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

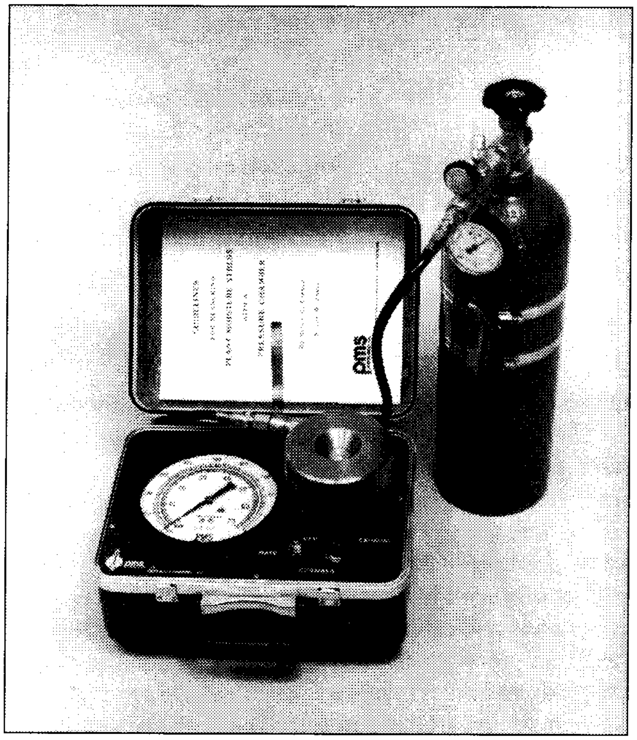
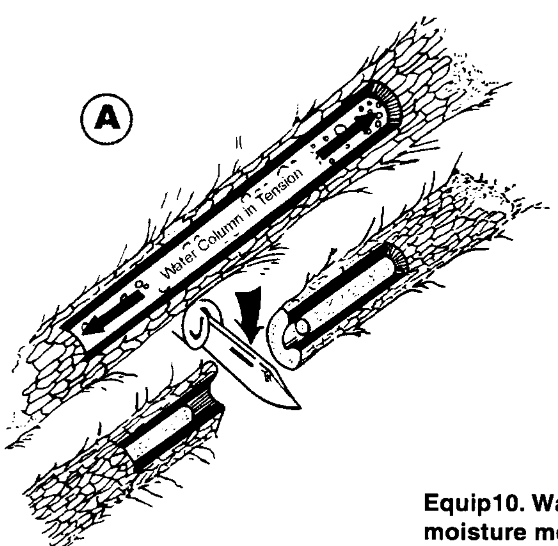


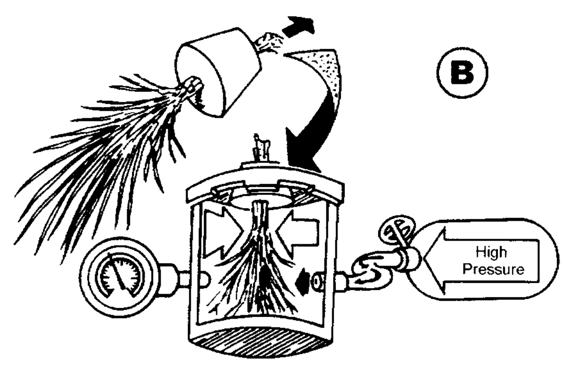
Figure 9. Plant moisture meters allow an instantaneous measure of seedling moisture stress (Courtesy of PMS Instrument Company)

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.

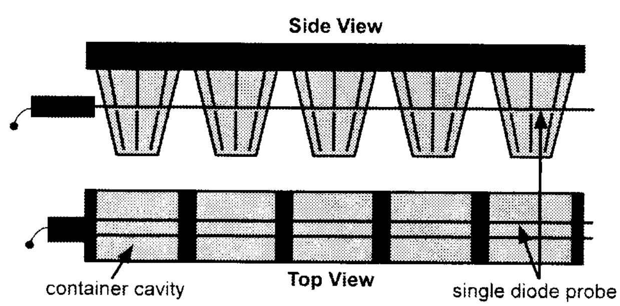
The PMS Instrument Company offers several models of plant moisture meters from portable models that can be used out in seedbeds or greenhouses to laboratory models with digital readout and data storage . For the latest information, you can contact them at:

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

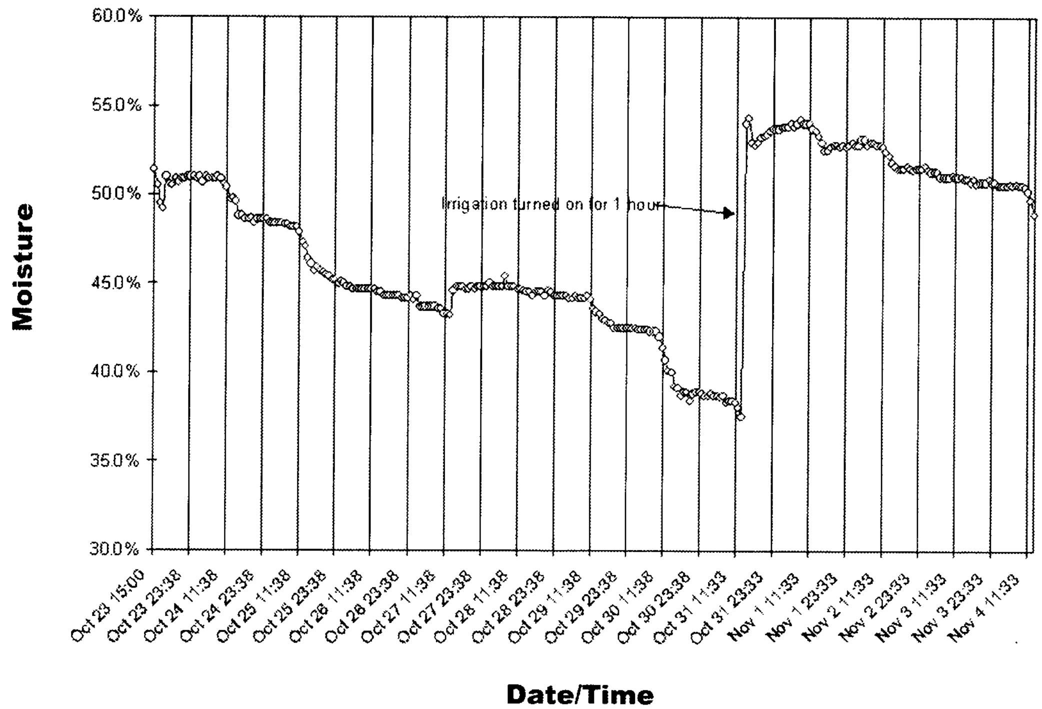
Moisture Meter for Soils and Growing Media. Measuring water in soils or growing media is always a challenge because there just never has been a quick and easy way to do it. Equipment such as tensiometers and gypsum blocks have been around for decades but both have limitations in nursery applications. 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:

<u>Dybvig Seed Cleaner:</u>

Melvin R. Dybvig
PO Box 372
Brightwood, OR
97011,
USA
TEL: 503/622-5242

<u>Model 193 Seed Cleaner</u>

Bouldin & Lawson, Inc.
PO Box 7177
McMinnville, TN
37110-7177,
USA
TEL: 800/443-6398
or 931/668-4090
FAX: 931/668-3209

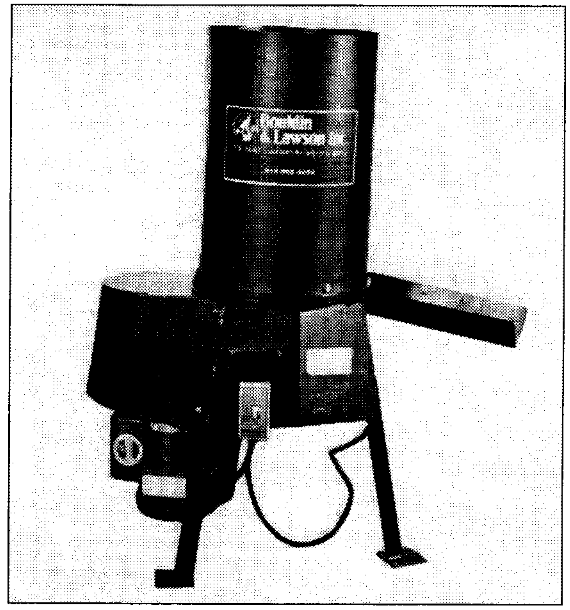


Figure 12. Macerators, like this Model #193 Seed Cleaner, are used to depulp fleshy fruits and berries (Courtesy of Boulding and Lawson, Inc)

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

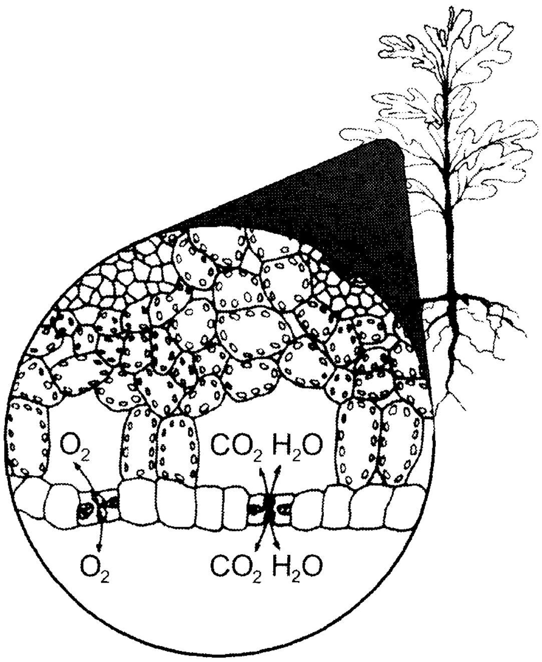


Figure 13. Anti-transpirants must reduce water loss through stomata while not completely restricting the exchange of carbon dioxide for photosynthesis and oxygen which is needed for respiration (Modified from Hartmann, Flocker, & Kofranek, 1981)

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
E-mail: gcwmiller@aol.com

Wilt-Pruf:
Brad Nichols
Wilt-Pruf Products
PO Box 469
Essex, CT 06426-0469
USA
Tel: 800/972-0726;
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.