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

by Thomas D. Landis and Kim Wilkinson

Introduction

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

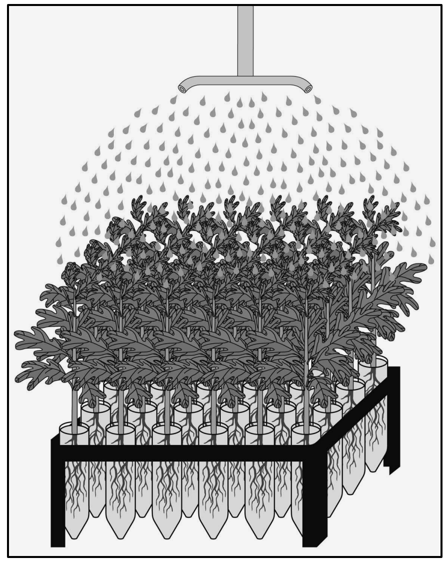

Figure 1 - Overhead irrigation is much less effective for broad-leaved plants like these oaks because so much water is intercepted by the foliage.

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

Types of subirrigation systems

Several different subirrigation systems have been developed:

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

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

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

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

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

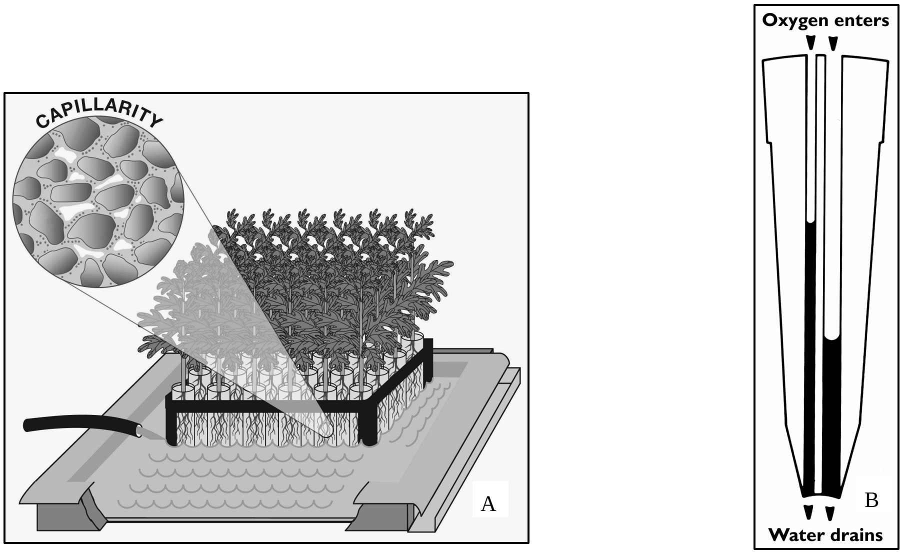

Figure 2 - Subirrigation works because water is drawn upward into the containers by capillarity (A). The amount and speed of water uptake will depend on the porosity of the growing medium, the smaller the pores, the more that will be absorbed (B).

How subirrigation "works"

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

Characteristics of subirrigation

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

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

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

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

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

Advantages:

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

Disadvantages:

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

Commercial subirrigation systems

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

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

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

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

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

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

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

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

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

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

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

Conclusions and Recommendations

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

References

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Seedling Quality Tests: Stress resistance

by Gary Ritchie and Tom Landis

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

The concept of stress resistance

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

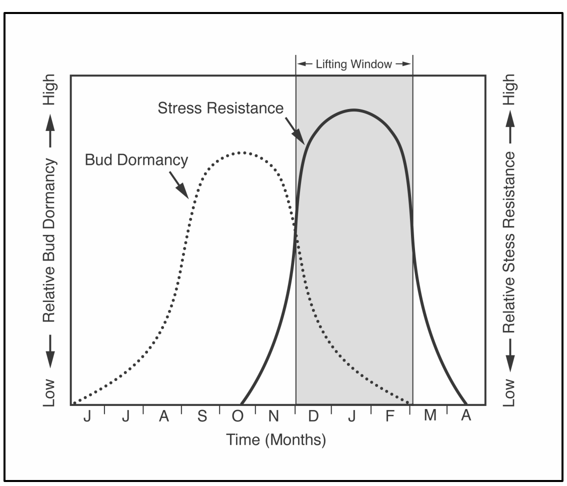

Figure 1 - This classic illustration shows the temporal relationships between bud dormancy, stress resistance and the traditional mid-winter lifting window (modified from 5).

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

Measuring stress resistance

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

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

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

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