Water Management in Container Nurseries To Minimize Pests

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Abstract

Water is the most important and most common chemical used in plant nurseries. It is also the most dangerous chemical used. Insufficient water, excessive water, and poorly timed irrigation can all lead to poor-quality crops and unacceptable mortality. Anticipated future declines of water availability, higher costs to use it, and continuing concerns about irrigation runoff harming the environment also spur interest in making more efficient use of water in nurseries. This article discusses water management in container nurseries and its influence on weeds, insects, and diseases. It also provides guidelines for minimizing pest issues with proper irrigation application and monitoring. This paper was presented at the joint annual meeting of the Western Forest and Conservation Nursery Association and the Intermountain Container Seedling Growers' Association (Troutdale, OR, September 14–15, 2016).

Introduction

Water is essential to a successful nursery, but not just any water will do. Nursery water must be of high quality, readily and consistently available at favorable cost, and well managed (Landis et al. 1990). Unfortunately, costs of obtaining and using water are expected to increase as water becomes less available, especially as restrictions on groundwater withdrawal grow and climatic variablity threatens surface water sources. Moreover, concerns continue about how nursery runoff may harm ground and surface sources of water (Beeson et al. 2004, Fulcher et al. 2016).

Dependable, high-quality water is necessary because it is the chemical applied in the largest quantity to nursery crops. Water is the fundamental component of plants, comprising 80 to 90 percent of the fresh weight and affecting every morphological and physiological attribute, including photosynthesis, nutrient transport, transpiration, growth, and gene expression. Water has a similar essential role for insects and diseases, many of which thrive in high-moisture, nutrient-rich environments. The quantity, quality, and frequency of water applied during each growth stage in the nursery directly affect seedling quality and incidence of pests and disease.

Thus, proper water management is a critical component to meet current nursery objectives of producing high-quality seedlings and limiting the incidence of pests and diseases, while positioning nurseries to meet future challenges of reduced water availability.

Not Enough Water

In typical reforestation and conservation container nurseries, insufficient water can occur two ways: chronically and acutely. Chronic, or long-term, exposure to insufficient amounts of water will reduce overall growth. Acute, or rapid, exposure to insufficient water, such as missing an irrigation event during an extremely hot and dry period, can cause dieback or even mortality. Chronic underwatering, if not satisfactorily diagnosed and remedied, will lead to failure to meet seedling target specifications and thus a decreased number of shippable stock. Chronic underwatering is a much less common problem than chronic overwatering.

Too Much Water

Excessive irrigation is much more common, in our experience, than insufficient irrigation in reforestation and conservation container nurseries and can lead to several chronic problems. Too much water causes excessive growth and succulent tissues that are then difficult to harden off. Excessive watering and subsequent nutrient runoff are expensive, wasting water, fertilizer, and the energy and labor required to apply the water. Nutrient runoff can also pollute groundwater and surface water (Dumroese et al. 1992, Juntunen et al. 2002, Wilson et al. 2010). Furthermore, a wet nursery environment results in favorable conditions for numerous cryptogams, insects, and diseases, as described in the following sections.

Cryptogams

Cryptogams (plants that reproduce from spores instead of seeds, such as algae, moss, and liverworts) flourish in environments with high levels of moisture and nutrients (Khadduri 2011). These pests are resilient because they can also tolerate long, dry periods. Once established in a container, cryptogams impede water infiltration into the growing medium and compete with crop seedlings for water and nutrients (figure 1). Mosses and liverworts can also overtop and smother small seedlings. Excess water in the nursery environment, such as standing water on the greenhouse floor, also promotes the spread of spores. Persistent water on floors can allow algae to develop and make surfaces slippery, which can be a safety hazard. Once established, cryptogams can be difficult to control, especially in smaller volume containers.

Figure 1. Liverworts thrive in the high-moisture, nutrient-rich environment associated with growing seedlings in container nurseries. Once established, they can be difficult to control. Liverworts compete with seedlings for nutrients and can often overtop slower growing crops, reducing seedling quality or even causing mortality. (Photo by R. Kasten Dumroese, 2011)

Insects

Many insects thrive in moist conditions. Adult fungus gnats (*Bradysia* spp. [Diptera: Sciaridae]) can be particularly noticeable, fluttering across the tops of containers in a greenhouse where the growing medium is irrigated excessively. At low population levels, fungus gnats are more of an unflattering nuisance than a problem to plant quality, with the larvae generally feeding on the organic matter found in the substrate. When population densities are high, however, the larvae will consume seedling roots and girdle stems (Wilkinson and Daugherty 1970). Adult fungus gnats are also potential vectors for disease (James et al. 1995). Unfortunately, new insect pests, some of which are resistant to insecticides, are appearing and may present future problems in container nurseries (Rosetta 2017).

Diseases

Warm, wet conditions in forest and conservation nurseries are conducive to the buildup and spread of pathogens (Dumroese and James 2005). Damage from foliar diseases (e.g., rusts and *Botrytis*) and root diseases (such as those in the genera *Fusarium*, *Cylindrocarpon*, and *Phytophthora*) can increase dramatically when too much water is applied (figure 2). In addition to mortality, seedlings can have significant chlorosis and poor root development. Thus, the number of seedlings meeting shipping criteria can be reduced because of failure to meet quality standards, particularly root plug integrity and seedling color. Moreover, infected seedlings may also wilt at the onset of symptoms, causing growers to erroneously conclude that the crop requires even more irrigation.

Sanitation and Water Management

Pest prevention through sanitation as part of an integrated pest management (IPM) program is the prudent first step in pest management (Dumroese 2012). Incorporating vigorous sanitation into the annual production cycle can further enhance the benefits of proper water management to suppress pests. Between crops is the best time to kill spores, seeds, insects, and pathogens. Precrop sanitation practices to disinfest the facility, containers, benches, floors, and equipment are recommended. Container sterilization can be done with steam or hot water. Dumroese et al. (2002) found that containers used for three crop cycles

Figure 2. Excessive irrigation and warm temperatures foster development of root diseases such as *Fusarium*, which can either ruin seedling quality or cause mortality. (Photo by Thomas D. Landis, 1987)

but cleaned annually with hot water yielded 13 percent more Douglas-fir (*Pseudotsuga menziesii* [Mirb.] Franco) seedlings than nontreated containers. Moreover, seedlings from treated containers had 20 percent more biomass and were 10 percent taller than those from noncleaned containers. Disinfesting seeds prior to stratification can reduce pathogen levels before sowing and can be accomplished by imbibing seeds in running water rather than stillwater soaks (James 1987) or by treating seeds with disinfectants such as bleach (Wenny and Dumroese 1987) or hydrogen peroxide (Barnett 1976). Using seeds with high vigor and controlling moisture during stratification will increase germination uniformity and minimize damping off (Karrfalt 2017).

Because water is the most critical environmental factor affecting the incidence, severity, and spread of cryptogams, insects, and diseases, proper management of irrigation frequency, timing, and quantity is paramount to minimize their effect and will also reduce the need for pesticides (Dumroese et al. 1990). Careful attention to the nursery's irrigation regime also has a direct effect on each growth stage of the crop (Mexal and Khadduri 2011). Following are some guidelines for each phase of crop production.

During Germination

Selection criteria for the types of growing media used in the nursery should include consideration of water holding capacity and drainage (Landis et al. 1990). Each growing medium should hold enough water to meet the crop's needs and to optimize water use efficiency but not so much that roots are waterlogged.

Misting for the first week or two after sowing is a typical practice to promote rapid and uniform germination. Frequent misting, however, can result in high-moisture conditions favorable to pests and diseases. In a study to compare the effects of misting frequency on lodgepole pine (*Pinus contorta* Douglas ex Loudon var. *latifolia* Engelm. ex S. Watson) seed germination, no significant differences in germination capacity and speed (table 1) were found among low, medium, or high frequency treatments, although seed zone temperature tended to be lowest with the highest frequency (figure 3), which can reduce germination speed (Pinto et al. 2009). We recommend experimenting with misting frequency to find the minimal amount required to achieve germination objectives. The frequency will depend

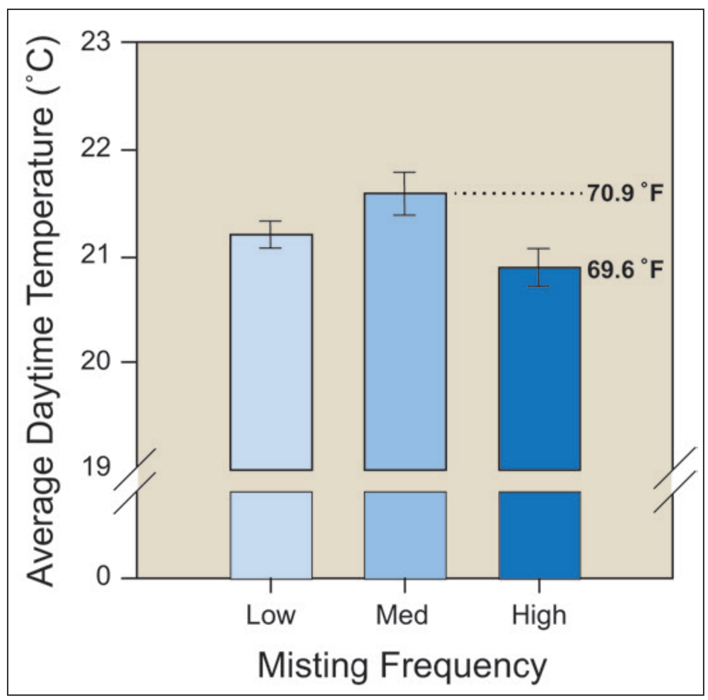

Figure 3. Misting frequency during the germination phase had a significant effect on the temperature at the seed-medium interface, with the most frequent misting reducing the average temperature. (Adapted from Pinto et al. 2009)

Table 1. Average amount of water applied per container cavity and means (± standard errors) for lodgepole pine seed germination parameters among three misting frequencies. Germination rates did not differ significantly among treatments (from Pinto et al. 2009).

Misting treatment	Amount of water per application	Number of applications every 4 days	Total water applied every 4 days	Germination after 21 days (%)	Germination rate (days to 50% germination)
Low	6.7	1	6.7	82.0 (1.0)	9.6 (0.2)
Medium	4.2	2	8.4	84.0 (1.4)	9.4 (0.2)
High	2.1	12	25.4	84.0 (1.4)	9.7 0.2)

on environmental conditions, seed characteristics, and growing medium and may vary from year to year depending on weather conditions. Daily or multi-daily examination can determine the optimum misting frequency to keep the seed-medium interface moist but not wet. Regular observation and experience is part of the art of being a nursery manager.

In addition to misting frequency, other practices—such as acidifying irrigation water, lowering fertilizer rates, using seed coverings, and rogueing infected germinants—will help minimize the incidence of cryptogams, fungus gnats, and diseases (table 2).

During Rapid Growth and Hardening

Irrigation based on a routine schedule is convenient for the nursery staff but can lead to issues with growth, quality, and pests. Efficient irrigation scheduling is based on the plants' requirements, not on a regular schedule (Regan 1994, figure 4). Plant needs can change daily and are determined by species, provenance, plant size, container type and size, growing medium, fertilizer concentration, temperature, sun intensity, ventilation, relative humidity, and other influencing factors. Irrigating early in the day to container capacity results in maximum water availability during warmer, daylight hours and promotes rapid drying to minimize the duration of water on foliage and other surfaces. Good ventilation in the growing area will also keep humidity down and help discourage buildup of pests.

In the next section, Monitoring Water, the use of container weights to determine irrigation frequency is described. Adherence to this technique can provide

Table 2. General guidelines for reducing cryptogams, fungus gnats, and diseases during growth phases at the nursery.

Nursery practice to minimize the indicated pests	Cryptogams	Fungus gnats	Disease
Germination and establishment			
Acidify water	-	-	X
Allow medium surface to dry	X	X	X
Use low fertilizer rates during early development	X	-	X
Add a biological control	-	Parasitic nematodes	*Trichoderma*
Use seed coverings (e.g., grit)	X	-	-
Sanitize (rogue affected plants)	X	X	X
Rapid growth and hardening			
Acidify water	-	-	X
Allow medium surface to dry	X	X	X
Irrigate early in the day	-	-	X
Add a surfactant	-	-	X
Sanitize	X	X	X

Figure 4. Proper irrigation scheduling is based on the needs of the seedlings, not necessarily the convenience to the nursery workers. (Photo by R. Kasten Dumroese, 1995)

opportunities to reduce irrigation frequency without adversely affecting seedling quality. Dumroese et al. (2011) found that the target for irrigating ponderosa pine (*Pinus ponderosa* Lawson & C. Lawson) seedlings could be reduced 15 percentage points during the entire growing season without significantly changing seedling morphology and water-use efficiency. Moreover, that reduction increased the average interval between irrigations from 2 days to nearly 5 days.

Sanitation and other IPM measures (table 2) should continue throughout the growing cycle. The crop should be inspected daily for any problem areas, and all dead and dying seedlings should be removed to minimize infection of adjacent plants and discourage development of *Botrytis* (Haase and Taylor 2012).

Monitoring Water

Daily observation of the growing area for standing water, undesirable growth patterns in the crop caused by variable water availability, and development of weeds, moss, or algae will provide useful feedback for making necessary adjustments or repairs to the irrigation system. In addition, daily monitoring of growing-medium water content or plant water status will guide decisionmaking for irrigation frequency and quantity. Many growers use a visual-tactile method to make a determination of growing-medium moisture based on experience. This technique can provide some information but can have limited usefulness. For example, if the growing medium in the lower portion of the container is quite dry or quite wet, the grower may not make the best irrigation determination or, if the grower is on vacation, the employees may not have the same level of experience to determine proper irrigation frequency. Quantitative methods, such as measuring container weights or xylem water potential, offer repeatable and reliable assessments of current water conditions in the crop.

Container Weights

Monitoring container weights is the most common quantitative approach used for determining irrigation scheduling (Mexal and Khadduri 2011). The standard approach is to irrigate the medium in the container until it reaches container capacity (water begins dripping from the drainage holes), allow the water to drain for several minutes, and then weigh the container to determine its container capacity weight (figure 5). The container is periodically weighed as it dries down to a specified target (e.g., 70 percent of container capacity weight). Target container weights vary by the type of growing medium, container size and type, plant species, and growth stage. When the container weight reaches the target level, it is irrigated again (Dumroese et al. 2015). The target level is chosen based on plant species and growth stage; container weight targets are lower (i.e., drier) during hardening than during active growth. Depending on crop size and greenhouse variability, two or more representative containers are designated for repeated container weight measurements. Weights can be measured by placing the container on a scale (on the bench or a traveling cart) or suspending the container with a handheld scale (figure 5). Note that this approach does not account for the dry weight of the container, medium, or grit and thus does not measure the true water content as would a scientific approach typically used in research (Dumroese et al. 2015). Nonetheless, this monitoring tool is very effective and efficient.

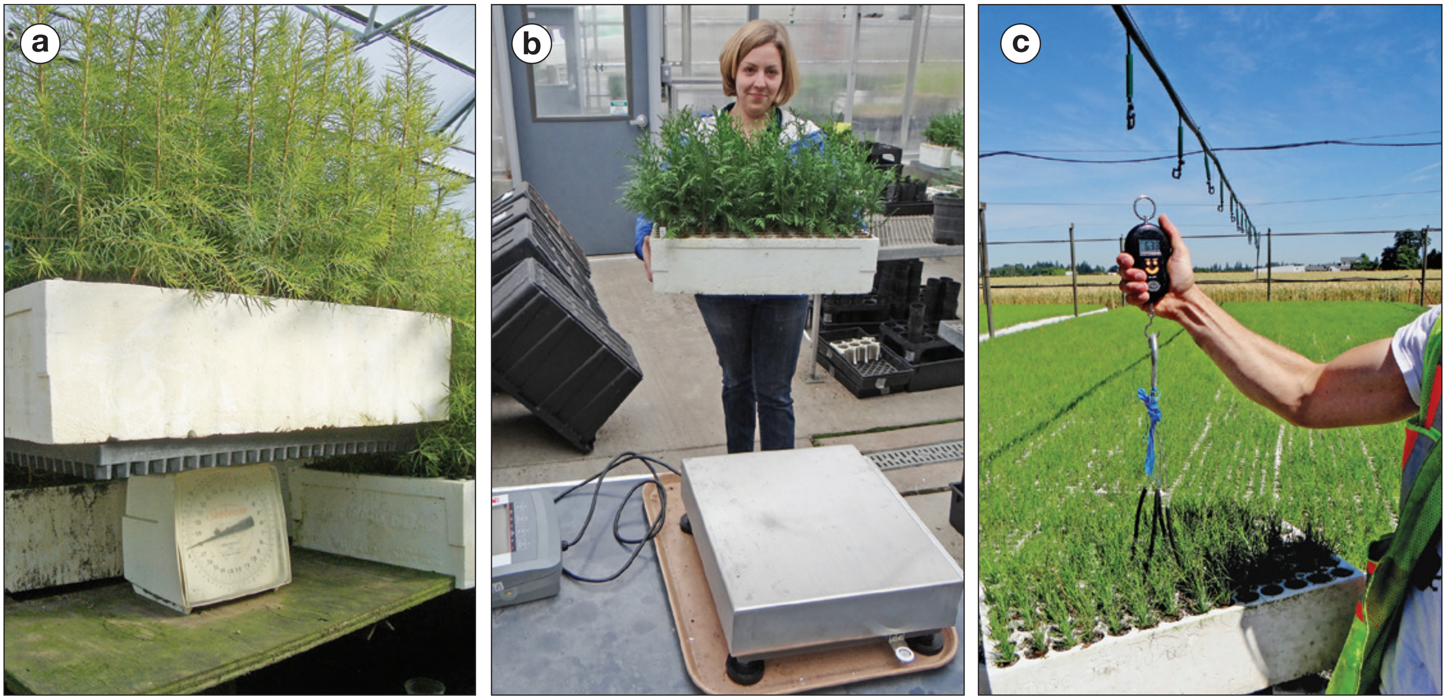

Figure 5. Weighing containers, a common method of monitoring irrigation needs in container nurseries, can be accomplished with (a) dedicated balances in the crop, (b) carrying or carting a balance to different locations in the nursery, or (c) using a hand-held balance. (Photos by R. Kasten Dumroese, 2006, 2015, 2014; from Dumroese et al. 2015)

Xylem Water Potential

Another monitoring method to assist with water management is assessment of xylem water potential (ψ_{xylem}), a direct measure of the plants' water status (Haase 2008). This measurement reflects interactions among water supply, water demand, and plant regulation. In this method, representative plants are assessed in a pressure chamber to determine ψ_{xylem}. Irrigation is then applied when a target ψ_{xylem} threshold is reached.

Other Considerations

Many aspects of the nursery's facility and cultural practice can influence water management requirements to prevent and control cryptogams, insects, and diseases.

Irrigation System

In addition to irrigation timing and amount, the irrigation delivery system influences the effect that water has on pest populations in the nursery. For example, subirrigation is an efficient water delivery system that reduces the amount of water and fertilizer needed to produce plants while also reducing wastewater, nutrient leaching, and the incidence of cryptogams as compared with overhead irrigation (Dumroese et al. 2006, Pinto et al. 2008, Schmal et al. 2011).

Fertigation

In most container nurseries, fertilizer is mixed with the irrigation water to deliver nutrients at a set concentration to the plant. When adjusting watering frequency, one must also adjust the amount of nutrients. Increases or decreases in the stock solution concentration can be made to compensate for watering frequency.

Pesticide Applications

Applying pesticides to the container crop should be aligned with the irrigation schedule. For example, a grower typically applies fertigation followed by a clear water rinse. The rinse could include a foliar fungicide to simultaneously remove the fertilizer salts and maximize the amount of time the pesticide is on the foliage.

Cooling

Irrigation is a common tool for cooling plants under high temperatures. The cooling occurs when the water evaporates (i.e., evaporative cooling). Thus, it is important to be sure that water applied for cooling actually evaporates, so there is no time to create a favorable pest environment. Good ventilation to keep humidity down is critical.

Every Nursery Is Unique

Growing seedlings in a nursery is an art and a science. Although the concepts (science) of water management may be specific, how they are applied (art) may vary because of differences in the facilities, species provenances, tools and supplies, customer expectations, water quality, and environmental patterns of individual nurseries. The philosophy of the managers can further lead to a preference for being either a "wet grower" or a "dry grower." Thus, determining a water management plan that works equally well for all nurseries is not possible (Dumroese and Wenny 1997). Nevertheless, it is essential for nursery managers to annually reevaluate irrigation scheduling, sanitation practices, pest and disease occurrences and their causes, and crop performance. These annual evaluations can be used to improve techniques and yields for future crops.

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