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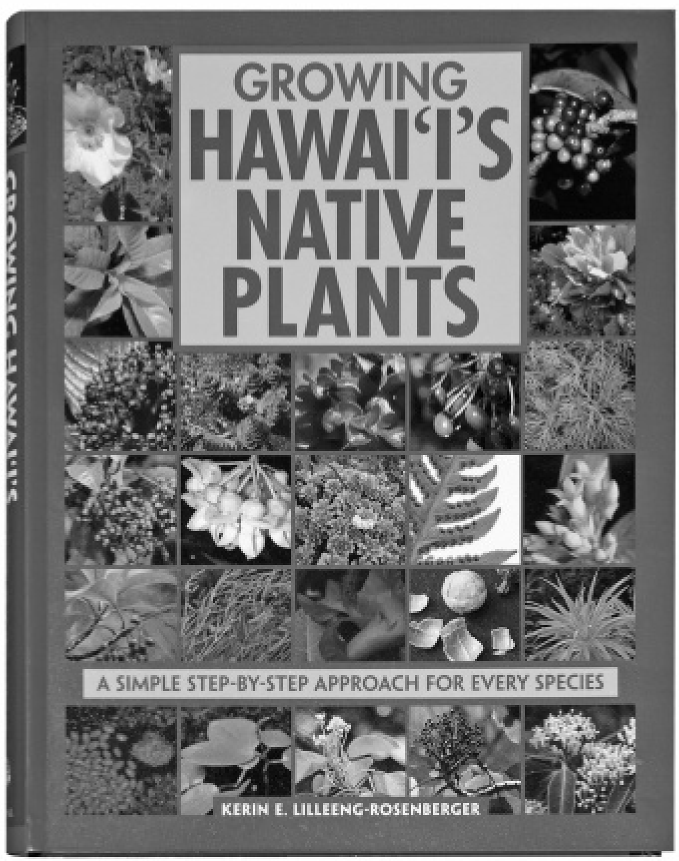
Forest Nursery Notes

Winter 2006



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Nursery Meetings

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

An intensive workshop, **Vegetative propagation of native Hawaiian and fruit trees for domestication and commercial purposes,** will be held in Kealakekua, Kona, Hawai'i on **May 20, 2006.** For registration and workshop information please contact:

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The **Western Forest and Conservation Nursery Association (WFCNA)** will be meeting in Eugene, OR on **June 19 to 21, 2006**. For more information please contact:

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The Southern Nursery Conference will be in Tyler, Texas, **July 11 to 13, 2006**. Field trips to the Texas Forest Service Indian Mound Nursery and International Paper Nursery. For more information please contact:

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The exhibition, **Nursery Machinery 2006,** is taking place **August 17 and 18, 2006** at the Horticulture Centre in Ellerhoop, Kreis Pinneberg, Germany. Exhibition and registration forms are available at:

E-Mail: info@baumschultechnik.de
TEL: 0049.0.4101.205922
FAX: 0049.0.4101.20593
WEB: www.baumschultechnik.de
www.nurserymachinery.com

Container Tree Nursery Manuals (CTNM) Now Available as E-Books

If you are as technologically challenged as I am, your first question is "What is an E-Book?" An E-Book, or electronic book, is a digital book that you can read on a computer screen. Some E-Books can also be read on portable electronic devices such as a Palm or handheld computer, but this requires special software.

The CTNM series has been very popular but unfortunately several volumes are now of print. We have reprinted some volumes, notably Volume Five: *Nursery Pest and Mychorrhizae*, several times but we are already out of hard copies. With the current tight federal budget, it is extremely doubtful that we will be able to locate enough funds to reprint any of the CTNM volumes. So, we recently converted all 6 available volumes to E-Book format (Figure 1).

Figure 1—Volumes One through Six are now available as E-Books.

Before you can read any E-Book, you must have the proper software installed on your computer. You need Adobe Acrobat 7.0 to read the CTNM E-Books and access all the features. The software is included on each CD so you have everything you need.

The E-Book format has a number of advantages:

1. User-friendly Format—Because E-Books are small and light, they are easy to handle, transport, and store. The CD version of Volume One: *Nursery Planning, Development, and Management* weighs only 3 ounces compared to the hard copy which weighs well over one pound.

2. Inexpensive—Many E-Books can be downloaded for free on-line, and others can be purchased. We were able to have the CTNM series formatted for free so the only

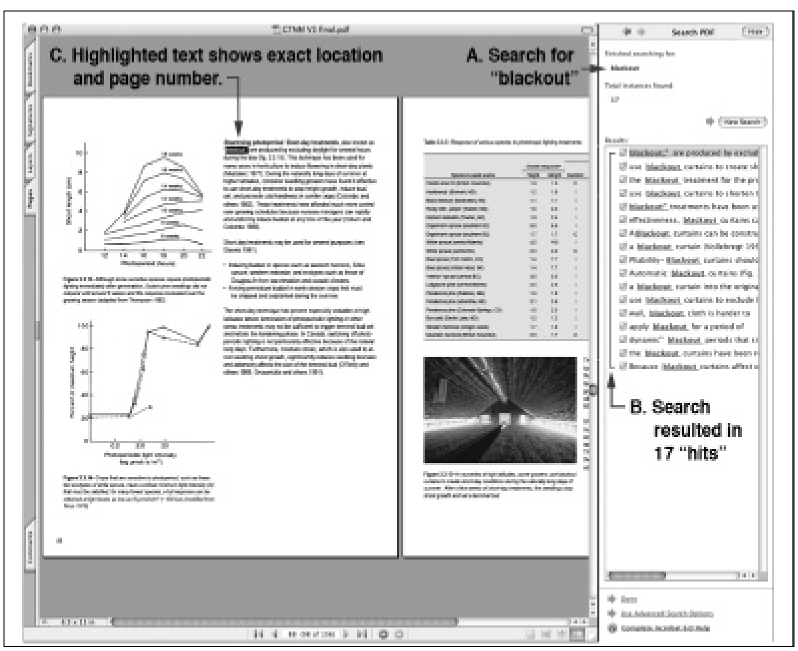

Figure 2 - One of the most attractive featuers of E-Books is that you can search for terms.

expense was burning the CDs, purchasing the jewel cases, and the graphics and printing of the cover material. So, you can purchase any of the six available CTNM volumes for $15 which includes shipping and handling expenses. Compare that to the prices of the original hard copies for $25.

3. Searching—One of the most useful features of the CTNM E-Books is that you can search for any keyword quickly and accurately. For example, let's search for "blackout" in Volume Three: *Atmospheric Environment* (Figure 2, A). Go to the "Edit" heading and scroll down to "Search", which opens a panel on the right. Type in "blackout" and, on my computer, the search took less than 15 seconds and resulted in 17 "hits" (Figure 2, B). Each hit shows the exact location of the text and page number in the book where the word "blackout" occurs (Figure 2, C). This sure beats thumbing through a Table of Contents or Index of a hard copy book.

If you copy all of the CTNM E-Book files to your hard drive, then you have the ability to search the entire series at once. Of course, this takes a little longer but is a very useful feature.

4. Copying Text and Graphics—This is the feature that I find the most useful, and I think you will too. Once you have found the section of interest, you can either just read it or copy any desired sections to the clipboard on your computer. Go to the select tool in the top toolbar, and highlight the text of interest (Figure 3). Next, right-click your mouse to copy the text section onto the clipboard of your computer. Then it can be pasted into any word-processing software.

Use the same procedure to copy any of the illustrations or photographs, which you can copy to any word-processing or graphic software. The resolution of any graphic is limited to 72 dpi but this is good enough for MS Powerpoint or other screen resolution applications.

Note: All of the information in the CTNM series is copyright-free so all we ask is that you acknowledge the source whenever you use copied text or graphics.

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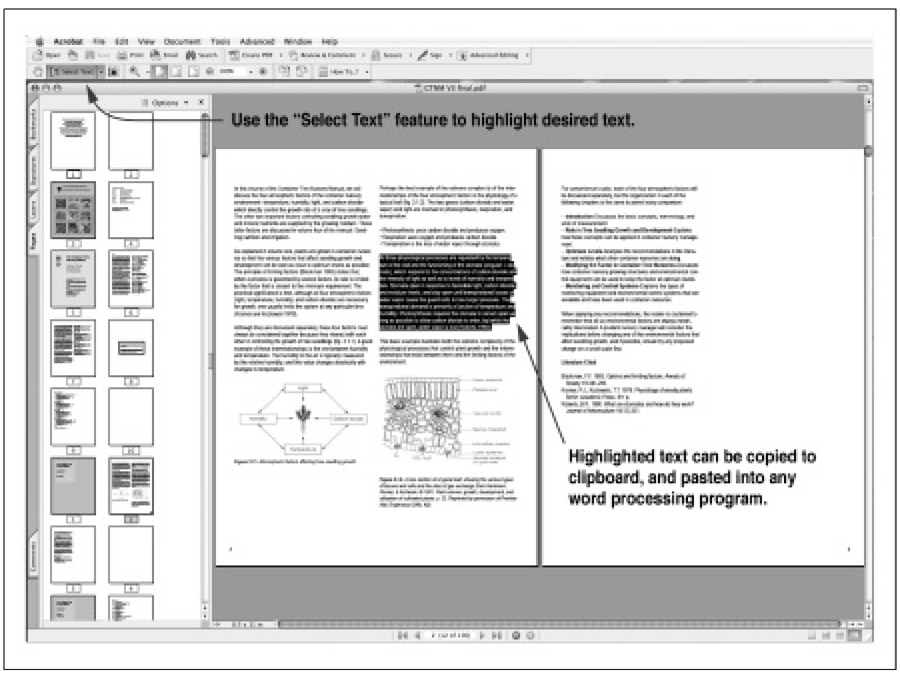

Figure 3 - You can also copy text to the computer clipboard and paste it inot word-processing programs. Photos and illustrations can also be copied.

Seedling Quality Tests: Root ElectrolyteLeakage

by Gary A. Ritchie and Thomas D. Landis

Introduction

Roots are among the most fragile parts of plants and, hence, are sensitive to many environmental and operational stresses. These include high and low temperatures (Lindström and Mattson 1989, Stattin and others 2000), desiccation (McKay and Milner 2000), rough handling (McKay and White 1997), improper storage (McKay and Mason 1991, McKay 1992, Harper and O'Reilly 2000) and even water logging and disease. It is sometimes possible to detect root damage using the time-honored thumbnail scraping and browning examination, but often damage is invisible or impossible to quantify. A more rigorous test and useful test is called root electrolyte leakage (REL). It measures the health and function of root cell membranes, so REL can be used as an indication of root injury and therefore seedling quality.

The REL technique can be traced back to the early work of Wilner (1955, 1960), but Helen McKay and her co-workers in the United Kingdom were among the first to use REL to evaluate bareroot nursery stock. REL has also been used in Canada (Folk 1999), and is currently one of a battery of seedling quality tests developed by the Ontario Ministry of Natural Resources (Colombo and others 2001). In the United States, however, electrolyte leakage has only been used to test the cold hardiness of foliage but, to our knowledge, REL is not being used.

REL has many desirable features: the procedure is relatively simple, uses readily available equipment, and produces results quickly. However, interpretation of these results can be problematic due to species, seedlot and seasonal interactions.

Theory

Water in roots is contained within two different systems – the symplast and the apoplast (see Ritchie and Landis 2003). The symplast includes all tissues that are enclosed within cell membranes (that is, the cell contents), while the apoplast includes everything else (that is, xylem elements, cell walls and voids). Apoplastic water is nearly pure, while symplast water contains a variety of ions. The semi-permeable membranes surrounding the symplast allow water to pass freely, but not the ions. As cell membranes become degraded through damage, disease, or age, they loose the ability to contain ions. So, if you were to measure the quantity of ions that leaked across damaged root membranes, this would provide an estimate of the relative viability of the root system (Palta *and others* 1977). If the damaged tissues are placed in distilled water, the amount of membrane leakage can be easily and quickly measured with a standard nursery device—an electrical conductivity (EC) meter. This is the basis of the REL test.

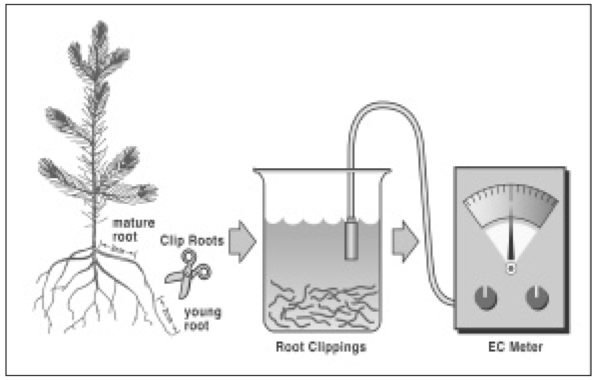

Figure 1. In a root electrolyte leakage (REL) test, root viability is rated by measuring the relative permeability of root cell membranes.

Measurement Procedure

The technique that is most often used (McKay 1992, 1998) has changed little from the initial protocol described by Wilner (1955). The steps are as follows (Figure 1):

1. Roots are first washed in water to remove soil, then in deionized water to remove any surface ions that may be present.
2. A central mass of roots is removed from the plant. With tree seedlings, this is often a band about 1 in. (2.5 cm) wide running across the mid-section of the root system.
3. Roots with diameter greater than 0.08 in. (2 mm) are removed from the sample leaving only "fine" roots.
4. Fine roots are placed into a 1.7 in^3 (28 ml) glass vessel containing 1 in^3 (16 ml) of deionized water.
5. The vessel is then capped, shaken, and left at room temperature for about 24 hours.
6. The conductivity of the solution ("C_{live}") is measured with a temperature-compensated electrical conductivity meter.
7. The root samples are removed and killed by autoclaving at 100 °C (212 °F) for 10 minutes.
8. The conductivity of the solution surrounding the dead root samples ("C_{dead}") is measured.
9. The REL is calculated as the ratio of the EC of the live roots divided by the EC of the dead roots: REL=(C_{live}/C_{dead}) x 100.

The Biological Significance of REL

McKay (1998) offers the following explanation for why the REL test has application as a seedling quality test. After outplanting, the main cause of seedling mortality is transplant shock induced by water stress. A newly planted seedling must be able to extract water from the surrounding soil using its existing roots, and REL measures the viability of the root system. A low REL reading indicates high root viability, allowing water uptake to mitigate transplant shock.

Applications of REL in Nurseries

The REL test is most often used to assess effects of cold damage to roots, poor storage conditions, root exposure causing desiccation, or rough handling of tree seedlings. Nearly all the published work has been with commercial conifer seedlings, primarily Douglas-fir *(Pseudotsuga menziesii*), spruces, pines, and larch. Use of REL to detect freezing damage to roots is applied in one of two contexts: evaluation of cold hardiness test results, and detection of root injury following unseasonably cold weather or sun exposure.

Cold hardiness testing. Classic cold hardiness testing involves two steps: (1) exposing test seedlings to a predetermined sub-freezing temperature (or range of temperatures), and (2) after an incubation period, determining the amount of damage sustained by the frozen tissues (Ritchie 1991, Burr and others 2001). REL is a quick and quantitative way of measuring root damage in Step 2. For example, root samples from bareroot Norway spruce (*Picea abies*) seedlings were exposed to either -5 °C (23 °F) or -10 °C (14 °F) bi-weekly from September 22 through December 15, 1997 in Sweden (Stattin and others 2000). As winter progressed, the difference in REL cold - treated and untreated seedlings became smaller, indicating that the seedlings were becoming increasingly more cold hardy (Figure 2).

Detecting cold or heat injury. Because they are exposed, the roots of container seedlings are easily injured by extreme temperatures. This is especially true when container seedlings are over-wintered outdoors under snow, as is done in eastern Canada and Scandinavia (Lindstrom and Mattson 1989). If snow fails to accumulate, or there is a sudden warm period, container crops are exposed and their roots can be severely damaged. The REL test is ideally suited for making rapid assessment of potentially damaged nursery stock (for example, Coursolle and others 2000).

Determining lifting windows. REL has been used as a direct indicator of the best time for harvesting Sitka spruce (*Picea sitchensis*) and Douglas-fir in the United Kingdom (McKay and Mason 1991).

Monitoring quality of stored seedlings. REL can also be used to monitor seedling quality during overwinter storage (McKay 1992, 1998, McKay and Morgan 2001). In one test (McKay 1998), spruce and larch seedlings were lifted throughout winter, beginning October 1, and

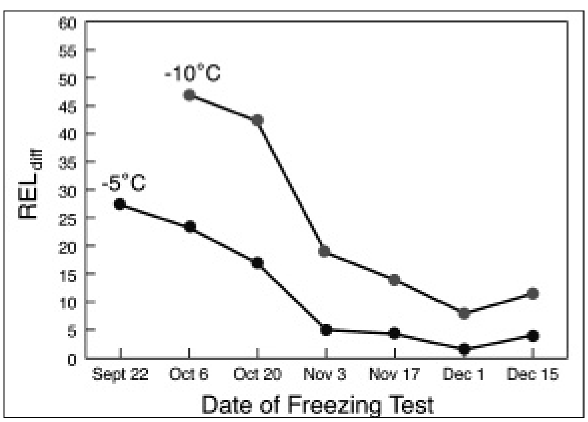

Figure 2. Changes in root electrolyte leakage (REL$_{diff}$) of outdoor grown Norway spruce seedlings measured biweekly from September 22 through December 15. REL$_{diff}$ is the increased electrolyte leakage from roots following exposure to -5 °C or -10°C compared with leakage from unfrozen seedlings (Modified from Stattin and others 2000).

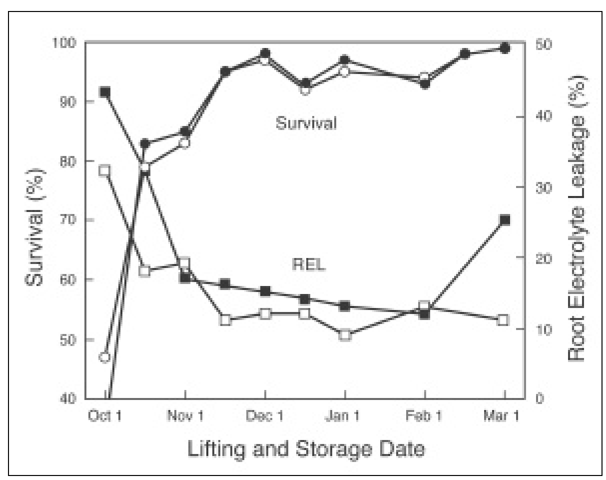

Figure 3 - Mean survival after two growing seasons and root electrolyte leakage (REL) measured after cold storage of Sitka spruce (dark symbols) and Japanese larch (open symbols) planted in April 1990 after storage at +1 °C on different dates in 1989-1990 (modified from McKay 1998).

then placed in storage at +1 °C (33 °F). All seedlings were removed from storage in April, tested for REL, and then outplanted. With both species, REL decreased and survival increased as lifting was delayed (Figure 3).
In another experiment, Douglas-fir seedlings were lifted in October, November, December, and January in Ireland (Harper and O'Reilly 2000). They were "warm stored" at 15 °C (59 °F) for 7 and 21 days, and then tested for REL. REL readings taken at the time of lifting decreased with later harvest dates indicating that the seedlings were becoming more hardy. For each lift date, however, the readings increased sharply with storage duration suggesting that warm storage contributed to fine root degradation (Figure 4).

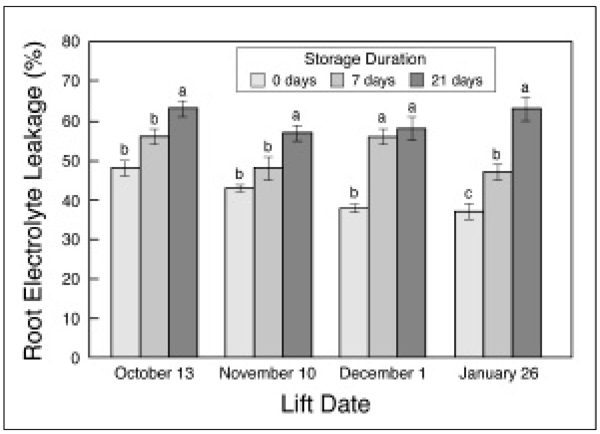

Figure 4 - Effects of zero, one and three weeks warm storage duration on root electrolyte leakage in Douglas-fir seedlings. Within the same lift date, bars with different letters are statistically significant. (Modified from Harper and O'Reilly 2000).

Desiccation and rough handling effects. REL has also been used to evaluate the effect of root desiccation in several studies. Bareroot Sitka spruce and Douglas-fir seedlings were held in controlled environment chambers with their roots exposed to drying conditions for up to three hours (McKay and White 1997). They were then measured for REL and outplanted on several sites in Britain. The REL readings increased with the intensity of the desiccation treatment indicating root injury. This was confirmed when the desiccation treatments had poor outplanting performance on sites with low spring rainfall.

Rough handling in combination with root desiccation was assessed in Douglas-fir, Sitka spruce, Japanese larch and Scots pine (*Pinus sylvestris*) using REL (McKay and Milner 2000). Rough handling consisted of dropping bags of seedlings from a height of 3 meters (9.8 ft). Desiccation was achieved by exposing roots to warm dry air for five hours. Although effects varied with lift date and species, REL was significantly higher in stressed seedlings than in un-stressed seedlings across species and treatments.

REL as a Predictor of Outplanting Performance

The ultimate objective of any seedling quality test is to predict how well nursery stock will survive and grow after outplanting, and many studies have used REL for this purpose. Unfortunately, results have been mixed. With Sitka spruce and Japanese larch seedlings, for example, REL was closely related to both survival and height growth (Figure 5). In Sitka spruce and Douglas-fir seedlings, REL was correlated with survival on some sites but not others (McKay and White 1997). REL predicted establishment of Japanese larch (*Larix leptolepis*) seedlings to some extent, but Root Growth Potential (RGP) was a better predictor (McKay and Morgan 2001). Similar results were found with black pine

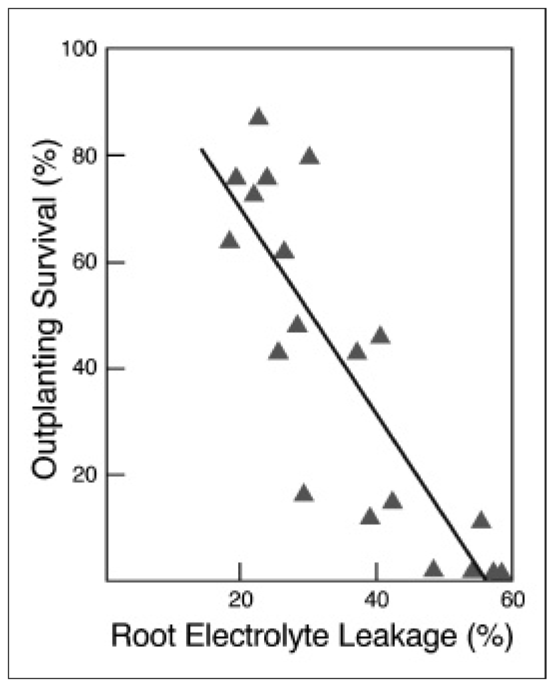

Figure 5—Root electrolyte leakage has been closely correlated with outplanting performance (modified from McKay and Wason 1991).

(*Pinus nigra)* (Chiatante and others 2002), while Harper and O'Reilly (2000) reported that REL was a poor predictor of survival potential in warm-stored Douglas-fir seedlings.

Limitations of REL

So, why does REL predict survival in some cases but not others? As with many things “the devil is in the details.”

Genetics. REL has been shown to vary with species and even seed sources within species. For example, jack pine and black spruce, following exposure to a range of damaging root temperatures, had REL values in the range of 27% to 31%, while white spruce exposed to the same temperatures had REL between 36% and 38% (Coursolle and others 2000). Sitka spruce seedlings from Alaska, the Queen Charlotte Islands (QCI) and Oregon provenances, were evaluated for their ability to withstand root drying and rough handling (McKay and Milner 2000). Oregon and QCI seedlings exposed to root drying had lower REL values than Alaska seedlings, while Alaska and QCI seedlings, when exposed to rough handling had lower values than Oregon seedlings. Douglas-fir had higher REL values than Sitka spruce, Scots pine, and Japanese larch, regardless of the type of stress encountered. Two coastal seedlots of Douglas-fir (British Columbia) gave different relationships between REL and survival (Folk and others 1999).

Dormancy status. McKay and Milner (2000) found that the resistance to stresses mentioned above varied seasonally and was correlated with the intensity of bud dormancy, as measured with a Dormancy Release Index (for definition, see Ritchie and Landis 2004). A similar result was reported by Folk and others (1999) for Douglas-fir seedlots. They argued that REL must first be calibrated to bud dormancy status before it can be effectively used to assess root damage in Douglas-fir.

Seedling age. REL gave good correlations with survival in two-year-old black pine seedlings, but the correlations were weak for one-year-old seedlings (Chiatante and others 2002). The authors speculate that the efficiency of REL as a seedling assessment tool could be closely related to the developmental state of the root system.

Summary and Conclusions

Electrolyte leakage from fine roots is a robust and easily measured parameter that has a rapid turn-around time and can be used to evaluate the viability of seedling root systems.

REL measures the ability of membranes within the root system to contain ions. Damaged membranes tend to leak ions so, if ion leakage is quantified, it can provide an indicator of root viability.

REL has been used successfully to evaluate the effects of cold damage, rough handling, desiccation, cold and warm storage, and other stresses on root viability and seedling vigor.

REL is sometimes closely correlated with seedling survival, but in other cases these correlations are weak. This is because factors other than root damage can affect REL. Some of these factors are species, seedlot, seedling age, season, and bud dormancy intensity. When REL is calibrated for these effects it can offer a simple, easy test of seedling root system viability.

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Protective Root Dips - Are They Effective?
By Thomas D. Landis

The concept of dipping plant roots has been around for many years because it is intuitively attractive. Roots of nursery plants dry as they are exposed to the atmosphere during harvesting and handling and so it would make sense to rehydrate them or apply a coating to protect them (Chavasse 1981). Southern nurseries have been dipping the roots of their bareroot stock in a clay slurry for decades (May 1985). In the western states, the use of root dips is less common but some forestry organizations sell protective root dips as part of their tree distribution programs (for example, Kansas State Forest Service 2005). Root dipping bareroot stock in a peat moss slurry is recommended in some reforestation handbooks (Mitchell and others 1990).

Water - Many bareroot nurseries wet their stock immediately after lifting and therefore the first root dips were undoubtedly water. In the late 1960's and early 1970's, a series of experiments with various durations of root exposure after harvesting and water dipping of roots was conducted on conifer seedlings at Midhurst Nursery in Ontario, Canada. The results varied considerably by species (Mullin in Table 1). For white spruce (*Picea glauca*), dipping roots in water improved survival and had a positive effect on shoot growth after five years. With red pine (*Pinus resinosa*) and white pine (*P. strobus*), however, the dipping treatment showed no benefit except when the seedlings were exposed for considerable periods (Mullin 1978).

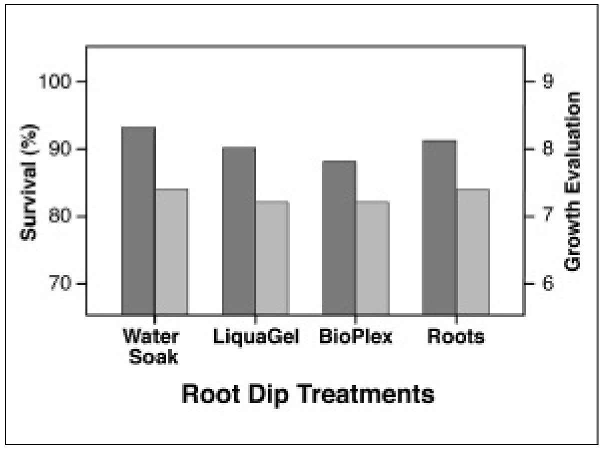

Figure 1 - Compared to a water dip, none of three commercial root dips improved survival or growth of four conifer seedlings two years after outplanting (Bates and others 2004).

Commercial root dips - In the intervening years, many different commercial root dips have become available and most are superabsorbent hydrogels. These crosslinked polymers can absorb and retain many times their own weight in water, and root dips for bareroot stock is just one of the agricultural applications. Erazo (1987) did a good review of the products available at that time and I haven't seen anything newer. I did a check of the FNN database and found quite a few articles that tested various root dip products (Table 1).

While reviewing the published literature for this issue, one recent experiment caught my eye that tested 3

Table 1-Comparison of recent research trials on protective root dips prior to outplanting of bareroot seedlings

Source	Root Dips Tested	Control	Results
Bates and others (2004)	BioPlex®, Roots® , Liquagel®	Water	Negative
Alm and Stanton (1993)	Terra-Sorb®, Terra-Verde®	Untreated	Variable
Hicks (1992)	Supersorb-F®	Untreated	Variable
Echols and others (1990)	Terra-Sorb®	Untreated	Variable
Sparkman (1998)	Ag-Sorbent®	Untreated	Positive
Tung and others (1986)	Terra-Sorb®	Untreated	Negative
Magnussen (1986)	Waterlock®	Untreated	Variable
Dunsworth (1985)	Symbex®	Water	Negative
Mullin (1978)	Water	Untreated	Variable

products (see #150 in the New Nursery Literature section: Bates and others 2004). The thing that I liked about this trial is that they tested the products against a water control. In most previous experiments, commercial root dips were compared to no treatment at all. All of these products are applied in a water slurry and so it just makes sense to me to use a water dip as a control. The authors applied the commercial root dips and the water dip controls to four conifer species in a Christmas tree plantation: Fraser fir (*Abies fraseri*), Colorado spruce (*Picea pungens*), Douglas-fir (*Pseudotsuga menziesii*) and white fir (*Abies concolor*). When evaluated for survival, none of the products showed a significant improvement over the water dip control (Figure 1). The commercial root dips gave no appreciable benefit for growth after 2 years, when compared on a 10-point scale: 1 = poorest and 10 = best.

The recently published literature showed a similar trend (Table 1). The one article reporting positive results was anecdotal and presented no real data (Sparkman 1988). The majority of the articles reported variable results, with the dips helping some species but showing no effect with others. Several suggested that the dips would be most beneficial when harvesting during dry, windy weather or when roots were exposed for extended periods. Interestingly enough, there apparently have been no studies with root dips on container stock.

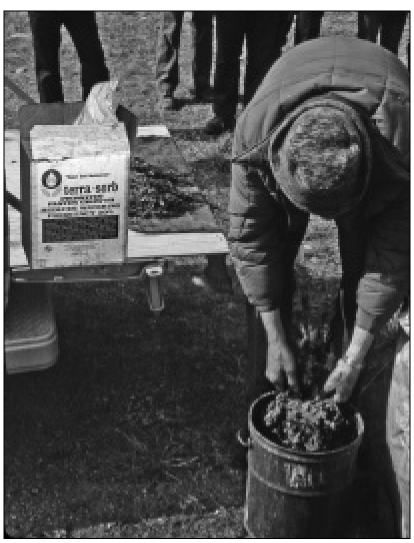

Figure 2 - Al Dahlgreen, reforestation specialist for the USDA-FS, taught that dipping seedling roots in a slurry of wet vermiculite, or products such as Terra-Sorb®, was a critical part of seedling care and handling before outplanting.

That being said, dipping seedling roots after harvesting or before outplanting is still being practiced and many foresters and other seedling users believe that this practice has merit. Al Dahlgreen was the reforestation specialist for the USDA Forest Service in the Intermountain Region for many years as was the person responsible for making significant improvements in their tree planting program. Al taught reforestation workshops every year and convinced many foresters that acclimatization was important for seedling survival and growth on their harsh outplanting sites. Root dipping in a slurry of vermiculite or commercial root dips such as Terra-Sorb® was a critical part of his acclimatization process (Figure 2).

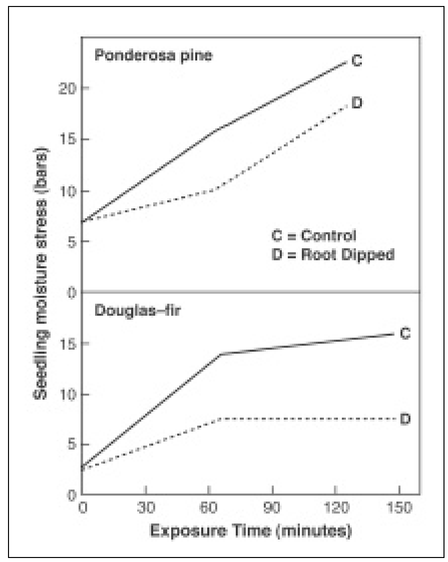

Figure 3 - Bareroot seedlings with their root dipped in a slurry of water and peat moss were more resistant to desiccation when exposed in the planting bag (modified from Lopushinsky 1986)

In the early 1980s, Bill Lopushinky of the USDA Forest Service Pacific Northwest Research Station attempted to verify root dipping and other aspects of acclimatization in a series of controlled experiments on outplanting sites in Washington and Oregon. The root dip treatments consisted of a control and dipping in a peat moss and water slurry for a few seconds on the outplanting site. Subsequent measurements of outplanting performance showed a slightly significant increase in survival for the root dipped versus the control seedlings but no apparent differences in height growth. In a related test of plant moisture stress on untreated and root dipped seedlings in planting bags on a warm, sunny day showed a very favorable effect of the root dipping (Figure 3).

So, in summary, root dipping seedlings in water or in water slurries of peat moss, vermiculite or any of the commercial root dip products is not detrimental and, in several cases, has been shown to benefit seedling survival and growth. I'm sure that many field trials of root dipping have been done over the years but that the results were not collected so as to allow statistical analysis. I'm a great fan of such anecdotal observations, however, so I'd appreciate hearing about any of your thoughts or experiences.

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Subirrigation Trials with Native Plants
by Thomas D. Landis, Kas Dumroese, and Rhiannon Chandler

An article in the Summer, 2004 issue of FNN introduced the idea of using subirrigation to improve the growing of broadleaved native plants. The problem is that, under traditional sprinkler irrigation, large leaves create an "umbrella effect" that inhibits equal distribution of water from container to container or cavity to cavity in block containers. We suspect that this variation in moisture content would be reflected in uneven growth and perhaps even seedling mortality in excessively dry containers or cells.

Layout - Last summer, we conducted a subirrigation trial growing 2 native plants [blue spruce (*Picea pungens*) and pale purple coneflower (*Echinacea pallida*)] in a greenhouse at the USDA Forest Service Rocky Mountain Research Station in Moscow, Idaho. We designed an experiment using 3 different Styroblock™ containers receiving either standard overhead boom irrigation or subirrigation. Each Styroblock™ has the same outer dimensions but contains a different number of cavities. The Styro 4 has 160 cavities with a volume of 5.5 in^3 (90 cm^3); the Styro 6 has 112 cavities with a volume of 6.6 in^3 (108 cm^3); the Styro 20 has 45 cavities with a volume of 20.5 in^3 (336 cm^3). We randomly installed 3 separate, plastic Ebb-Flo subirrigation trays (Midwest GroMaster Inc, St Charles, Illinois) on top of greenhouse benches. Each tray was plumbed to a submersible pump in separate reservoir tanks under the bench. The trays were filled with water when a timer triggered the pump (Figure 1A) and, when the pump stopped, the water slowly drained back into the tanks (Figure 1B).

In late May 2005, containers were filled with a 1:1 (v:v) *Sphagnum* peat:vermiculite growing medium that contained 2.8 lb/ft^3 (3.2 kg/m^3) of Apex® 14-14-14 controlled-release fertilizer with a 3 to 4 month release rate. The 2 species x 3 container x 2 irrigation treatments were in a completely randomized design and replicated three times. Once filled with medium, each container was sown with seeds and all containers were irrigated with overhead irrigation to field capacity and weighed. As required, containers were misted with the overhead irrigation system to promote germination. After germination, seedlings were thinned to one plant per cavity and any empty cavities were noted.

Containers in all treatments were irrigated when they had dried to 85% of their wet weight. For the overhead irrigation treatments, each species by container combination was monitored separately and irrigated as needed. For the subirrigation treatments, whenever any container type required irrigation, all of the species x container combinations in that tray were irrigated. All of the treatments were also monitored for leachate volume and electrical conductivity (EC). Following each subirrigation, a subsample from the reservoir tank was removed and tested for EC and soluble nitrogen.

After the plants had grown for 3 months, final survival was measured and 5 seedlings from each species by container by irrigation combination were harvested. Spruce seedling height was measured from the groundline to the tip of the terminal; root collar diameter was measured at groundline. For coneflowers, height was defined as the longest petiole length on the plant. For both species, roots were gently washed to remove medium, and shoots and roots were separated and dried to constant weight at 140 °F (60 °C) and ovendry weight measured.

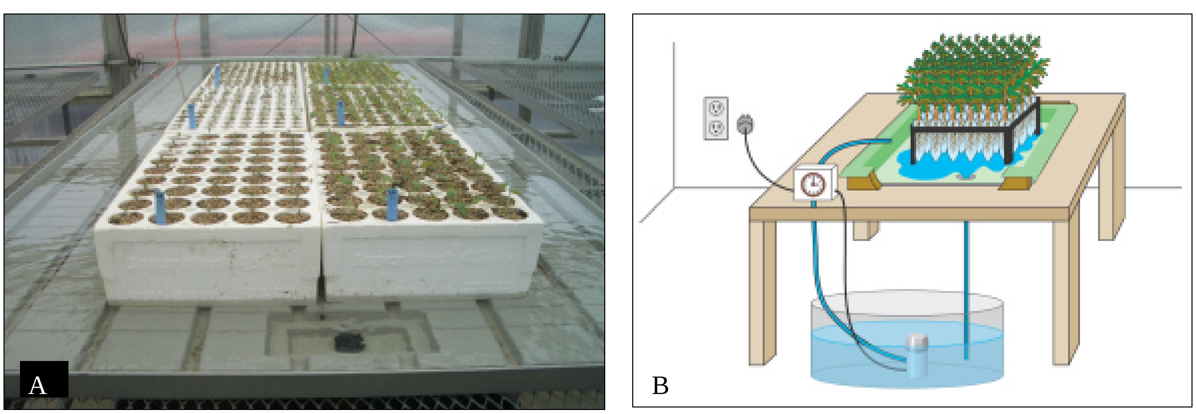

Figure 1 - Two Stryoblock™ containers of 3 different volumes and growing densities fit into each subirrigation tray (A). They filled with water when an irrigation timer started a submersible pump in a water tank below the greenhouse bench. When the irrigation timer stopped, the water slowly drained back into the tank (B).

Preliminary Results - When Tom saw the plants at the end of the growing season, the first thing that impressed him was the fact that the plants in the subirrigation trays were as large as the sprinkler treatment (Figure 2A). This confirmed our first hypothesis - that native plants would grow as well under subirrigation as with traditional sprinkler irrigation. His second observation was the very uniform height and stem diameter of the spruce seedlings in the subirrigation treatment (Figure 2B). This was probably due to the fact that subirrigation supplies an equal amount of water to each cell in the Styroblock™. Perhaps the most striking observation was the irregular stocking in the coneflower plants in the sprinkler treatment. In each of the container types, more coneflower seedlings had died under sprinkler irrigation than under subirrigation (Figure 2C). Although we can't prove the cause of death, it appears that some plants had become severely moisture-stressed due to irregular water distribution between cells.

We are currently analyzing all the data and will have a final report by next summer. Other subirrigation trials are currently underway with oaks and other broadleaved tree seedlings at Purdue University and with broadleaved tropical plants at native plant nurseries in Hawaii. There are still many questions to be answered but it's obvious that subirrigation can be used to grow native plants as well as overhead sprinklers and probably with a lot less water. Because seedling foliage is kept dry, there should be fewer problems with many diseases. Another attractive benefit of subirrigation is that runoff is completely contained which has obvious benefits for eliminating potential fertilizer pollution.

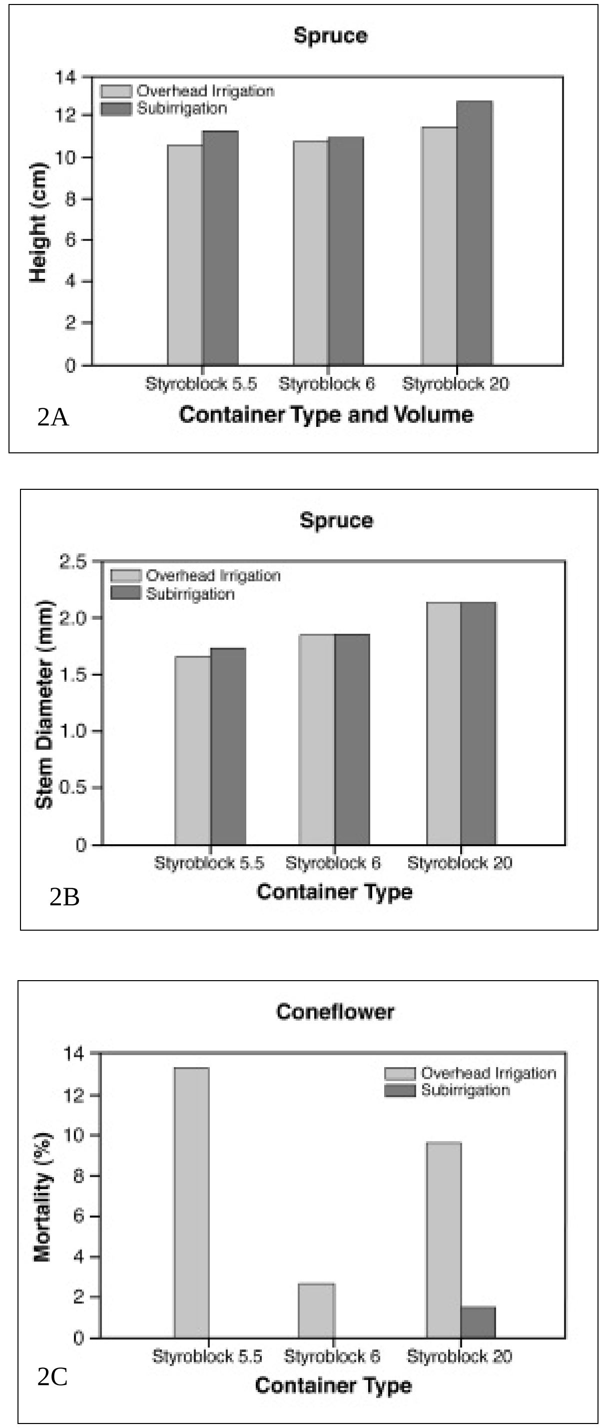

Figure 2—Spruce seedlings were slightly larger with subirrigation compared to sprinkler irrigation in all three container types (A, B). The most impressive result was that many more coneflower seedlings died under sprinkler irrigation, which supports our hypothesis that their large leaves interfered with water distribution between cells.

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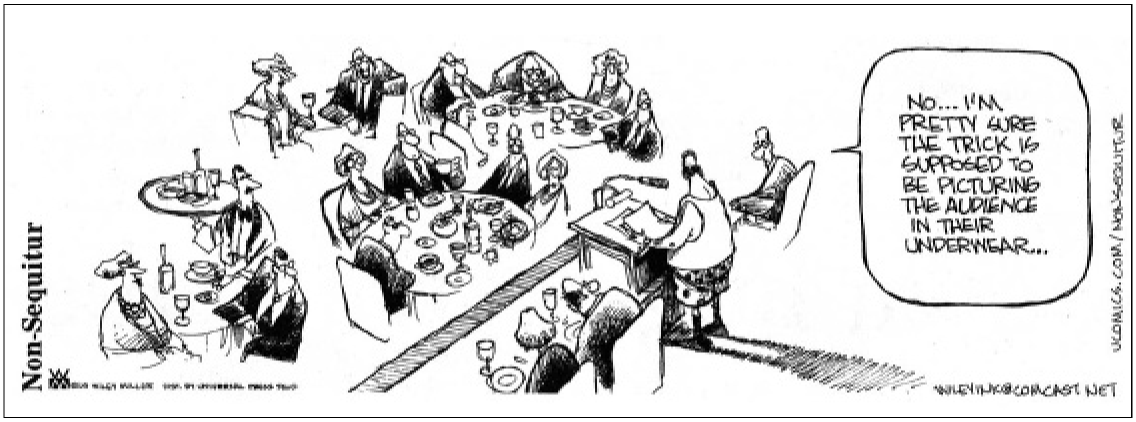
Horticultural Humor



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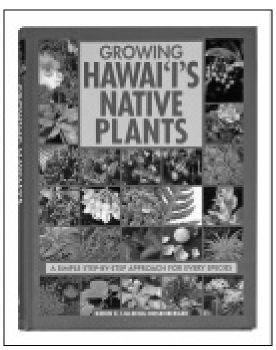
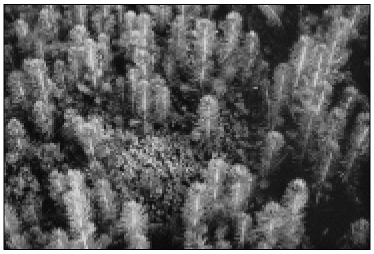


Growing Hawai'i's native plants: a simple step-by-step approach for every species. Lilleeng-Rosenberger, K.E. Mutual Publishing. 416 p.

First of all, this large-format softbound book is just beautiful. It's filled with high-quality color photographs of a wide variety of native Hawaiian plants. In Part One, basic propagation techniques are discussed starting with how to collect, process, and store seeds. The information on seed and vegetative propagation is comprehensive and well-illustrated. Discussions of pest control and outplanting fill-out this section. Part Two present profiles of native Hawaiian plants and how they can be propagated, and is organized by family and genera. This book is a must for anyone interested in the propagation of tropical native plants, and information on how to order it can be found at the end of the Diverse Species section.

A new technology for production of broad-leaved forest seedlings to promote sustainable management of European forestry. Ciccarese, L.; Mattsson, A.; Andersen, L. APAT (Italian Agency for Environmental Protection and Technical Service), Rapporti 53. 115 p.

This softbound publication reports on one of the first comprehensive research trials on miniplug transplants using stabilized growing media. The research is part of a joint program by Italy, Denmark, and Sweden to propagate broadleaved trees using stabilized media miniplugs produced by International Horticultural Supply, and miniature Jiffy plugs of compressed peat moss surrounded by plastic webbing. Results are presented in color photographs, line and bar graphs; of particular note, one pie chart gives a detailed breakdown of production costs. I'm working on an article on stabilized media transplants for the *Native Plants Journal* and will also feature this technology in the Summer 2006 issue of FNN. Ordering information can be found at the end of the Container Production section.



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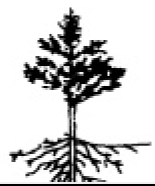
Liverworts have been a problem for container growers for years but, until now, there really wasn't a single source of information on these plant pests. James does an excellent job of discussing all aspects of how to manage liverworts, including the very latest chemical controls. Just circle #193 on the Literature Order Form, mail it, and we'll get you the full article.

Bareroot Production



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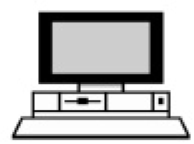

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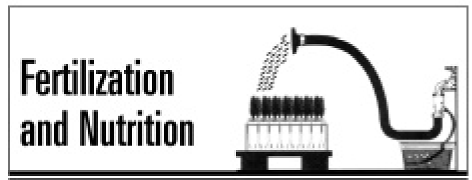

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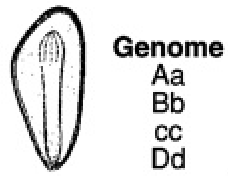
Genetics and Tree Improvement



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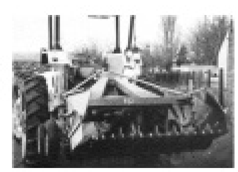

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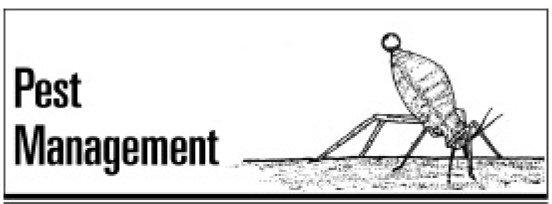

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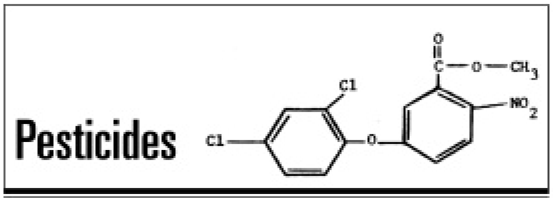

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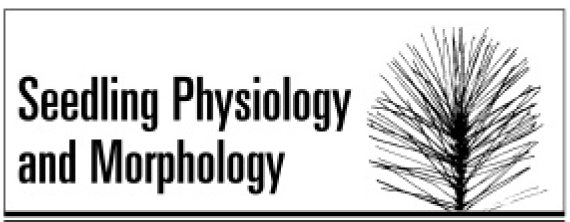

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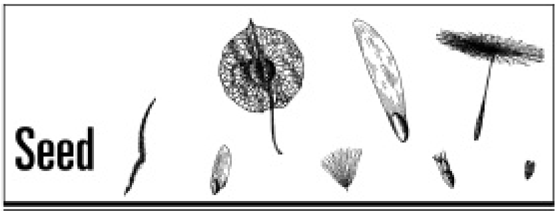

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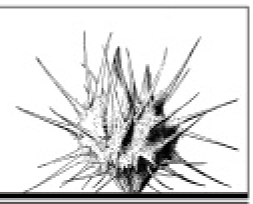

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