WATER QUALITY IN THE PRODUCTION OF CONTAINERIZED LONGLEAF PINE SEEDLINGS

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INTRODUCTION

The consistent production of quality container grown seedlings requires that key production variables be identified and controlled; otherwise, quality and the percentage of marketable plants will be erratic (Garber and Ruter 1993a). Additionally, production times and costs may increase unless production variables are monitored and managed throughout the production cycle.

Accessing and maintaining water quality is essential for quality seedling production. As a prime factor influencing plant growth: water is the major plant constituent making up 80 to 90 percent of plant fresh weight; it serves as solvent, providing nutrient transport within the plant; it is a biochemical reactant for plant processes; and it is requisite for maintenance of cell turgor to promote cell expansion and growth (Kramer 1983).

Water is the principle agent limiting plant growth, and thus frequent irrigation is necessary to maintain optimal growth. Water is also used as a mixing agent or carrier for the application of fungicides, fertilizers and insecticides used in container seedling production.

REVIEW

Two excellent reviews of water quality issues specific to the production of containerized tree seedlings have been prepared by Landis (1989), and Tinus and McDonald (1979) that the reader is referred to for a detailed discussion of greenhouse/container water quality. This paper will highlight selected irrigation water quality issues pertinent to longleaf pine container seedling production. Two factors are of primary importance when evaluating irrigation water quality: the concentration and nature of dissolved salts and the presence of pathogens, weed seeds, algae, and pesticide contamination (Landis 1989). The pH of the irrigation water and its interactions with the growing substrate and mineral nutrition is a third important factor.

WATER-QUALITY ISSUES

Sources

Water source can greatly influence quality. Generally, irrigation sources available to most container operations will be from one of these categories:

€ Surface—ponds, streams
- Ground water wells
- Municipal—treated well or surface water.

Surface water sources can provide high-quality water supplies, but they must be carefully monitored. Suspended solids (such as sand, silt, and organic matter) may damage or clog irrigation systems. Weed seeds, algae and pathogens (such as fungi and nematodes from agricultural operations) in the watershed can pose serious production problems. Filtration can remove coarse suspended solids, but removal of silt, fine seeds, spores, etc., is difficult and expensive. Pesticides contamination, particularly from herbicides, or other chemical contaminants (such as fertilizers introduced from adjacent agricultural operations) can be detrimental to seedling production and may be difficult to remove.

Ground water wells generally provide water that has very little suspended matter. Levels of dissolved salts (total and individual ions) and pH must be monitored (table 1). Water quality will vary depending on location. In southern Georgia, most wells deliver alkaline (high pH) water, whereas those in central Georgia are generally acidic. Growers near coastal areas need to be aware of salt-water intrusion.

Table 1—Irrigation water quality target values

Factor	Target value
pH	5.4–7.0
Conductivity	0.2–2.0 dS/m
Bicarbonate	<100 ppm or 2 meq/L
Alkalinity or TC	<100 ppm VaCO3 or <2 meq/L
Hardness	<150 ppm or <3.0 meq/L
Sodium	<69 ppm or 3.0 meq/L
Chloride	<71 ppm or 2.0 meq/L
Nitrate-N	<10 ppm
Ammonium-N	<10 ppm
Phosphorus	<1 ppm
Potassium	<10 ppm
Calcium	<60 ppm
Magnesium	<25 ppm
Iron	<4 ppm
Sulfur	<24 ppm
Manganese	<2 ppm
Zinc	<0.3 ppm
Copper	<0.2 mmp
Boron	<0.5 ppm
Molybdenum	<0.1 ppm
Aluminum	<0.5 ppm
Fluorine	<1 ppm

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Municipal water supplies typically will be free of suspended matter as well. Potable water supplies still require monitoring of dissolved salts and pH (table 1).

Dissolved Salts

Salts dissolved in water release ions, or charged particles. A fertilizer salt such as KNO_3 releases one positively charged cation (K^+) and one negatively charged anion ($N03^-$). Both K^+ and $N03^-$ are plant nutrients. The total concentration of the salt in solution determines whether it is beneficial to the plant as a nutrient source or if concentrations are high enough to be harmful. Other dissolved salts can have toxic ions that damage or kill plants. Sodium chloride (NaCl) contains two ions (Na^+ and Cl^-) that will harm plant tissue even at low concentrations in water (Landis 1989).

The ions dissolved in water conduct electricity and the degree of salinity in water is expressed by electrical conductivity (EC). The greater the salt concentration, the higher the EC. Electrical conductivity can be rapidly determined using relatively inexpensive portable conductivity meters. These meters, which often include a pH meter, permit rapid testing of EC in irrigation water and leachates from container substrates. This is useful in monitoring the nutrient status of the water and container substrate throughout the growing cycle (Garber and Ruter 1993b, Ruter and Garber 1993). Monitoring of salt levels through EC is an important quality control measure as salinity can affect seedling growth and plant quality. Fuller and Haldermann (1975) and Landis (1989) discuss the following influences that salinity has on container seedling production:

- Availability of water (decreased by high salt concentrations)
- Presence of toxic ions
- Availability of nutrients
- Staining of foliage

The salinity of the water applied to the seedling growing substrate can influence the availability of water to the plant. The salt in solution creates a negative osmotic effect or potential in the substrate solution. This negative potential reduces the water availability to the plant. This becomes a serious problem when irrigation water with a high EC or dissolved nutrients are applied to dry media. Reduction in water uptake can be detrimental during germination (Landis 1989). Conifer seedlings are extremely sensitive to salinity damage and will exhibit reduced growth rates and foliar tip burn.

Direct toxicity of specific ions can induce growth losses and mortality. Sodium, chloride, and boron are ions that are directly toxic to seedlings. When present in high concentrations, metal ions such as manganese and zinc pose toxicity problems as well.

Nutrient availability in the media can be influenced by the excess of certain ions (Landis 1989). High levels of calcium and magnesium can induce nutrient imbalances in the growing substrate and retard plant uptake. Calcium levels in excess of 100 ppm in the irrigation water can lead to buildup of Ca^{2+} in the growing substrate that eventually causes a magnesium deficiency. A ratio of less than five parts calcium to one part magnesium is ideal for irrigation water. Likewise, high levels of Mg^{2+} (>50 ppm) can induce calcium and potassium deficiencies (Landis 1989).

Several ions can leave residues on foliage and accumulate on or eventually clog irrigation nozzles. Irrigation water with high levels of Ca^{2+}, Mg^{2+}, CO_3^{2-}, and HCO_3^{1-} (typically referred to as "hard" water) results in white deposits of calcium carbonate and magnesium carbonate on foliage. These deposits can also accumulate on the orifices of irrigation nozzles (Landis 1989).

Pests and Pesticides

Pests may be introduced into the irrigation water when surface water sources are used. Typically, weed seeds, moss, algae, and pathogenic fungi can be found in surface water sources (Baker and Matkin 1978). When surface water sources receive runoff from adjacent agricultural operations, *Pythium* and *Phytophthora* fungi can pose serious problems with damping-off during germination (Whitcomb 1984). Filtration and chlorination may be required to remove these pests from irrigation water.

Both surface and groundwater sources may become contaminated with pesticides. Pesticides may enter surface water supplies from runoff or over-spray from adjacent agricultural sites, and groundwater sources can be contaminated when a pesticide moves through the soil into recharge areas of the well or aquifer. Herbicide contamination poses the greatest risk for seedling nurseries. Seedlings may be stunted or die when irrigation water is contaminated with a herbicide. Specific assays are available to detect and characterize pesticide contamination in water.

pH

The pH of the irrigation water is an important factor that needs to be monitored and adjusted during seedling production. The pH is defined as a logarithmic expression of the hydrogen ion (H+)concentration with values ranging from 0 (very acidic), 7 (neutral), to 14 (very alkaline). The pH of the water and the growing substrate affect mineral nutrient availability. For container nursery operations where peat-based substrates are used, optimum nutrient availability occurs in a pH range of 5.2 to 5.5 (Peterson 1981). Specifically, conifers seedlings often grow best at a pH near 5.5 (Landis 1989).

Alkalinity is a measure of water's ability to neutralize acids. It is generally reported in ppm or meq/L. One meq/L is roughly equal to 50 ppm $CaCO_3$. Carbonates and bicarbonates primarily influence alkalinity in irrigation water. Because alkalinity influences pH, and pH influences nutrient availability, it is important to have the alkalinity of your irrigation water checked. Since small containers are irrigated more frequently than larger containers, high irrigation water alkalinity will cause the pH of the substrate to increase over time.

The pH of the water can also influence disease management. Notably, pH levels greater than 6.5 can encourage the development of damping-off diseases during germination and early seedling development (Carlson 1983). Acidic substrates in the range of pH 4.5 to 6.0 will discourage damping-off. Alkaline irrigation water can also have a negative influence on certain pesticides. Their effectiveness is reduced by a process known as alkaline hydrolysis (Ruter 1999). Commercial buffering agents can be tank-mixed with many pesticides to counter the effects of water with a high pH.

Testing Water Quality

Water quality testing should be a regular routine in a quality control operation. Testing should be done during nursery setup, and periodic monitoring should occur during production. Testing and evaluation can be done by private laboratories or by university laboratories through the county cooperative extension office in many states. Basic tests should include a salinity test listing the major ions and their concentrations, EC, and pH. Additional tests can be performed to detect pathogens and specific pesticides if contamination is suspected.

Corrective Treatments

If problems are found with irrigation water quality several treatments may be available:

- Acidification
- Reverse osmosis
- Deionization, water softeners, chlorination
- Filtration.

Acidification is used to lower the pH of the water. Typically, an acid such as sulfuric, phosphoric, or hydrochloric acid is injected into the water to remove the ions CO_3^{2-} and HCO_3^{1-} (Landis 1989, Garber and Ruter 1993b). If corrective measures are not taken, the pH of the substrate will increase over time when alkaline irrigation water is used. For irrigation water that is too acidic, amendments such as dolomitic limestone can be mixed with the substrate before planting to control potential problems.

Reverse osmosis systems and deionization may be used to remove salt ions from saline irrigation water. These systems have high initial costs and require regular maintenance. Deionization systems have relatively slow treatment times and water must be stored for irrigation use (Landis 1989).

Water softener systems are not recommended for irrigation water treatment as they use Na^+ to covert “hard” water with high levels of Mg^{2+} and Ca^{2+} to “soft” water (Landis 1989). The Na^+ poses a greater risk for seedling damage than the Mg^{2+} and Ca^{2+}. Chlorination is used to remove pathogens such as fungi and algae from the irrigation water. Typically, liquid sodium hypochlorite (household bleach) or powdered calcium hypochlorite is added to the water. Direct injection of chlorine gas is cost effective but requires specialized equipment and poses greater risks to operators. Free available chlorine levels of 2 to 3 ppm are generally sufficient to kill fungi. Approximately 2.6 fluid ounces of household bleach (5.25 percent sodium hypochlorite) in 1,000 gallons of water will produce 1 ppm of free available chlorine (Baker and Matkin 1978). Simple test kits are available to measure concentrations of free available chlorine.

Filtration removes suspended particles such as sand, weed seeds, and algae. Filter systems are recommended to prevent suspended particles from damaging irrigation pumps, injectors, and nozzles. Screen, cartridge, and granular medium (sand bed) filter systems are available.

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