Native Plant Germination and Growth in a Subirrigation System

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Abstract

Native plant and forest nurseries consume high amounts of water when irrigating crops with overhead and hand-watering systems. As water conservation continues to be an issue, subirrigation is being considered as an alternative watering method by growers and nursery owners. We tested the germination and growth of redosier dogwood (*Cornus sericea*) in a subirrigation system. During germination, we compared treatments with and without overhead misting and germination cloth in addition to subirrigation. We also tested two fertilizers—Osmocote® Pro 17-5-11 and Nutri-Rich 8-2-4—applied in two ways—incorporated or top dressed. Results showed that germination was successful using subirrigation only, but germination was highest in treatments that also had germination cloth and received overhead misting twice a day. The treatments with incorporated Osmocote® grew more in the nursery, but the treatments with top-dressed Osmocote® grew taller after outplanting. The Nutri-Rich fertilizer did not work in this experiment because of a pest infestation. The experiment showed that subirrigation can be used to successfully germinate seed and that nursery cultural practices can be manipulated to improve germination rates, to reduce overall water and fertilizer use, and to adjust growth rates in the nursery and the field. This paper was presented at the annual meeting of the Western Forest and Conservation Nursery Association (Eugene, OR, October 26–27, 2015).

Introduction

Forest tree and native plant nurseries grow seedlings for reforestation and restoration projects. Given that the seedlings are typically planted in projects that have environmental objectives, nursery growers want to ensure that the plants are grown in a sustainable manner. Growing seedlings in a nursery requires resources, including water. Developing more water-efficient practices to grow plants can reduce the nursery's water use (Landis 1989).

Subirrigation, or ebb-and-flood irrigation, is one system used in container nurseries to irrigate plants. In a subirrigation system, containers sit in a tray or reservoir, which is then flooded, allowing water to enter into holes in the bottom of the containers. After a period of soaking, any unabsorbed water is drained. The volume of water movement is a balance between medium porosity and bulk density, container configuration, and water requirements of the plants (Ferrarezi et al. 2015). Subirrigation applies water directly to the growing medium, resulting in a higher water-use efficiency compared with overhead irrigation (Gent and McAvoy 2011). Holding tanks can be used to store the unabsorbed water for reuse. Subirrigation systems have been used to grow healthy seedlings while reducing overall water and fertilizer use and decreasing weeds (Bumgarner et al. 2008, Davis et al. 2011, Wilen et al. 1999); in these experiments, the seedlings were either transplanted into the containers or grown with overhead irrigation during the germination phase.

As growers' repertoires expand to include growing a variety species of using subirrigation, it becomes necessary to identify the most effective way to optimize water use. At the same time, growers need to determine best practices and successful protocols to produce healthy seedlings of each species (Schmal et al. 2011). Nurseries that currently use subirrigation to grow seedlings still use overhead irrigation during the germination phase, which requires additional infrastructure (e.g., Dumroese et al. 2011). If subirrigation systems are to be used independent of overhead irrigation infrastructure, subirrigation must meet the water needs of the plant throughout the growing season. Therefore, the irrigation system and the growing media must provide sufficient water to the seed or seedling during each growing stage, particularly the germination phase. To properly grow high-quality seedlings it is likely that nursery cultural treatments, such as irrigation method and fertilizer application, may need to be adjusted.

The objective of our study was to determine whether it is possible to germinate redosier dogwood (*Cornus sericea* L.) seed in a subirrigation system and if fertilizer type and application method affect the growth of this species during its time in the nursery and its first year after planting. We also examined whether different nursery cultural practices affect germination.

Redosier dogwood is an appropriate species for this experiment. The species is often found along margins of streams and wetlands, where the soils are saturated for a portion of the growing season but are dry by late summer (Stevens and Dozier 2000). In addition, redosier dogwood is a popular choice for landscaping in the Pacific Northwest, with many nurseries and growers in the area producing it often and in large quantities. The species develops a broad canopy that deflects water when overhead irrigation is used. Using subirrigation can ensure that each container receives the water it needs (Davis et al. 2008, Landis and Wilkinson 2004).

Material and Methods

The experiment was conducted at Oxbow Native Plant Nursery, located within the Oxbow Farm and Conservation Center in Carnation, WA (~47°41'N., 121°58'W.). Seed for this study was obtained in northern Idaho and was stratified for 136 days at 0 to 1.5 °C (32 to 35 °F) before sowing. Seed viability was tested by placing seed in a closed, clear plastic container under a full-spectrum light and recording germination for 4 weeks. The light was on an automatic timer for 16 hours of daylight and 8 hours of darkness. The seeds were misted three times a day to keep them moist and were kept under ambient temperature, which was tracked with a temperature-humidity sensor (Decagon Devices, Inc., Pullman, WA). A seed was counted as germinated when 5 mm (0.2 in) of the radicle was visible (Baskin and Baskin 2014). Mean germination was 86 percent (n = 4, standard deviation = 3.63, descriptive statistics from R, version 3.1.1).

The greenhouse at the Oxbow Native Plant Nursery is a Cravo greenhouse (Cravo Equipment Ltd., Brandtford, ON, Canada) and regulates temperature automatically by opening and closing roof and side panels; there is no supplemental heating, cooling, or lighting in the greenhouse. For this experiment, Ray-Leach SC10 containers (Stuewe & Sons, Inc., Tangent, OR) were filled with Sunshine Mix #4 Aggregate Plus (Sun Gro® Horticulture, Agawam, MA, Lot S13-153). The medium was made of 65 to 75 percent Canadian Sphagnum peat moss; the remaining proportion was horticultural grade perlite and dolomitic limestone. The Ray-Leach cells were placed in racks that held 98 containers each. A total of 2,800 containers were used in the study, arranged in a split plot design with five replications. On June 11, 2014, three seeds were sown in each container. The seeds were then covered with approximately 0.5 cm (0.20 in) of medium.

Subirrigation

The subirrigation system consisted of cement mixing tubs measuring 0.61 x 0.91 x 0.20 m (24 in x 36 in x 8 in). Before sowing, all tubs were filled with 50 L (13 gal) of water and the trays were soaked for 2 hours. At this point, the containers were saturated, except for the unconsolidated peat at the top of the container. Any remaining water in each tub was drained into a 70-L (18-gal) container (Rubbermaid, Atlanta, GA) between subirrigations. The irrigation water was recycled for each irrigation, with a separate supply maintained for each subirrigation tub. Subsequent irrigations soaked for 1 hour (germination phase) or 15 minutes (growth phase). For each irrigation event, the supply was topped off to 50 L (13 gal) with fresh water from the greenhouse water supply. In the third replication, a temperature and humidity sensor (Decagon Devices, Pullman,WA) was installed in each irrigation treatment.

Fertilizer Treatments

Two nursery fertilizers were used: (1) Osmocote® Pro Control Release 17-5-11 (3-4 month release, Everris, Geldermalsen, Netherlands) and (2) Nutri-Rich 8-2-4 (Stutzman Environmental Products, Inc., Canby, OR). The Osmocote® product is a general purpose fertilizer made of coated prills and is acceptable for use in containerized nurseries. The Nutri-Rich product is an organic-certified, granulized product made primarily of chicken manure. The advertised applications of Nutri-Rich include use on trees and shrubs. Each fertilizer was applied in one of two ways: either (1) incorporated into the growing medium or (2) applied as a top dressing. The rate of fertilization was determined by the medium recommended application rate by Osmocote® (Dumroese et al. 2007). The amount of Nutri-Rich was adjusted to provide the same amount of nitrogen (N) as the Osmocote®. For the incorporated treatment, 96.36 g (3.40 oz) Osmocote® or 394.70 g (13.92 oz) Nutri-Rich were mixed into the medium before filling the containers. For the top-dressed treatment, 0.688 g (0.024 oz) of Osmocote® or 2.82 g (0.099 oz) of Nutri-Rich fertilizer were applied to the top of each container before sowing. In the top-dressed containers, care was taken to keep the seeds from contacting the fertilizer, though the higher top-dressing rate of Nutri-Rich fertilizer made this difficult. One-and-a-half container racks were placed in each of 20 subirrigation tubs (figure 1). From each of the four fertilizer treatments, 35 containers were put in a tub, for a total of 140 containers per tub.

Germination Treatments

Four germination treatments were used during the emergence phase (first 6 weeks after sowing): (1) unmisted and uncovered, (2) unmisted and covered with a germination cloth, (3) overhead misted and uncovered, and (4) overhead misted and covered with a germination cloth. The germination cloth was 0.5 oz Plant and Seed Guard (DeWitt Company, Sikeston, MO), a lightweight, white fabric. The treatments that were overhead misted were misted twice a day, in the morning and evening. All treatments were subirrigated during the emergence phase every other day in the morning. Each germination treatment was applied to five subirrigation tubs (whole plots in a split plot design).

Emergence Phase

Following sowing, redosier dogwood seeds were tracked twice daily for emergence. A seed was considered to have emerged when its cotyledons fully cleared the surface of the medium (figure 2). When a seed emerged, it was marked with a ballpoint pin; a different color was used for the first, second, and third seed to emerge in each container. Redosier dogwood seed is technically classified as

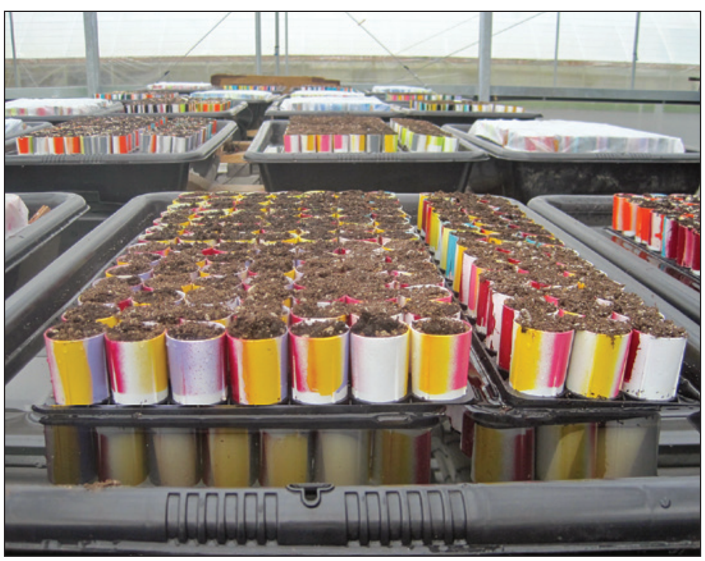

Figure 1. Large cement mixing trays were used to subirrigate seedlings grown in Ray-Leach containers. One-and-a-half racks of Ray-Leach containers fit in the mixing tray. The tray had a plug at the bottom to facilitate draining irrigation water into a storage tub. The containers covered with germination cloth are visible in the background. (Photo by Rebecca Sheridan, 2014)

Figure 2. Newly emerged seedlings were marked with a ballpoint pin when the cotyledons cleared the media surface. At this time, the date of emergence was recorded. (Photo by Rebecca Sheridan, 2014)

a stone containing two embryos. Therefore, each of the seeds planted could potentially produce two seedlings. If two germinants emerged in close proximity or had visibly emerged from the same seed coat, they were classified as seedlings from the same stone. Emergence was scored by container, where at least one seedling had to emerge in a container for it to be counted as having a successful emergence. Emergence was tracked for 5 weeks after the first seedling emerged. If a seedling died during the emergence phase, it was removed, its place was marked with an additional pin, and a possible cause of death was recorded. At the end of the emergence phase, the quality of each remaining seedling was noted.

Growth Phase

After the 6-week emergence phase, each container was thinned to one seedling per cell and the reservoirs of irrigation water were emptied and refilled. The containers, originally organized within the tubs by germination treatment, were reorganized so that the same fertilizer treatments were grouped within the same subirrigation tub. This reorganization meant that seedlings would be exposed to only the assigned fertilizer type if the fertilizer leached into the recycled irrigation water during the experiment. The original plot and subplot identities, however, were tracked through the rest of the experiment.

During the growth phase, the irrigation schedule was based on gravimetric weights, in which the containers were allowed to dry to 80 percent of field capacity during August, then to 70 percent during September and October. The pH and electrical conductivity (EC—a proxy measurement for available fertilizer) of the irrigation water were measured weekly to monitor whether the water stayed within safe ranges for seedlings. The seedlings were not pruned. At the end of August, the seedlings were moved from the Oxbow Native Plant Nursery to the Franklin H. Pitkin Forest Nursery in Moscow, ID (46°43'N., 116°57'W.) and kept outside. Samples were taken from the recycled irrigation water in August before the move and again in October at the end of the growing season and were tested for nutrients. In addition to the scheduled irrigation events, the seedlings received 2.64 cm (1.04 in) of rain during the 2 months they were held outside at the Pitkin Forest Nursery before outplanting.

Outplanting

Seedlings were outplanted in the last week of October 2014 to a relatively flat, tilled agricultural field at the Pitkin Forest Nursery, with coarse loamy soil. No additional experimental treatments or irrigation were applied when the seedlings were planted. During the week after planting, 1.88 cm (0.73 in) of rain fell. Seedling survival was recorded in May 2015. Seedlings were considered dead if they failed to leaf out, if leaves were fully desiccated, or if the seedling was missing entirely. Seedling root collar diameter and height were measured on all outplanted seedlings in November 2014, when the seedlings' leaves had turned red and were beginning to senesce, and again in July 2015, at which time growth was ceasing due to the seasonal summer drought. Field growth was calculated as the difference in height and root collar diameter from the time of outplanting to the final measurements in July.

Statistical Methods

Statistical analyses were done in R, version 3.1.1. The experiment was a split-plot design, in which the whole plot level (germination treatment) was a randomized complete block design. There were five blocks consisting of four irrigation tubs grouped on a table. The subplot level (fertilizer treatments) was also a randomized complete block design. The two phases of this experiment—(1) the emergence phase and (2) the growth and outplanting phase—were analyzed separately. Data collected during the emergence phase were subject to analysis of variance (ANOVA) to test the effects of fertilizer type and germination treatment on emergence. During the growth and outplanting phase, data were analyzed using a multivariate analysis of variance (MANOVA) with a Pillai's trace test to test the effects of fertilizer type and irrigation method on height and root collar growth. MANOVA was used because height and root collar diameter are dependent variables on the same experimental unit, a seedling. Significance was determined at the $\alpha \leq 0.05$ level. The model assumptions of normality and constant variance were evaluated using diagnostic plots, and the assumptions were determined to hold, with no data transformations deemed necessary.

Results

Emergence

In the treatments with Nutri-Rich fertilizer, very few seedlings emerged, which appeared to be due to a fungus gnat infestation, in which the larvae ate germinating seed before seedlings emerged. Therefore, those data were eliminated from the study. Interaction was significant between the Osmocote® fertilizer treatments and germination treatment ($p = 0.04$) (figure 3). Emergence was greater in treatments with overhead misting ($p < 0.001$). The treatments without overhead misting trended toward higher emergence in seedlings with top-dressed fertilizer than those with incorporated fertilizer ($p = 0.06$).

Growth

Measurements of height and root collar diameter in November 2014 accounted for seedling growth through their time in the nursery. A significant interaction occurred between the germination and fertilizer treatments ($p = 0.02$). Seedlings with incorporated Osmocote® fertilizer were taller than seedlings with top-dressed fertilizer (figures 4 and 5). The seedlings with incorporated Osmocote® also had larger root collar diameters (data not shown).

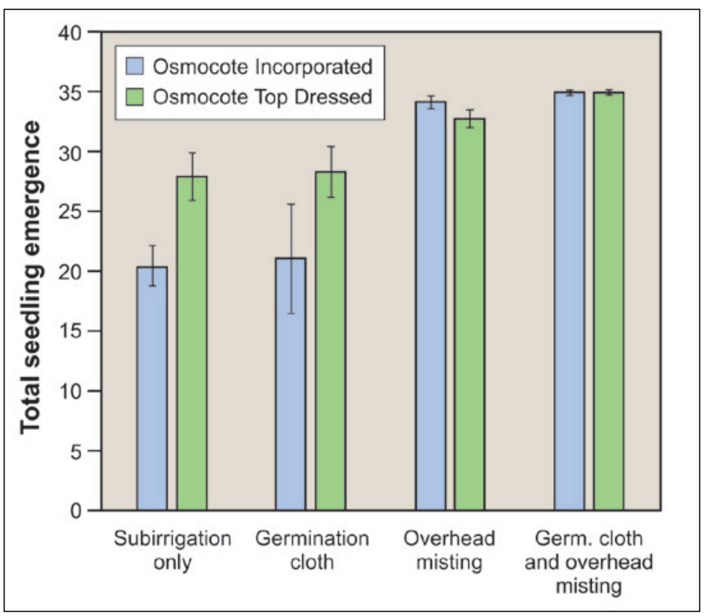

Figure 3. Seedling emergence was tracked by irrigation and fertilization treatment. The highest rates of emergence occurred in treatments that received overhead irrigation in addition to subirrigation. A statistically significant interaction ($p < 0.05$) occurred between the irrigation type and the fertilization method. The bars show standard error for five replications.

Figure 4. The seedlings were germinated and grown using subirrigation. In this photo, seedlings on the left were grown with top-dressed Osmocote® fertilizer and those on the right were grown with incorporated Osmocote® fertilizer. By November 2014, the seedlings with incorporated fertilizer were significantly taller than the seedlings with top-dressed fertilizer. (Photo by Rebecca Sheridan, 2014)

After planting, some seedlings suffered from herbivory, presumably by rabbits (Riley 2014), and some experienced frost heave; however, most were able to persist and grow in spite of these challenges. Redosier dogwood has the ability to resprout, and this growth pattern was observed in some cases in the field.

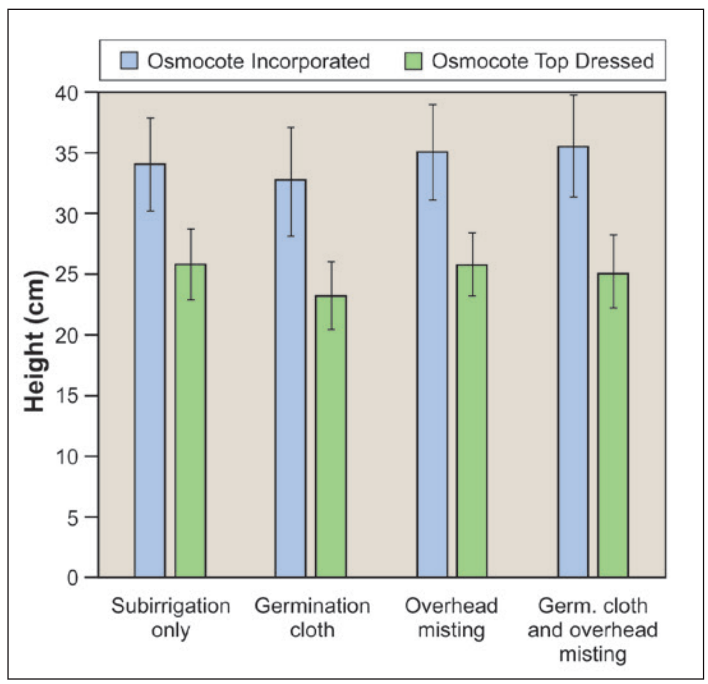

Figure 5. Seedling height after the nursery growing season (measured in November 2014, after the seedlings had dropped their leaves). Seedlings grown with incorporated Osmocote® fertilizer were taller than those with top-dressed fertilizer ($p<0.001$). The bars show standard error for five replications.

Seedling growth after outplanting was significantly affected by fertilizer type ($p < 0.001$) and germination treatment ($p < 0.02$), with no significant interaction between the two treatments. Seedlings with top-dressed fertilizer had greater height and root collar diameter growth than did those with incorporated fertilizer (table 1).

Discussion

The first phase of this experiment showed that it is possible to germinate seed using subirrigation only, but the emergence rates were lower in this treatment compared with those that also received overhead misting. The emergence phase has been identified as a challenge to adoption of subirrigation in nurseries (Dumroese et al. 2007). Even without sufficient water, seed may still germinate, but the seed will be more vulnerable to disease and decay, and germination will be less uniform (Bewley and Black 1994). Nursery growers work to avoid these situations. Alternative nursery cultural techniques, such as a grit layer on the top of containers, could also be used in conjunction with subirrigation to create favorable germination conditions. As nursery growers make decisions about propagation protocols using subirrigation, they will need to consider the natural history of the species with which they are working (Schmal et al. 2011). The redosier dogwood seed used in this experiment is relatively large, and the species is a wetland plant. The size and germination characteristics of other species might affect their suitability for use in a subirrigation system.

The treatments with Nutri-Rich fertilizer did not produce many seedlings. Although fungus gnat larvae were seen in all the treatment types, a greater number of larvae were observed in the containers with Nutri-Rich. It is unknown whether this condition was a direct consequence of the fertilizer, or if it was due to changes in the physical characteristics of the medium resulting from the fertilizer. In another study, Nutri-Rich fertilizer increased the medium's water-holding capacity in a subirrigation system (Dunlap 2015). Fungus gnats were also a problem in a previous subirrigation study, and reducing irrigation frequency helped address the issue (Dumroese et al. 2006).

In subirrigation systems, nitrogen (N) from the controlled-release fertilizer is primarily retained within the medium and plant, and little N is lost in runoff water (Morvant et al. 2001, Pinto et al. 2008). EC is higher at the top of containers that are subirrigated when growing a species that does not have fibrous roots in the upper layer of medium (Davis et al. 2008). By contrast, subirrigated containers that are planted with a species that has shallow, fibrous roots do not show elevated EC in the upper medium (Pinto et al. 2008). In this experiment, the seedlings were not observed to have numerous shallow roots, and the seedlings grown with incorporated fertilizer probably had better access to the fertilizer while growing in the nursery. Fertilizer that is retained within the media is available to the plant for use after outplanting (Dumroese et al. 2006, 2011), which may explain

Table 1. Fertilizer treatment ($p < 0.001$) and germination treatment ($p < 0.02$) had a significant effect on height and root collar diameter growth.

Treatment	Height growth (cm) and (standard error)	Root collar diameter growth (mm) and (standard error)
	Osmocote® incorporated	
Subirrigation only	15.9 (4.0)	1.57 (0.51)
Germination cloth	21.5 (5.4)	2.03 (0.31)
Overhead misting	18.2 (4.0)	1.73 (0.40)
Germination cloth and overhead misting	15.1 (3.6)	1.78 (0.38)
	Osmocote® top dressed	
Subirrigation only	18.9 (4.2)	1.78 (0.43)
Germination cloth	20.4 (4.0)	2.04 (0.43)
Overhead misting	22.5 (5.0)	1.97 (0.46)
Germination cloth and overhead misting	20.0 (3.8)	1.95 (0.40)

cm = centimeter. mm = millimeter.

Note: The standard errors are for five replications.

why we observed greater growth of the top-dressed seedlings after outplanting. The top-dressed fertilizer, which stays relatively dry in a subirrigation system compared with the incorporated fertilizer, may have broken down more slowly and, therefore, may have been available to the seedling in greater amounts after outplanting. Improving seedling quality or outplanting success with fertilizer has its limits, and extremely high rates of fertilization can negatively impact seedling quality and survival (Bumgarner et al. 2015), especially on dry sites. The germination treatments also had significant effects on growth after outplanting, which demonstrates the importance of following seedlings through outplanting to determine if nursery cultural practices continue to affect seedlings after outplanting (Davis et al. 2011).

This experiment demonstrated that it is possible for seed to germinate using subirrigation. This finding leads to further questions about how to improve germination and what options are best for fertilizing seedlings in subirrigation. Subirrigation will not be the irrigation method of choice for every nursery or every species, but it is an important tool that nursery growers can consider among their propagation options.

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