they recommended that hardwood cuttings be collected in the Fall. This operational trial was a complete success with excellent rooting and survival of the cutting grown in containers. The seeds of many native plants have complex dormancy requirements and getting the stubborn seeds to germinate is a real challenge **(Table 7).** Stone nursery personnel have developed seed treatments which are being documented in technology transfer publications like *Propagation of Pacific Northwest Native Plants* which is being published by the Nursery Technology Cooperative at Oregon State University. Producing a consistent crop from year to year is another problem, however. The Stone nursery was able to grow a nice crop of bareroot mockorange *(Philadelphus lewsii)* the very first year and thought that they had conquered the seed dormancy problem. However, we all know how nursery work keeps you humble, and another sowing of the same seedlot the following year never germinated at all - a complete crop failure. The nursery will continue to work on these propagation challenges and report their results in annual reports and at regional nursery meetings.

Native Seed and Plant Materials Workshops. How best to share propagation information is always a challenge. The Stone nursery has helped put on technology transfer workshops for the past several years

Figure 18. The J. Herbert Stone Nursery grows 944 different seedlots of 81 commercial and noncommercial native plants, as well as grass seed, for federal government agencies all over the Pacific Northwest.

which have been attended by project planners from federal land management agencies from across Oregon and Washington. Just organizing these workshops requires a lot of work but the nursery personnel also do much of the instruction. Topics at recent workshops have included How to Collect and Process Seed, and Genetic Considerations in Planning Revegetation Projects. Of course, it is always easiest to demonstrate a new procedure and so the nursery uses their seed processing facilities, seedbed trials, and greenhouses to share what they have learned.

Producing Native Grass Seed. National Forest personnel have traditionally sown grass seed after forest fires and for restoration of roadside cutbanks but exotic grasses were used. Lately, restoration specialists are asking for site-specific native grass seed but are having trouble finding reliable local sources. Responding to this demand, the nursery now produces 24 species of native grasses, some of which have 20 or more different varieties. Although seed dormancy has been bred out of most commercial grasses, the nursery has learned that one-fourth of the species required some type of seed stratification. Each species also has its own unique cultural requirements which must be learned and documented. Although many people have the misconception that native plants are more pest-free than cultivated crops, nursery workers are learning that this is not the case. When they are grown close together under nursery conditions, native grasses have some serious insect and disease pests. One sowing of June grass (Koeleria cristata) was totally wiped out by a rust fungus- the 200 lbs. of seed that was collected by was totally worthless.

The original intent of the native grass program was to produce breeder seed for local private grass seed growers, who would then gear-up to meet the demand. This has worked to a limited degree. About a half dozen local farmers grow native grass seed on contract for the Forest Service and Bureau of Land Management. The Stone nursery serves as a source of expertise for these growers and also produces seed of the other species that are not yet considered economical to grow. All of these developments have radically changed the operation of the Stone nursery. In 1988, they produced just 16 species and offered only three bareroot stock types. Just ten years later, the Stone nursery staff is growing 944 different seedlots of 81 plant species, which are produced as 14 different stock types. This broad range of experience insures that the Stone nursery will continue to discover and share new propagation information for years to come.

Sources:

Christensen, J. 1998. Bringing salmon back. American Forests 103(4): 16-20, 41.

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

Steinfeld. D. 1997. You want us to do what!? Diversifying plant products at the J. Herbert Stone Nursery. IN: Landis, T.D.; Thompson, J.R., tech. coords. National Proceedings. Forest and Conservation Nursery Associations. Gen. Tech. Rep. PNW-GTR-419. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 63-67.

"Sister" Nurseries

I'm sure that many of you have heard of the Sister City program where cities in two different countries agree to a cultural exchange to promote mutual understanding. How about a Sister Nursery? Raul Moreno of Microseed Nursery and I have worked on several projects in Mexico over the past several years but have been discouraged by the steadily decreasing governmental funding. Maybe the answer is a more direct one-on-one a program in which

Table 7. Seed Propagation Information for Some Riparian Plants Grown at the J. Herbert Stone Nursery

Common Name	**Scientific Name**	**Seed Treatment**	**Cultural Tips**
Sitka alder	*Alnus sinuata*	Cold (C), Moist (M) stratification for 30 days	Grow as 1+0 bareroot (BR) but seed needs light to germinate so use a thin sand or grit mulch
Water birch	*Befula occidentalis*	C/M stratification for 30 days	Grow as 1+0 BR
Thimbleberry	*Rubus paraviflorus*	C stratification for 90 days	Grow as RL 10 in^3 container (C) stock
Western redcedar	*Thuja plicata*	*C* stratification for 30 days	Grow as RL 10 in^3- C and transplant to 4 gallon C and grow for two years

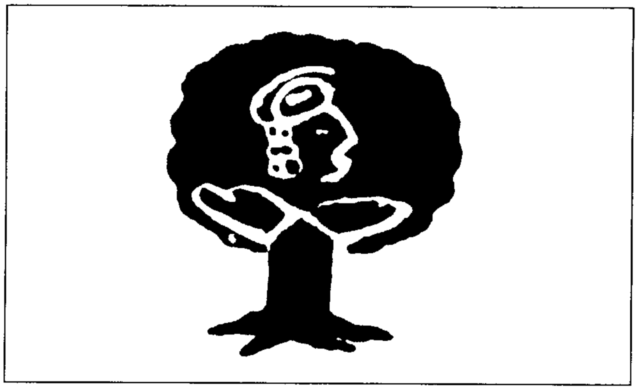


Figure 20. The Organization of the Forest Ejidos of the Mayan Zone (OEPFZM) is working to establish sustainable timber harvest while increasing biodiversity in the tropical forests of the Yucatan peninsula in Mexico

Figure 21. Raúl Moreno of Microseed Nursery confers with technical advisors and managers at the Carrillo Puerto nursery in the Yucata region of Mexico

nurseries or individuals in the USA or Canada give technical and financial assistance to small nurseries in other parts of the world.

Although a Sister Nursery program could be done anywhere, we're starting our Vivero Hermano relationship in the Yucatan peninsula region of Mexico. Most of the forest land in Mexico is owned by communities called ejidos, many of which are composed of indigenous people working to improve their economic self sufficiency. The Organization of the Forest Ejidos of the Mayan Zone (OEPFZM) **(Figure 20)** manages over 250,000 ha. (620,000 acres) of dry tropical forests in the Yucatan region. These forests contain several native trees such as Honduras mahogany *(Swietenia macrophylla)* and Spanish cedar *(Cedrela odorata)* which are highly prized for their beautiful wood. Unfortunately, until the last few years, these species have been overcut by foreign timber companies and attempts at reforestation have had limited success. So, the OEPFZM is working to establish sustainable harvests of these two valuable timber species and, at the same time, enhance the rich biodiversity of the remaining tropical forest.

The OEPFZM has established a new nursery in the town of Carrillo Puerto where mahogany and Spanish cedar seedlings are grown for enrichment plantings in the jungle **(Figure 21).** For the past 3 years, the Center for the Reforestation of the Americas (CEFORA) at New Mexico State University has been monitoring the survival and growth of their outplantings, and have identified that poor root form and outplanting technique are serious problems. Copper-coated polybags have improved root morphology with other species and so we're going to install some operational trials in the Carrillo Puerto nursery. Another exciting possibility is using copper landscape cloth as a root growth barrier under polybags and under the traditional raised bareroot seedbeds. Other ideas for technical assistance include developing a compost-based growing media, and improving the method of harvesting and transporting of seedlings to the field. As you can see, there are plenty of possibilities.

Financial support is also needed. With the help of Patricia Negreros-Castillo, a Microseed associate from Iowa State University, we are going to find a way to channel some funds to the Carrillo Puerto nursery. The idea is to provide them with funding which can be used for both practical research as well as day-to-day nursery production. To give you an idea of how far a small contribution can go, consider the following:

- A day's wages for a nursery worker is about 25 pesos or $3.00
- A kilo of poly bags costs 17 pesos ($ 2.09)

One of the real deficiencies of the new nursery is that it doesn't have a reliable well pump and irrigation system. Because this will require more funding that we have at present, we're hoping to attract additional funds to see if we can fix that problem too.

In conclusion, we're not sure exactly how this Sister Nursery program will work but we envision a loosely-organized network of people and nurseries who like to get things done. However, we realize that this program will need some structure and so Raúl has offered to let his nursery serve as the focal point. We should be able to set-up a nonprofit organization which would provide a tax credit for the donations of individuals or nurseries. If anyone would like to talk about exploring this intriguing opportunity, get in contact with Raúl or me:

Raúl Moreno
Microseed Nursery
P.O. Box 35
Ridgefield, WA 98642
USA
Tel: 206/887-4477
Fax: 206/887-3721
E-mail: microseed@aol.com
WWW: www.microseed.com

Editorial

Let's Standardize Nursery Terminology

Like it or not, words are important and convey information and so I am proposing that we consider making changes in some traditional nursery terms:

Seedlings. Some time ago, Bob Kintigh of Kintigh's Mountain Home Ranch here in Oregon contacted me and suggested that we standardize the codes that we use to describe bareroot seedlings. This was an idea that Mary Duryea and I tried to get started back in 1984 when we published the *Bareroot Nursery Manual: Production of Bareroot Seedlings.* It didn't seem to catch-on, however, so I'm going to propose the idea again.

Bareroot stock—I propose that seedling age classes should be described with pluses instead of dashes because the years are cumulative and the sum gives the total age of the stock. For example: "The 1+0 seedlings were significantly smaller than the 1+1 transplants"

Container stock—The terminology of container seedlings is even more confusing because you will see "containerized", "container-grown" or "plug seedlings" frequently used in the literature. Again, I propose that we standardize and just use the term container seedling because it is simple and definitive **(Figure 22).** We already talk about "container nurseries", and the use of many different terms is confusing. For example, "containerized" is used by ornamental nurseries to describe bareroot seedlings that have been transplanted into containers. The "plug seedling" term also can be misinterpreted because an entire industry has developed around plug technology - container seedlings grown in miniature containers expressly for transplanting. Even if everyone agrees to standardize, this change is not going to be easy because these other terms have been used extensively in the literature - *e.g.* "Proceedings of the Canadian *Containerized* Tree Seedling Symposium". The problem of describing different sizes of container stock is a real "can of worms". The situation will not be simple to resolve because there are so many different types of containers and several naming systems are currently in use which, I am sure, is confusing to our customers. Because most container seedlings are grown in one season or less in the US, , they are generally defined by the type and volume of the growth container. For example, a "Styro 4" refers to a seedling that has been produced in a Styrofoam® block container with cells that are approximately 65 cm^3 (4 in^3) in volume. Other regions use different terminology. In British Columbia, some container stock types are grown for more than 1 year and so their names include container type, size, and length of growing period. For example, a PSB313B 1+0 seedling was grown for one year in a Styrofoam® block container that has cells that are 3 cm (1.2 in.) wide and 13 cm (5.1 in.) deep.

Figure 22. An "RL10-49" container seedling

The ideal nomenclature would include the three things that are biologically and operationally important: 1) the composition of the container, 2) the volume of the cavity, and 3) the spacing between cavities. So, a Ray Leach (RL) container that has cells of 10 in^3 and are spaced at 49 cells/ft^2, would be called an "RL 10-49" **(Figure 22).** Simple, yet descriptive.

Planting vs. Outplanting. I propose that we use the term "outplanted" when referring to seedlings on the reforestation site to avoid confusion with planting in the nursery. We *plant* seed and we *transplant* seedlings in the nursery but we ship the seedlings for *outplanting.*

Metric vs. English Units. Although the rest of the world is already using metric, it seems like the politicians here in the US will never allow us to change. So, I propose that whenever we use units in writing, we supply both. In FNN, I'm trying to use metric units with English units in parenthesis. When giving ranges of units, please use "to" because dashes can be misinterpreted as negatives. For example:

The height of the seedlings ranged from 10 to 18 cm (4 to 7 in.)

In conclusion, I'm not naive enough to think that all of you are going to agree with me but I still think that we owe it to our customers to standardize the terms that we use in nurseries and reforestation. Think it over and let me know your opinion!

Sources:

Landis, T.D.; Tinus. R.W.; McDonald, S.E.; Barnett, J.P. 1995. Nursery Planning, Development, and Management. Vol. 1, The Container Tree Nursery Manual. Agric. Handbk. 674. Washington, DC: USDA Forest Service.] 88 p.

Scagel, R.; Bowden, R.; Madill, M. Kooistra, C. 1993. Provincial seedling stock type selection and ordering guidelines. Victoria, BC: British Columbia Ministry of Forests. Silviculture Branch. 75p.

Horticultural Humor

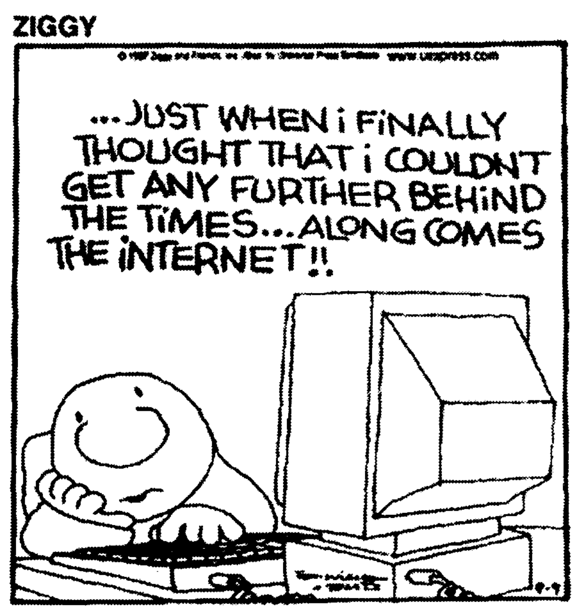
Metric Humor

It doesn't look like the US will ever adopt the Metric System, so we might as well make fun of it:

10^{12} Microphones = 1 Megaphone
10^{6} bicycles = 2 megacycles
2,000 mockingbirds = two kilomockingbirds
10 cards = 1 decacards
½ lavatory = 1 demijohn
10^{-6} fish = 1 microfiche
453.6 graham crackers = 1 pound cake
10^{12} pins = 1 terrapin
10^{21} piccolos = 1 gigolo
10 rations = 1 decoration
100 rations = 1 C-ration
10 millipedes = 1 centipede
10 monologs = 5 dialogues
5 dialogues = 1 decalogue
2 monograms = 1 diagram
8 nickels = 2 paradigms
2 snake eyes = 1 paradise
2 wharfs = 1 paradox

Computer Humor

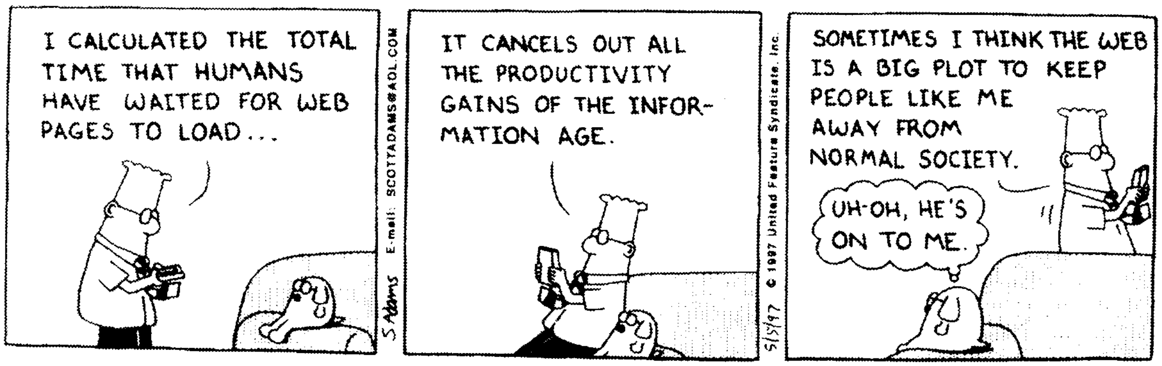
In spite of what some of us would like, computers seem to be taking over the workplace so we might as well have a few laughs at their expense:



CLOSE TO HOME

"Look at that, everyone! Annette was able to walk right past the computer *even though she knows* there are 27 e-mails waiting for her!"

DILBERT



NON SEQUITUR

New Nursery Literature

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

Special Orders

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

SO. Okholm, D.1997. **Pacific Northwest Nursery Directory and Report.** Publication No. R6-CP-TP-97. Portland, OR: USDA Forest Service, State and Private Forestry. 62 p.

This softbound report consists of a directory of forest and conservation nurseries in Oregon and Washington and surrounding states, as well as tabular and graphical seedling production information for the current year. Although it doesn't list which plant species that a nursery grows, it does list stock groupings such as commercial conifers, wildlife habitat, and windbreak species.

COST: Free **ORDER FROM:** Write "A" on the Literature Order Form

SO. Landis, T.D.; Thompson, J.R., tech. coords. **National Proceedings, Forest and Conservation Nursery Associations -1997.** Gen. Tech. Rep. PNW-GTR-419. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 163 p.

This softbound publication is the combined proceedings from the two regional forest and conservation nursery meetings in 1997. The Northeastern Forest Nursery Association conference was held in Bemidji, MN on August 11-14, and the Western Forest and Conservation Nursery Association meeting was held in Boise, ID on August 19-21. The 27 papers cover subjects ranging from seed collection and processing; through bareroot and container cultural practices; to harvesting, storage and outplanting.

COST: Free **ORDER FROM:** Write "B" on the Literature Order Form

SO. Longman, K.A. 1995. **Preparing to Plant Tropical Trees.** London: Commonwealth Secretariat Publications. 238 p.

This spiralbound book is the second in Tropical Trees: Propagation and Planting Manuals series which will eventually contain five volumes. The chapters in this book include: Introduction, General Principles of Tree Survival, Types of Planting site, and Which Tree species, For What Purpose? Deciding on the Growing System, and Preparing the Ground. The target audience is small, private landowners in tropical climates and text is written in an easy-to-understand style that addresses common questions.

COST: £30.00 **ORDER FROM:** **Commonwealth Secretariat Publications**
S&H= 15% of order
c/o Vale Packaging Ltd
420 Vale Road
Tonbridge, Kent
TN91TD
Great Britain
Tel: (44)1732359387
Fax: (44)1732770620

SO. Haase, D.L.; Rose, R. 1997. **Symposium Proceedings: Forest Seedling Nutrition from the Nursery to the Field.** Oct. 28-29, 197, Corvallis, OR. Corvallis, OR: Oregon State University, College of Forestry. 161 p.

The spiral-bound publication contains 18 papers on principals of seedling nutrition, fertilizer technology, monitoring seedling nutrition, and current research and practices in both nursery and field applications. A limited number of copies are available.

COST: $20.00

ORDER FROM: **Diane Haase, Nursery Technology Cooperative**
OSU Department of Forest Science,
FSL-020 Corvallis, OR97331-7501
USA
TEL: 5411737-6576
FAX: 541 /737-5814
E-MAIL: haased@fsl.orst.edu
WWW: www.fsl.orst.edu/coops/ntc/ntc.htm

SO. **Proceedings: 1997 Annual International Research Conference on Methyl Bromide Alternatives and Emissions Reductions.** Nov. 3-5, 1997. San Diego, CA. Fresno, CA: Methyl Bromide Alternative Outreach.

This softbound publication contains over 120 articles from presentations and posters by scientists from all over the world. Although those dealing with forest and conservation nurseries are relatively few, growers can learn much from the work that is being done with other crops. Single copies are available from the address below, and a mailing charge may be required for foreign shipments.

COST: Free

ORDER FROM: **Methyl Bromide Alternatives Outreach**
144 West Peace River Drive
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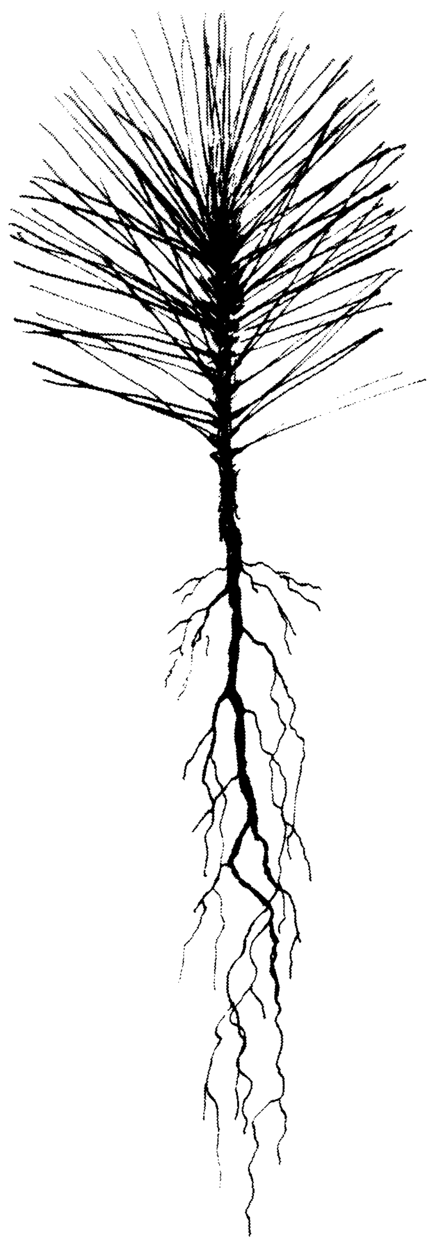

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