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Celebrating 75 years of Tree Planters' Notes

On the cover:
The forests of the Pacific Northwest are case studies in managing an effective "restoration pipeline." Seed collection, nursery operations, planting, and sustainable harvesting all play a part in the conservation of timber resources. USDA Forest Service photo by Preston Keres

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Letter from the Editor

Dear TPN Reader,

This year marks the 75th anniversary of *Tree Planters' Notes*. The release of the very first issue in 1950 featured a list of forest tree (and a few other) nurseries and their production in the fiscal year. Back then, the purpose of the publication was being a platform for the nursery industry to share practical information, best practices, and the latest research. Today, the purpose remains steadfast in these core values so managers can produce the best plants for their intended purposes with the best chance for success. The U.S. Department of Agriculture, Forest Service is proud to support a periodical that offers a forum for plant growers everywhere to share their knowledge. The agency continues to support free access to this publication in both hard copy and electronic formats to help meet the Forest Service mission of conserving forests for current and future generations.

Tree Planters' Notes reflects a humbleness and long-term mindset of the nursery industry and the greater reforestation and restoration space. Practitioners are always learning how plants grow and respond to their environments, and learning is a worthy investment. Research trials, particularly involving trees, require multiple collaborators across years—or even decades. In "Conifers' Responses to Stock Types After 11 and 12 Years in Northern Idaho," Hsu and Nelson report results from a study made possible through a partnership between private industry and the University of Idaho.

Another value of *Tree Planters' Notes* is that its longevity connects the present to the past. As Tom Landis shares in "Stories and Lessons Learned From a Career in Reforestation and Restoration Nurseries," there is value in "consult[ing] published literature—even sometimes going way back—and the answer just might be there."

And lastly, with the larger societal focus on making businesses efficient and profitable, we cannot overlook that nurseries, even nonprofit nurseries, are businesses too, accountable to employees, funders, customers, and accountants. However, there are future outcomes nurseries produce that have no line item on a balance sheet. The reforestation efforts described in Vradenburg's article, "Reforestation of Nonindustrial Private Forest Lands Following Two Oregon Wildfires," will grow trees that provide wildlife habitat, improve water quality, and generate future income for landowners in south-central Oregon. Starting a native plant nursery in a public school, as described by Vanderwal in "Incorporating Native Plant Restoration Nurseries into Public School Programs," will produce future nursery employees and citizens aware of why supporting nurseries is a worthwhile investment.

Growing plants makes a difference,

Andrea Watts

Tree Planters' Notes (TPN) is published by the Forest Service, an agency of the U.S. Department of Agriculture. The purpose of Tree Planters' Notes is to benefit the nursery community by sharing information and raising awareness of issues related to nursery production and outplanting of trees, shrubs, and native plants for reforestation, conservation, and restoration.

TPN welcomes unsolicited manuscripts from readers on any subject related to nursery production. For editorial questions or to contribute an article, contact Editor Andrea Watts at andrea.watts@rngr.net. Tree Planters' Notes is available online **(https://rngr.net/publications/tpn)**.

TPN accepts both technical and research articles; each is reviewed by the editor. Please see the guidelines for authors for details about editorial policy, formatting, style, and submission **(www.rngr.net/publications/tpn/author_guidelines)**.

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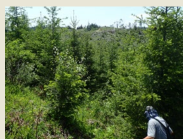

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Events and Announcements

Upcoming Nursery Conferences and Meetings

2025 Forest Nursery Association of British Columbia Conference

September 23–25, 2025, Mary Winspear Centre, Sidney, BC

https://www.fnabc.com/

2025 Environmental Horticulture Workshop and IR-4 Grower Survey

October 7–8, 2025, Kansas City, Missouri

https://www.ir4project.org/events/2025-eh-workshop/

If you work in the nonprofit nursery space, you're invited to join the recently formed Non-Profit Nursery Network. The group meets virtually each month to share best practices and exchange information. To join, email Megan Higgins Palomo, heritage nursery director with Tree Pittsburgh, megan@treepittsburgh.org.

Tree Planters' Topics

Do you have an idea for an article in *Tree Planters' Notes*? Is there a topic you would like to see covered in a future issue? Please send your ideas to Editor Andrea Watts. The editorial team at wants this periodical to remain relevant to practitioners' needs, and your ideas will help ensure that it does.

Contact Andrea at andrea.watts@rngr.net.

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Reforestation of Nonindustrial Private Forest Lands Following Two Oregon Wildfires

Leigh Ann Vradenburg

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Abstract

Recent large wildfires in south-central Oregon have challenged the capacity of restoration partners and necessitated innovative partnerships and approaches to set burned acres on the path to forest recovery. The nonprofit Klamath Watershed Partnership (KWP) has worked with owners of nonindustrial private forest lands affected by the 242 Fire (in 2020) and the Bootleg Fire (in 2021) to restore and reforest these lands. KWP has leveraged diverse funding sources and an abundance of in-kind support from the Oregon Department of Forestry and Green Diamond Resource Company, an industrial timber company. This collaboration has facilitated the reforestation of more than 2,300 acres following the 2024 planting season, with more than 2,000 planned for 2025. This case example shows how collaboration may overcome the challenges presented by working across multiple nonindustrial lands and emphasizes that all lands are relevant in landscape-scale recovery efforts.

Introduction

In 2020 and 2021, Klamath and Lake Counties in south-central Oregon experienced their largest wildfire years in recent history (figure 1). The Oregon Department of Forestry (ODF) and local watershed councils sought to help private nonindustrial landowners assess forest loss and the need for restoration and reforestation, but the scale of these fires necessitated innovative partnerships. The Klamath-Lake Forest Health Partnership, a collaboration of Federal and State agencies, nonprofits, and private landowners focused on forest health and wildfire resiliency, began a process of identifying opportunities to bring the necessary technical and financial resources to the region to achieve postfire restoration at a landscape scale. Whereas Federal and industrial landowners experienced the greatest loss of acres, the comparatively smaller nonindustrial landowners were at much greater risk of forest land conversion due to their inability to secure resources. Fortunately, the State recognized this disparity and developed programs that would provide critical and timely support to accelerate restoration.

The Klamath Watershed Partnership (KWP) is the nonprofit watershed council for the upper Klamath River Basin that works with private landowners to conserve, enhance, and restore natural resources. Although the local conservation organizations had not previously dealt with postfire restoration, the immediate needs necessitated that KWP take on these reforestation projects. Through its partnerships, the Klamath Lake Forest Health Partnership could ensure that private lands were restored and reforested swiftly.

Unlike working with one large ownership to reforest an area, preparing for and conducting reforestation across multiple ownerships presents a unique set of challenges. Reforestation success is susceptible to the nuances of technique, site conditions, microsite selection, and other environmental factors that may be within or outside the control of the planter. Reforestation of multiple nonindustrial private lands at the scale of a wildfire will vary from place to place, but those inherent challenges will be compounded with issues related to land management variability, a paucity of technical expertise, availability of seedlings, and timing and nature of funding. This article highlights how KWP has overcome these issues in postfire reforestation, starting with 30 acres in 2021 in the footprint of the 242 Fire and continuing through with plans for more than 2,000 acres in 2025 in the footprints of the 242 and Bootleg Fires.

Editor's Note: *The "Reforestation in Oregon" article, published in the Tree Planters' Notes fall 2023 issue, provides a helpful context for how reforestation is undertaken in the State (Christiansen et al. 2023).*

The Project

Site Description

In September 2020, the 242 Fire burned 14,473 acres north and west of Chiloquin in Klamath County in south-central Oregon. Approximately one-third of the burned acres were private land, primarily dry-type forests dominated by ponderosa pine (*Pinus ponderosa*). The Bootleg Fire, which started July 6, 2021, burned over 413,000 acres and is the third-largest wildfire in recent Oregon history. Although the fire burned primarily on the Fremont-Winema National Forest (260,000+ acres) in Klamath and Lake Counties, private lands, predominately industrial timber, accounted for more than 150,000 acres that burned. The lands owned by nonindustrial private ownership were primarily stocked with ponderosa pine, but also included lodgepole pine (*Pinus contorta*), white fir (*Abies concolor*), incense cedar (*Calocedrus decurrens*), and western juniper (*Juniperus occidentalis*).

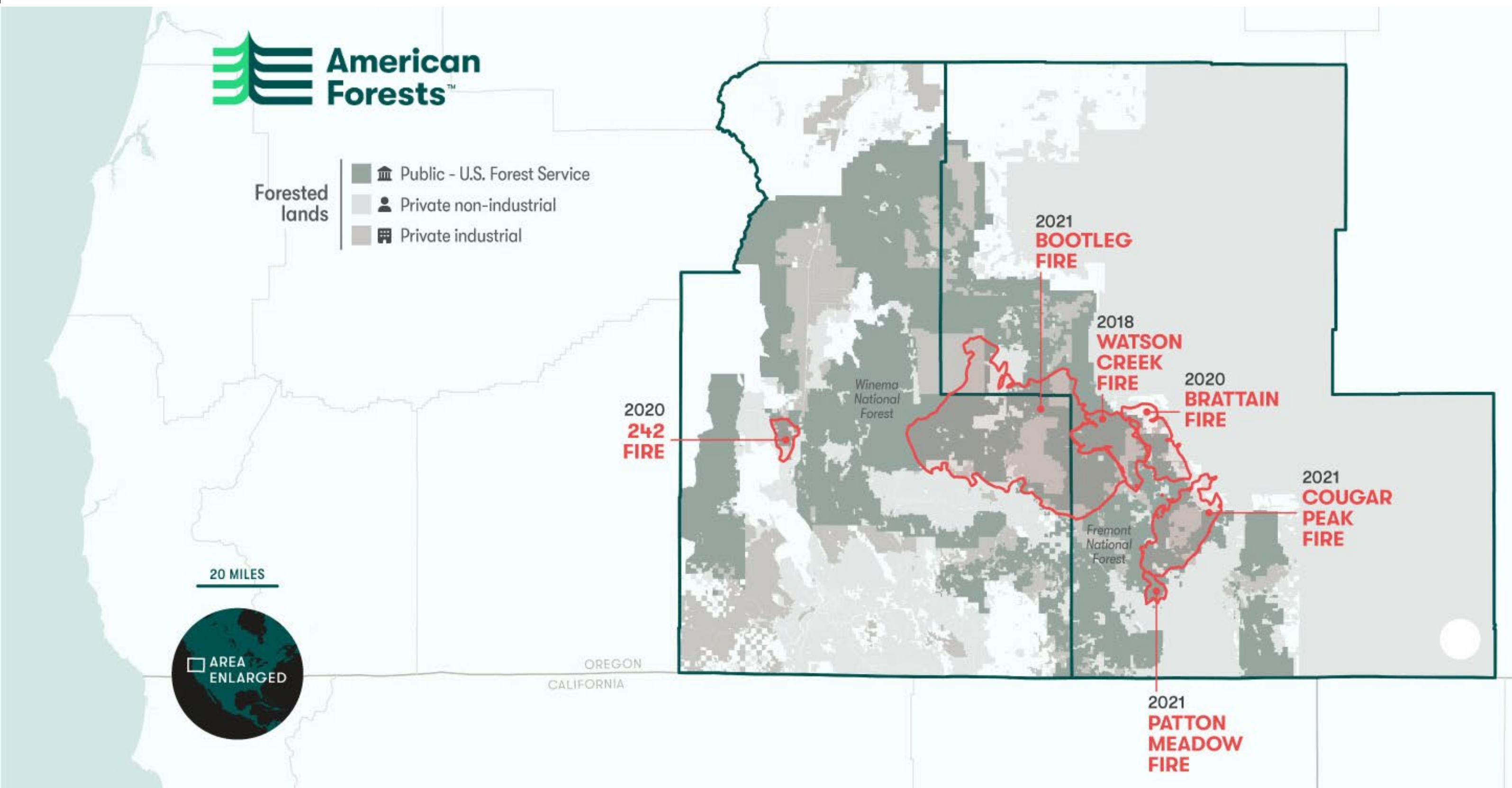

Figure 1—The 242 and Bootleg Fires are two of six fires that have burned in Klamath and Lake Counties since 2018. Collectively, these six fires burned approximately 660,000 acres. Map by American Forests, 2023.

Prioritization

Local Federal, State, Tribal, and industrial partners developed an integrated postfire resilience strategy to assess and prioritize restoration and reforestation across six recent fires in Klamath and Lake Counties (Pansing et al. 2023). This assessment found that many of the acres burned at high severity and the resulting lack of seed sources, exacerbated by a warmer and drier climate, would hinder, if not inhibit, natural regeneration of native tree species.

Although these prioritizations sought to identify areas where reforestation had the greatest likelihood of success and greatest benefit based on land management priorities, they did not have the purpose, function, or resolution to guide reforestation across numerous, discrete nonindustrial parcels. If time, funding, or seedlings are limiting, then prioritization is necessary.

With the goal of reforesting lost forested acres, KWP's approach is to work with every interested landowner. This site-specific approach seeks to reforest areas while also preserving limited habitats, such as meadows and aspen stands, by not reforesting them. The impetus behind this approach is recognition that funding and seedlings may not be available to these landowners in the future and acknowledging that the social and economic impacts of the fire on the community are as important to repair as the ecological impacts. Although recovery is a decades-long process, landowners are tremendously appreciative of the hope that newly planted seedlings bring.

Approach

Land Management

Following a wildfire, private landowners may face multiple issues that take precedence, such as loss of structures or improvements, impacts to land management, and the trauma of the event. There may be a lack of understanding regarding the timelines and processes for salvage logging or other techniques for removing burned material, or even if reforestation is needed. The outreach and educational components are ongoing in the months and years following a wildfire to ensure landowners receive the support needed to make timely decisions to set their properties on the trajectory for forest restoration.

Following the 242 Fire, many landowners consulted the Oregon Department of Forestry and other local resources to identify, clear, and transport burned material to processing mills and generate some profit from logs or chips. This early progress on the landscape is due in part to the landowners living in the area and having greater access to these resources, as well as more time and opportunity for getting materials to the mills. In contrast, once the Bootleg Fire was extinguished, winter was fast approaching, mills were full from previous fires, and wood quality was rapidly declining. Small landowners, nearly 90 percent of whom lived outside of the area, were at a disadvantage for acquiring technical and operational support for site prep. Additionally, markets for materials were farther from the Bootleg footprint than the 242.

KWP and others have used various means to reach and engage landowners, including community meetings, mailings, and phone calls. Although initial estimates and planning for restoration and reforestation were developed based on geographic information systems (GIS) analyses with taxlot maps and rapid assessment of vegetation condition after wildfire (RAVG) maps, KWP worked with the State and private contractors to visit and map every property considered for reforestation. Landowner input was necessary at every site to understand previous conditions, the work done to date, future objectives, and desired conditions.

Technical Expertise

Silviculture in this region is primarily driven by uneven-aged management practices where reforestation is not needed. Following the wildfires in 2020 and 2021, it became apparent that the forestry professionals in the region lacked the resources and experience to conduct restoration across all ownerships at the scale and timelines needed. This lack of expertise particularly impacted the nonindustrial private landowners who were largely dependent on outside technical support and resources.

Fortunately, two entities in the region, the local State Forests division of the Oregon Department of Forestry and Green Diamond Resource Company, an industrial timber company, have experience conducting reforestation on their respective lands. Although these partners did not have the capacity or objective to undertake reforestation on private lands, they were (and continue to be) generous with information sharing.

In the initial years after these fires, with funding from the State, KWP secured seedlings with the help of the Oregon Department of Forestry and Green Diamond and did not have to manage the upfront seed collection aspects. However, KWP did need to understand nursery coordination, seedling storage and transportation, planting contracts, timing of planting, and other logistics to provide a comprehensive reforestation effort (figure 2). Reforestation infrastructure in the area was also deficient, consisting of old, unstaffed coolers that were remnants of previous Federal programs.

Seedlings

Seed and seedling shortages across the West have highlighted a need that must be addressed in this new era of megafires. This realization is most impactful for private landowners who do not have seed stores and depend on seed collected by others on other properties in appropriate seed zones.

After the 242 Fire, this was a minor issue because Green Diamond and the Sun Pass State Forest had local seed available for purchase. This seedling availability proved timely because the interested private lands had been site prepped, salvage logged, or both in the 1–3 years preceding planting. Partners have reforested 2,400 acres across 55 land ownerships (68 percent of all private acres in the fire's footprint) as of 2025.

The Bootleg Fire presented a different challenge. It had a much larger footprint, and initially there was no appropriate seed available for private landowners, nor was there a State forest with seed reserves. Green Diamond, due to their loss of more than 110,000 acres, heavily invested in using their stored seed and collecting more for reforestation of their industrial land. Nonindustrial private landowners were reliant on collaborative, long-term cone collection efforts driven by the U.S. Department of Agriculture's Forest Service and the nonprofit American Forests under their "Integrated Post-Fire Resilience Strategy" (Pansing et al. 2023), which could put them on a timeline and trajectory to miss funding opportunities and prime planting windows.

However, in 2024, Green Diamond worked with KWP to provide almost 43,000 seedlings for purchase by nonindustrial private landowners. Green Diamond is also working with KWP and the Oregon Department of Forestry to provide approximately 750,000 seedlings from their woods-run collected seed stores to plant in 2025. Although it is almost 4 years since the fire, many of the properties to be planted were prepared in fall 2024 and are ready to receive seedlings.

Figure 2—In 2023, KWP coordinated the planting of 177,600 seedlings across 592 acres of private nonindustrial lands. Photo by Leigh Ann Vradenburg, 2023.

Funding and In-Kind Support

As a nonprofit, KWP secures grants and other types of support to conduct projects. In the case of these and other recent wildfires, the State of Oregon, through the Watershed Enhancement Board and the Department of Forestry, has developed timely and meaningful levels of support for restoration of private land. KWP secured two emergency grants through the watershed board's 2020 and 2021 postfire programs and two additional grants, all totaling $2.4 million. The U.S. Partners for Fish and Wildlife Program has also supported postfire restoration, including reforestation, with nearly $700,000 in funding. The Oregon Department of Forestry secured more than $5.8 million from the Forest Service in the form of disaster relief funds for wildfire recovery, largely focused on the Klamath and Lake County fires. This funding and effort will also include the development of new staff positions at the department focused on postfire support at the local level.

Equally important to this effort is the in-kind support from the Oregon Department of Forestry and Green Diamond. Oregon wanted to develop additional and ongoing opportunities for seedling production for private landowners impacted by wildfires. KWP's success reforesting the footprint of the 242 Fire was largely due to the Department of Forestry's efforts at identifying seed and setting up nursery contracts. In 2024, this involved multiple seed lots at three nurseries, which KWP would not have had the capacity or connections to do otherwise.

Green Diamond's engagement in reforestation efforts began in 2021 when they donated extra seedlings from their 242 Fire reforestation to KWP for planting on private lands. They helped KWP work with a planting contractor and stored the seedlings. In 2023 and 2024, Green Diamond grew their in-kind support as the number of seedlings and planting days for the 242 Fire increased dramatically. In 2023 Green Diamond stored 177,600 seedlings for KWP in their refrigerated trucks, providing daily forklift loadout for the planting crew for 2 weeks (figure 3). In 2024 this effort grew to 445,504 seedlings with seedling sorting, counting, and loadout for three crews (figure 4).

Figure 3—Green Diamond's in-kind support for KWP's reforestation efforts included providing logistical support for the 445,504 seedlings that were to be planted in a 2-week period. Photo by Leigh Ann Vradenburg, 2024.

Also in 2024, KWP planted the first nonindustrial private acres in the Bootleg Fire footprint. KWP worked directly with Green Diamond to plant 160 acres on two private properties adjacent to Green Diamond ownership that they were also planting. KWP paid for the seed, seedlings, and planting crew, but Green Diamond's coordination of the entire effort, including provision of planting inspectors, brought efficiencies and cost savings to the project.

Figure 4—Critical to the reforestation success is the availability of planting crews. In south-central Oregon, this forest worker industry is still robust. Photo by Leigh Ann Vradenburg, 2024.

Discussion

The need for postfire restoration and reforestation is increasing and will continue to increase across the Western United States. Because megafires impact all ownerships, entities such as KWP and the Oregon Department of Forestry must be ready to provide resources to owners of private forest lands. Working across multiple private lands presents unique challenges, including variable management regimes and objectives, the need for technical and operational resources, access to appropriate seedlings, and financial support. Thanks to readily available funding and the tremendous support of partners such as Green Diamond Resource Company, dozens of private landowners in the 242 and Bootleg Fires of south-central Oregon will have new forests that are on their way to free-to-grow status. Looking ahead, collaborative efforts such as cone collection and seed storage are being implemented to meet current and future needs across all ownerships. A seed orchard is also in the works to provide seed security in the coming decades, preserving genetic diversity suited to the landscapes of south-central Oregon.

Nonindustrial private landowners may be undervalued at the scale of a wildfire because the relative ecological impact of the acres burned pales in comparison to Federal, State, or industrial ownership, or because the ownerships are so variable and subdivided that restoration may occur as disparate postage stamps. At the landscape scale, however, the process of rebuilding these lands and empowering land stewards has value beyond the acres treated. A form of social license is formed with the community, ensuring private landowners that restoration partners "see" them in the recovery processes. Restoring healthy forests across wildfire footprints is in the best interest of all parties, and with the trending size and severity of fires, every acre and every partner matter.

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Conifers' Responses to Stock Types After 11 and 12 Years in Northern Idaho

Hsin-Wu Hsu and Andrew S. Nelson

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Abstract

When planning the future composition of a forest stand, the target plant concept is a useful guideline for selecting an appropriate stock type. However, there is conflicting data as to whether using a larger stock type affects long-term growth. To test whether stock type affects the long-term growth of three conifer species native to the Pacific Northwest, seedlings of Douglas-fir (*Pseudotsuga menziesii* var. *glauca*), western larch (*Larix occidentalis*), and western white pine (*Pinus monticola*) were grown in five of six container types (313B, 315B, 415B, 415C, 415D, 615A) and planted in 2007 and 2008 at two sites in northern Idaho. Authors measured morphological traits (heights and root-collar diameters) and calculated stem volumes and survival rates through 11 and 12 years. Some species and site combinations showed no difference among stock types while the largest container stock type (615A) had significantly greater growth for all three species. These results suggest that stock type selection may not affect long-term survival and growth in some species, while other species do respond positively to being grown in the 615A stock type. Based upon these results, when determining which stock types to use for a reforestation project in northern Idaho, the target plant concept should be followed and species and site conditions should be considered.

Introduction

The increased intensity and scale of forest disturbances in the Western United States have significantly amplified the demand for seedlings for reforestation, but the capacity is not meeting the demand. Reforestation on lands managed by the U.S. Department of Agriculture's Forest Service has fallen short of demand for over two decades (Dumroese et al. 2019). Increasing reforestation capacity and addressing the reforestation backlog are priorities of the Repairing Existing Public Land by Adding Necessary Trees (REPLANT) Act that became law in 2021. REPLANT and other efforts should help increase seedling production to address demand. For these efforts to be successful, seedlings need to survive and grow at desired rates following planting. This can be achieved by using the best stock type for given site conditions, but when programs call for planting millions of seedlings per year the general trend is using smaller stock types.

There are budget considerations for which stock type to use. Larger seedlings require more medium, fertilizer, and growing space than smaller containers, which increases production costs. If seedlings grown in smaller containers survive and grow comparable to larger ones in the long term, then nursery costs could be reduced without lowering field performance. Therefore, a properly selected stock type can significantly increase the cost-benefit ratio.

The best seedling stock type for a particular site depends on both site conditions and project considerations, such as drought, vegetative competition, and cost-effectiveness. To assist reforestation managers in selecting stock types for a project, the target plant concept was proposed to focus on morphological and physiological seedling characteristics linked to outplanting success (Landis 2009). Although many studies show that field performance is correlated to physiological qualities, physiological tests are often time-consuming and expensive. Therefore, nurseries tend to use morphological traits as indicators of seedling quality (e.g., height and root-collar diameter). Many studies suggest that seedlings with larger height and root-collar diameter outperform smaller seedlings after outplanting (Johansson et al. 2015, Regan et al. 2015, van den Driessche 1984). However, sufficient seedling height and root-collar diameter for a particular species to survive is often regionally specific.

Several studies have examined the impact of stock type selection on interior Douglas-fir (*Pseudotsuga menziesii* var. *glauca*) growth, yet many of these studies are relatively short-term and results are often contradictory. Haase et al. (2006) reported that during the third and fourth growing seasons there were no differences in annual height or stem diameter growth. After 3 years, Douglas-fir seedlings grown in 20-in^3 containers remained larger than seedlings grown in 8-in^3 and 5.5-in^3 containers.

Comparatively, van den Driessche (1992) examined the survival and growth of six different stock types of Douglas-fir over a 6-year period on a site in south-central Vancouver Island. The larger seedlings had a lower mean relative growth rate than smaller seedlings. Due to this growth rate difference, the average stem volume did not differ after six growing seasons despite large initial size differences. Wightman et al. (2018) found similar results where the initial sizes (height, root-collar diameter, shoot and root volumes, and shoot/root ratio) differed significantly among stock types, but initial size differences disappeared after 8 years of growth. Pinto et al. (2018) also found the height, height increment, and root-collar diameter of Douglas-fir seedlings cultured in 4.9-in^3 cavities were significantly smaller than the other three sizes (7.9, 12.2, and 15.3 in^3). However, after 2 years, no differences in root-collar growth or mortality among stock types were observed.

These contrasting results make it difficult to determine general trends of stock type impacts on Douglas-fir seedling outplanting performance and suggest early differences among stock types may not continue as trees age. Thus, long-term trials are needed to capture stock type effects that may persist into later stages of a rotation.

A few studies (Pinto et al. 2011, South et al. 2005, Wightman et al. 2018) have examined the stock type effects linked to the seedling size and initial growth in the field, particularly the long-term effects. The general hypothesis is that larger stock types survive better under a broad range of field conditions. Smaller stock types may survive and grow equally well with improved vegetation management programs but may have fewer resources to overcome environmental stress.

The objective of this study is to examine the effect of a seedling's stock type on height, root-collar diameter, volume growth, and seedling survival over an 11- to 12-year period for three commonly planted conifer species: interior Douglas-fir, western larch (*Larix occidentalis*), and western white pine (*Pinus monticola*) at two moderately productive sites in northern Idaho.

Materials and Methods

Species and Seedling Production

The study used three common conifer species—interior Douglas-fir (DF), western larch (WL), and western white pine (WP)—that are ecologically important and economically valuable to western North America. The latitudinal range of DF is the greatest of any conifer of western North America; its native range extends from central British Columbia southward along the Pacific Coast Ranges for about 1,367 mi (2,200 km) and along the Rocky Mountains into the mountains of central Mexico over nearly 2,796 mi (4,500 km) (Herman and Lavender 1990). The deciduous conifer WL grows in a relatively moist, cool climatic zone with low temperatures limiting its upper elevational range and deficient moistures limiting its lower extremes in Montana, Idaho, Washington, Oregon, and southeastern British Columbia (Schmidt and Shearer 1990). WP grows along the west coast, from southern British Columbia southward through Washington and Oregon and in the Cascade Mountains. It is also found in northern California. In the interior, WP grows from British Columbia through eastern Washington and northern Idaho, and into western Montana. Its southernmost interior limit is in the Blue Mountains of northeastern Oregon (Graham 1990).

Seeds from single provenances of DF, WL, and WP were sown in March 2006 and 2007 at the University of Idaho Franklin H. Pitkin Forest Research Nursery and grown intermixed with

operationally produced seedlings. Seedlings were grown in five different sizes (313B for DF and WL, 315B for WP, and 415B, 415C, 415D, and 615A for all three species) of Styroblock (Beaver Plastics, Edmonton, AB, Canada) containers (table 1) using propagation protocols for container-grown seedlings of each species (Dumroese and Wenny 1995; Wenny and Dumroese 1992, 1994).

The seedlings were grown following the same protocol for each species, but being grown in different years resulted in differing greenhouse environments due to local weather conditions. At the end of the growing season, seedlings were lifted and stored in a freezer at 28.4 °F (-2 °C) until planting the following spring.

Outplanting Sites

Following freezer storage, seedlings were outplanted in April 2007 at site 1 and in June 2008 at site 2 in north-central Idaho (table 2). Both sites are western redcedar/bride's bonnet (*Thuja plicata/Clintonia uniflora*) habitat type and mixed, even-aged one-story plantations (figure 1). Both sites were treated with broadcast burn before planting. No thinning was conducted on the site after planting. The site index is 69 at site 1 and 94 at site 2 (Douglas-fir model). The study was a randomized complete block design: 4 blocks at site 1 and 3 blocks at site 2. The seedlings were planted in rows with 8 ft (2.4 m) of spacing between seedlings and 10 ft (3.0 m) between rows. At both sites, there were 20 seedlings per stock type of each species in each block. Prior to outplanting, WL seedlings grown in 615A containers were top pruned to remove tissue damaged due to dehydration during freezer storage. Additionally, at site 2, spring temperatures were too cool to outplant in April (NOAA), and seedlings were planted in June. By the end of June, temperatures quickly shifted from average spring (March to May) temperatures of 38.9 °F (3.8 °C) to summer (June to August) temperatures of 54.5–63.3 °F (12.5–17.4 °C).

Table 1—Styroblock types, configuration, and species associated with each type

Styroblock type	Species	Cavities per block (row x column)	Diameter (mm (in))	Depth (mm (in))	Volume (mL (in^3))
313B	DF, WL	160 (16 x 10)	30 (1.17)	126 (4.97)	65 (3.9)
315B	WP	160 (16 x 10)	30 (1.18)	151 (5.96)	90 (5.5)
415B	DF, WL, WP	112 (14 x 8)	36 (1.40)	148 (5.83)	108 (6.6)
415C	DF, WL, WP	91 (13 x 7)	39 (1.53)	151 (5.96)	130 (7.9)
415D	DF, WL, WP	77 (11 x 7)	42 (1.65)	151 (5.96)	164 (10.0)
615A	DF, WL, WP	45 (9 x 5)	59 (2.33)	151 (5.96)	336 (20.5)

DF = Douglas-fir; WL = western larch; WP = western white pine

Table 2—Outplanting sites and measurement dates

	Site 1	Site 2
Elevation	2,900 ft (900 m)	3,100 ft (945 m)
Aspect	Northwest	Southwest
Slope	17%	19%
Site preparation	Broadcast burn	Broadcast burn
Outplanting date	April 26, 2007	June 5, 2008
First measurement	Following outplanting	Following outplanting
Second measurement	November 2007	October 28, 2008
Third measurement	October 2014, 2010	September 17, 2010
Final measurement	June 19, 2019	June 24, 2019

Measurements and Statistical Analysis

Height, root-collar diameter, and survival were measured four times: following outplanting, at the end of the first growing season, in 2010, and in 2019 (table 2). Stem volume (V) was calculated by using the formula for an elliptical cone (Pinto et al. 2011).

$$V = (\pi d^2 h)/6$$

where

d is the root-collar diameter (cm)

h is the height (cm)

The quasi-binominal logistic function estimated the odds of survival for each millimeter increase in diameter. One-way analysis of variance tested the stock types' effects on seedling survival rate, height, root-collar diameter, and stem volumes at each time point. Statistical significance was recognized at $\alpha = 0.05$ for all models. All analyses were done in R Programming (https://www.r-project.org/).

Figure 1—This study tested Douglas-fir, western larch, and western white pine seedling growth based on stock type at two similar sites in north-central Idaho. Photo by Andrew Nelson, 2019.

Results

Survival Rate and Odds of Survival

The survival rates of DF, WL, and WP decreased over time at both sites (figure 2). The survival rates between stock types were comparable and higher at site 1 than site 2. At site 2, the survival rates were lower than 80 percent, 65 percent, and 75 percent for DF, WL, and WP, respectively, in the 11th year. The survival rates of the species at both sites were not statistically different among stock types at each time of measurement (DF: p=0.076 to 0.736; WL: p=0.082 to 0.86; WP: p=0.13 to 0.934). The odds of survival did not change as root-collar diameter increased significantly in most years at site 1 (figure 3). However, the odds of survival increased as root-collar diameter increased in most years at site 2 (figure 4). The odds of survival in relation to initial root-collar diameter increased over time. For example, the odds of survival for WP at site 2 increased from 4.7 percent to 10.1 percent for each millimeter increase in root-collar diameter between years 1 and 11.

Height, Root-Collar Diameter, and Stem Volume

Height

Douglas-fir seedlings in the 615A stock type were the tallest for the entire study period at site 2, increasing from 13.9 in (35.3 cm) after outplanting to 200.9 in (510.3 cm) 11 years later. Differences between the other four stock types at site 2 were less consistent. For example, although 415D seedlings were shorter than other stock types after outplanting, their height did not differ in the following years through age 11. Similar trends were observed at site 1; 615A seedlings were the tallest in all years, while the other four stock types were less consistent following planting through age 12 (table 3a).

The seedling heights of WL in the 615A stock type were the tallest—13.5 in (34.2 cm)—after outplanting at site 1, but the difference among stock types shrank after the 1st and 3rd years and eventually disappeared in the 12th year. At 7.0 in (17.9 cm), WL 615A seedlings were also the tallest at the time of outplanting at site 2, but there was no difference between stock types immediately after the 1st growing season, which persisted through the 11th year (table 3b).

The seedling heights of WP in different stock types were significantly different in all years, and 615A was consistently the tallest: from 8.1 in (20.6 cm) after outplanting to 110.4 in (280.4 cm) 12 years later at site 2. However, significant differences in heights among stock types after outplanting and in the 12th year at site 1 were not observed (table 3c).

Root-Collar Diameter

DF 615A seedlings had the largest root-collar diameters across all years at site 1. Site 1 also had a greater differentiation of root-collar diameter than site 2; seedlings in larger stock types had larger increases in root-collar diameter through the third year after planting than those in smaller stock types. By the 12th year, root-collar diameter was greatest for the 415D and 615A containers: 3.2 in (81.2 mm) and 3.18 in (80.7 mm), respectively. At site 2, the DF 615A seedlings had the largest root-collar diameters, which persisted over time, while there were no differences among the other four stock types (table 4a).

The root-collar diameters of WL seedlings in the 615A stock type were also the largest in all years and the same as 415D, which was 3.07 in (78.0 mm) in the 12th year at site 1. The diameters of WL in 615A were the largest after outplanting at site 2. However, the root-collar diameter differences among stock types disappeared in the 11th year (table 4b).

Following outplanting and after the first year at site 1, WP 615A seedlings had the largest root-collar diameters (table 4c). However, the root-collar diameters of these seedlings were smaller than those in 415D containers in the 3rd year and smaller than both 415D and 415C containers in the 12th year. Root-collar diameters of WP in 615A were also the largest in all years at site 2. However, by the 11th year, there were no differences among stock types in root-collar diameter.

Stem Volume

DF 615A seedlings at site 1 had the largest stem volume for the entire study period, but seedlings in the 415D stock type had a comparable volume in the 12th year. The stem volumes of DF in 615A were also the largest for the study duration at site 2. The other four stock types did not have significant differences in volume during all years (table 5a).

The volumes of WL in 615A were also the largest after outplanting and in the first and third years at site 1. By the 12th year, volumes in 615A and 415D containers were similar: 1,495.5 in^3 (24,506.4 cm^3) for 615A and 1,501.8 in^3 (24,609.9 cm^3) for 415D (table 5b). At site 2, the stem volumes of WL in 615A were also the largest after outplanting and in the first year, and almost the same as 415D in the second year: 11.91 in^3 (195.2 cm^3) for 615A and 12.06 in^3 (197.7 cm^3) for 415D. However, by the 11th year, no significant differences among stock types were found.

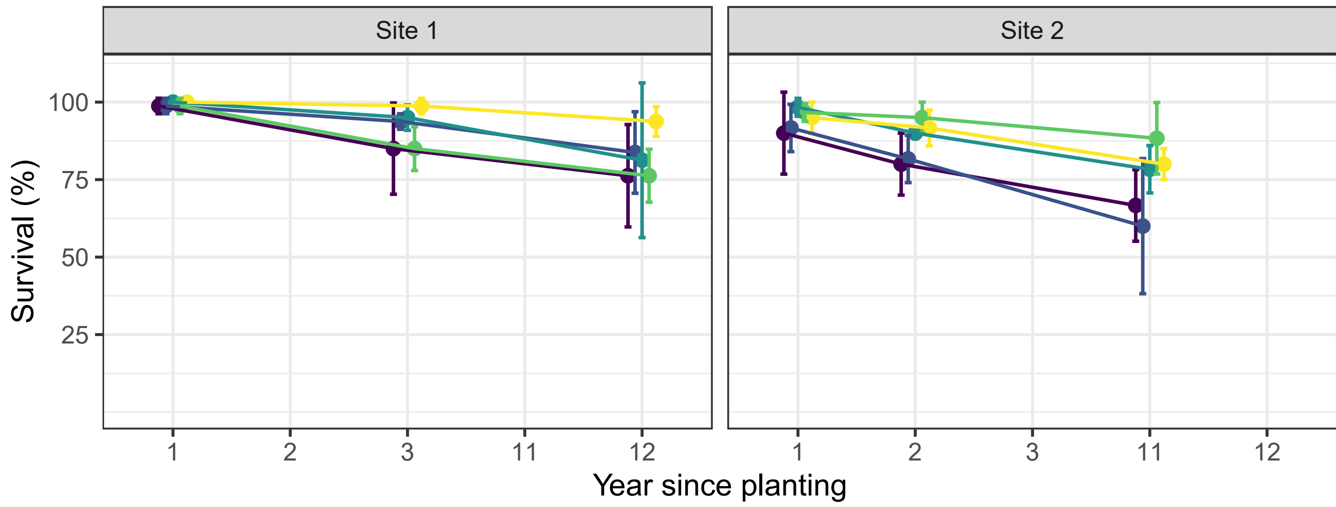
The stem volumes of WP 615A seedlings were also the largest after outplanting and in the 1st and 3rd years at site 1, but by the 12th year, there were no significant differences among stock types (table 5c). The volumes of WP 615A seedlings at site 2 were also the largest in all years and showed that there were significant differences among stock types in all years.

Discussion

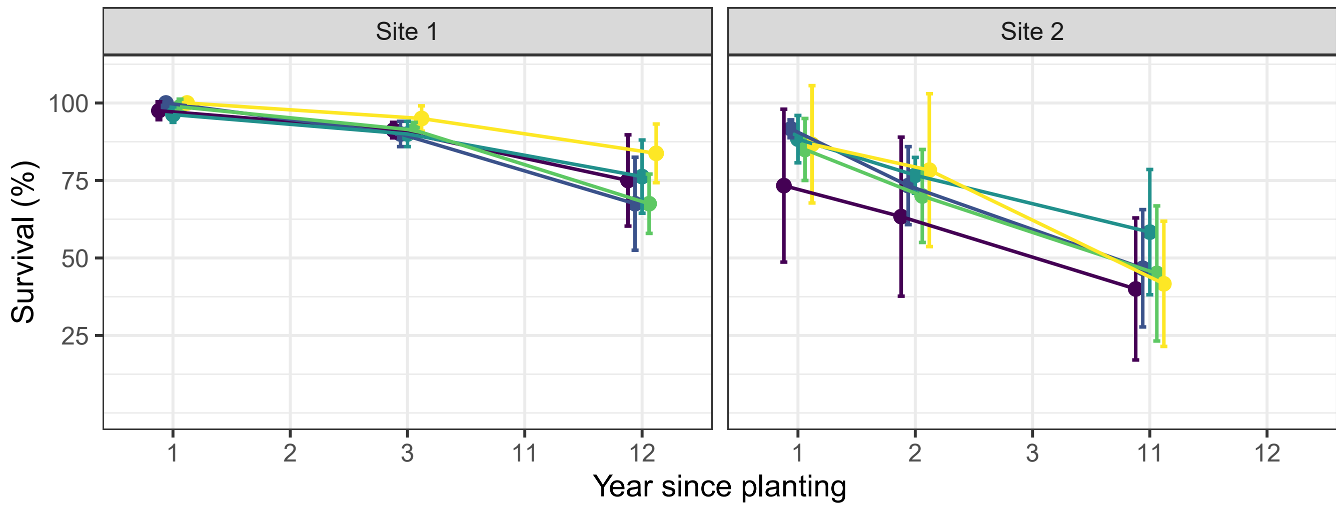
Large seedlings usually have higher survival rates than small seedlings after outplanting (van den Driessche 1984), although smaller seedlings may survive better on dry sites (Tuttle et al. 1987, van den Driessche 1991). Survival was slightly greater, although not statistically different, for larger stock types in this study (see figure 2). The inability to detect differences could be due to site quality since both sites are considered good quality for northern Idaho. However, survival rates varied more at each time point and were lower at site 2 than site 1. A possible cause is because the temperatures quickly changed from 38.9 °F (3.8 °C) to 54.5–63.3 °F (12.5–17.3 °C), and seedlings may have had less time with moist soil to grow new roots.

Stock type 313B 415B 415C 415D 615A

(a) Douglas−fir



(b) Western Larch



(c) Western White Pine

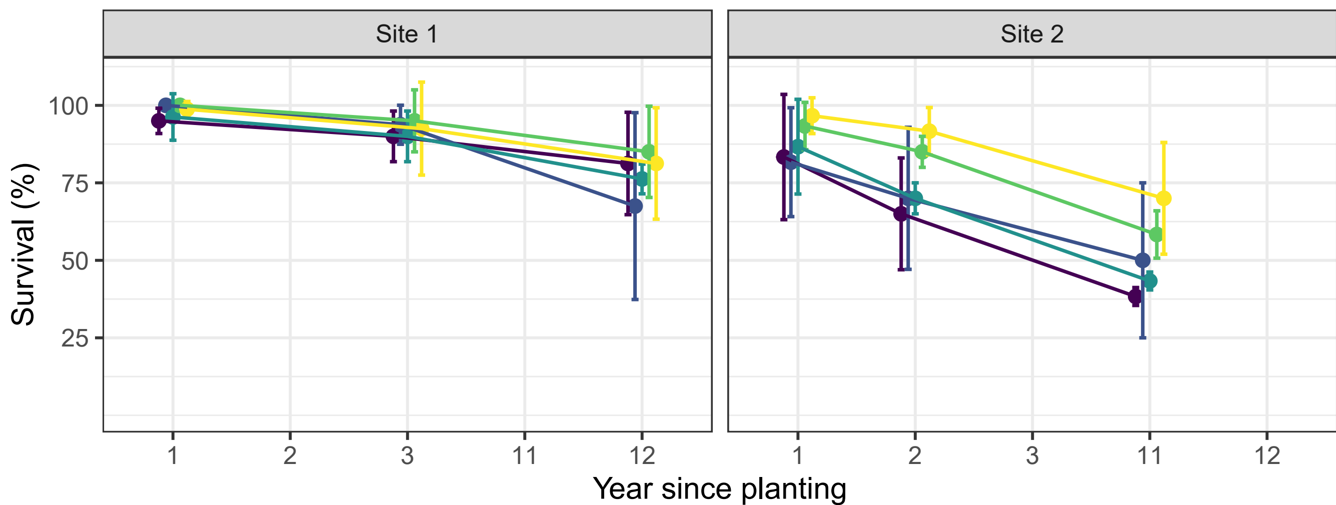


Figure 2—The survival rates of different stock types after different years since planting for (a) Douglas-fir, (b) western larch, and (c) western white pine at site 1 and site 2. There was no statistical difference among stock types at each time point.

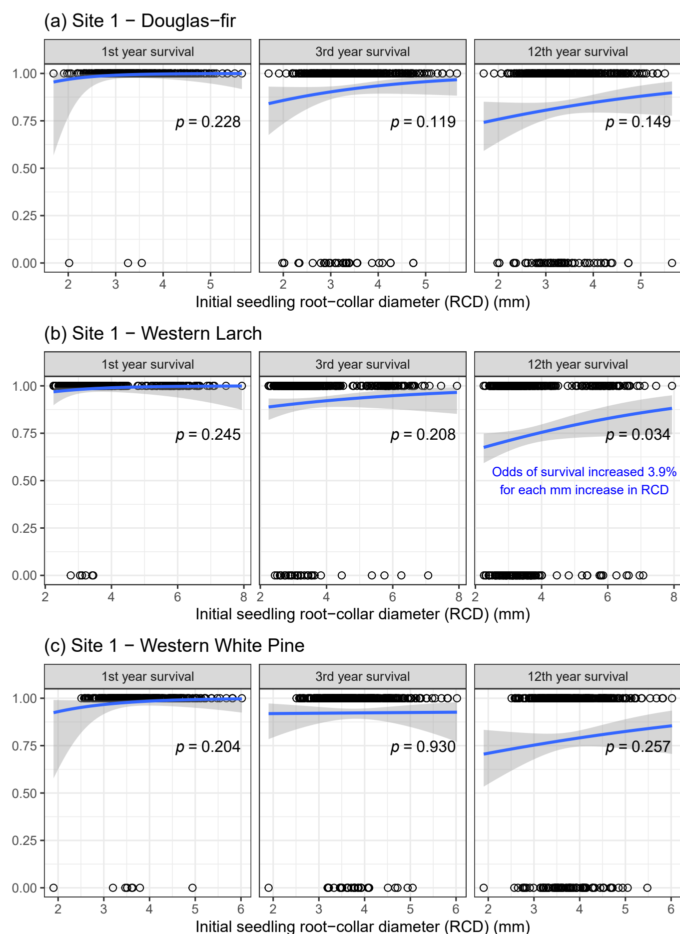


Figure 3—The odds of survival by initial root-collar diameter after different years since planting for (a) Douglas-fir, (b) western larch, and (c) western white pine at site 1.

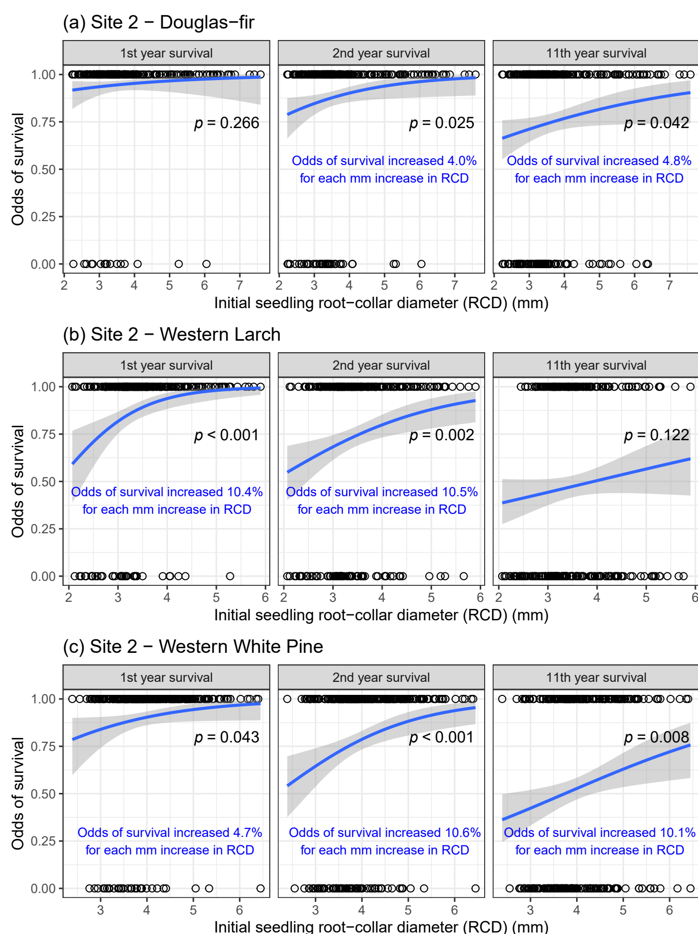


Figure 4—The odds of survival by initial root-collar diameter after different years since planting for (a) Douglas-fir, (b) western larch, and (c) western white pine at site 1.

Table 3a—Heights in centimeters (inches) by stock type for Douglas-fir at sites 1 and 2

	Site 1				Site 2			
Stock type	After planting	1st year	3rd year	12th year	After planting	1st year	2nd year	11th year
313B	16.7 ± 1.9[cd] (6.6 ± 0.8)	23.6 ± 3.0[c] (9.3 ± 1.2)	89.0 ± 25.5[c] (35.0 ± 10.0)	471.1 ± 100.6[ab] (185.5 ± 39.6)	18.7 ± 1.8[bc] (7.4 ± 0.7)	26.8 ± 4.5[b] (10.6 ± 1.8)	67.5 ± 16.9[b] (26.6 ± 6.7)	442.2 ± 110.8[b] (174.1 ± 43.6)
415B	16.1 ± 1.7[d] (6.4 ± 0.7)	23.4 ± 2.8[c] (9.2 ± 1.1)	90.6 ± 26.2[c] (35.7 ± 10.3)	466.9 ± 122.6[b] (183.8 ± 48.3)	20.2 ± 2.6[b] (8.0 ± 1.0)	29.3 ± 4.4[b] (11.5 ± 1.7)	69.5 ± 14.7[b] (27.4 ± 5.8)	419.8 ± 116.6[b] (165.3 ± 45.9)
415C	17.8 ± 2.1[b] (7.0 ± 0.8)	26.2 ± 3.2[b] (10.3 ± 1.3)	99.5 ± 26.2[bc] (39.2 ± 10.3)	476.8 ± 110.5[ab] (187.7 ± 43.5)	19.5 ± 1.9[b] (7.7 ± 0.7)	27.6 ± 3.8[b] (10.9 ± 1.5)	76.0 ± 16.8[b] (29.9 ± 6.6)	446.4 ± 88.3[b] (175.8 ± 34.8)
415D	17.2 ± 2.6[bc] (6.8 ± 1.0)	26.2 ± 3.6[b] (10.3 ± 1.4)	104.0 ± 23.6[b] (41.0 ± 9.3)	516.3 ± 108.2[ab] (203.3 ± 42.6)	17.8 ± 2.0[c] (7.0 ± 0.8)	26.9 ± 5.8[b] (10.6 ± 2.3)	71.9 ± 15.4[b] (28.3 ± 6.1)	448.7 ± 103.8[b] (176.7 ± 40.9)
615A	32.7 ± 3.3[a] (12.9 ± 1.3)	42.0 ± 4.8[a] (16.5 ± 1.9)	122.1 ± 24.7[a] (48.1 ± 9.7)	520.6 ± 114.1[a] (205.0 ± 44.9)	35.3 ± 5.8[a] (13.9 ± 2.3)	48.1 ± 7.1[a] (18.9 ± 2.8)	100.1 ± 24.0[a] (39.4 ± 9.5)	510.3 ± 113.7[a] (200.9 ± 44.8)
p-value	<0.001***	<0.001***	<0.001***	<0.01**	<0.001***	<0.001***	<0.001***	<0.001***

Table 3b—Heights in centimeters (inches) for western larch at sites 1 and 2

Stock type	Site 1				Site 2			
	After planting	1st year	2nd year	12th year	After planting	1st year	2nd year	11th year
313B	15.5 ± 2.1^{b} (6.1 ± 0.8)	29.6 ± 9.6^{c} (11.6 ± 3.8)	143.2 ± 45.6^{b} (56.4 ± 17.9)	521.4 ± 150.6 (205.3 ± 59.3)	15.6 ± 2.8^{bc} (6.1 ± 1.1)	33.9 ± 8.1 (13.4 ± 3.2)	89.9 ± 25.1 (35.4 ± 9.9)	439.6 ± 124.1 (173.1 ± 48.9)
415B	15.5 ± 2.2^{b} (6.1 ± 0.8)	32.2 ± 9.6^{bc} (12.7 ± 3.8)	153.3 ± 44.3^{ab} (60.4 ± 17.4)	535.4 ± 159.8 (210.8 ± 62.9)	14.8 ± 1.9^{bc} (5.8 ± 0.7)	35.3 ± 11.1 (13.9 ± 4.4)	106.1 ± 34.8 (41.8 ± 13.7)	464.7 ± 148.8 (183.0 ± 58.6)
415C	15.7 ± 2.8^{b} (6.2 ± 1.1)	34.5 ± 10.2^{b} (13.6 ± 4.0)	151.4 ± 37.4^{ab} (59.6 ± 14.7)	558.6 ± 159.6 (219.9 ± 62.8)	15.7 ± 2.8^{b} (6.2 ± 1.1)	34.4 ± 10.3 (13.5 ± 4.0)	94.0 ± 24.2 (37.0 ± 9.5)	467.7 ± 174.2 (184.1 ± 68.6)
415D	15.5 ± 2.3^{b} (6.1 ± 0.9)	36.2 ± 12.3^{b} (14.3 ± 4.9)	157.9 ± 47.4^{ab} (62.2 ± 18.7)	557.8 ± 183.1 (219.6 ± 72.1)	14.4 ± 2.0^{c} (5.7 ± 0.8)	39.3 ± 12.2 (15.5 ± 4.8)	106.8 ± 36.7 (42.0 ± 14.4)	457.5 ± 178.4 (180.1 ± 70.2)
615A	34.2 ± 2.8^{a} (13.5 ± 1.1)	48.5 ± 8.4^{a} (19.1 ± 3.3)	169.7 ± 45.6^{a} (66.8 ± 17.9)	598.1 ± 148.3 (235.5 ± 58.4)	17.9 ± 3.9^{a} (7.0 ± 1.5)	38.1 ± 13.2 (15.0 ± 5.2)	105.6 ± 38.6 (41.6 ± 15.2)	395.9 ± 170.0 (155.9 ± 66.9)
p-value	<0.001***	<0.001***	<0.01**	0.074	<0.001***	0.073	0.069	0.389

Table 3c—Heights in centimeters (inches) for western white pine at sites 1 and 2

Stock type	Site 1				Site 2			
	After planting	1st year	2nd year	12th year	After planting	1st year	2nd year	11th year
315B	12.0 ± 2.4 (4.7 ± 1.0)	17.0 ± 2.9^{c} (6.7 ± 1.1)	61.4 ± 18.0^{b} (24.2 ± 7.1)	345.9 ± 120.4 (136.2 ± 47.4)	14.7 ± 2.6^{c} (5.8 ± 1.0)	20.0 ± 3.2^{c} (7.9 ± 1.3)	52.3 ± 12.7^{c} (20.6 ± 5.0)	200.8 ± 74.0^{b} (79.1 ± 29.1)
415B	12.3 ± 2.4 (4.8 ± 1.0)	18.0 ± 2.8^{bc} (7.1 ± 1.1)	66.9 ± 20.6^{b} (26.3 ± 8.1)	362.4 ± 107.2 (142.7 ± 42.2)	17.5 ± 4.3^{b} (6.9 ± 1.7)	21.8 ± 4.6^{bc} (8.6 ± 1.8)	57.9 ± 16.0^{bc} (22.8 ± 6.3)	219.9 ± 74.8^{b} (86.6 ± 29.5)
415C	11.7 ± 2.2 (4.6 ± 0.9)	18.1 ± 3.3^{bc} (7.1 ± 1.3)	66.1 ± 18.4^{b} (26.0 ± 7.2)	369.3 ± 124.5 (145.4 ± 49.0)	15.1 ± 2.9^{c} (5.9 ± 1.1)	22.5 ± 4.8^{b} (8.8 ± 1.9)	61.1 ± 15.4^{bc} (24.0 ± 6.1)	231.4 ± 100.2^{ab} (91.1 ± 39.4)
415D	11.2 ± 2.6 (4.4 ± 1.0)	19.4 ± 4.3^{b} (7.7 ± 1.7)	75.9 ± 18.1^{a} (29.9 ± 7.1)	395.9 ± 98.5 (155.9 ± 38.8)	17.0 ± 2.6^{b} (6.7 ± 1.0)	25.0 ± 2.9^{a} (9.9 ± 1.1)	64.4 ± 11.4^{b} (25.4 ± 4.5)	256.0 ± 81.4^{ab} (100.8 ± 32.0)
615A	11.6 ± 2. (4.6 ± 1.0)	22.0 ± 4.3^{a} (8.7 ± 1.7)	81.4 ± 23.1^{a} (32.0 ± 9.1)	386.2 ± 107.9 (152.1 ± 42.5)	20.6 ± 3.6^{a} (8.1 ± 1.4)	27.0 ± 5.6^{a} (10.6 ± 2.2)	75.9 ± 21.6^{a} (29.9 ± 8.5)	280.4 ± 93.2^{a} (110.4 ± 36.7)
p-value	0.065	<0.001***	<0.001***	0.077	<0.001***	<0.001***	<0.001***	<0.01**

The superscript *a, b, c*, and *d* symbols are variables that indicate statistical similarities and differences (α=0.05) between stock types (rows) for a specific measurement (columns); statistical differences were calculated by using Tukey's honest significance test (HSD). For example, in table 3a for site 1, the observed height of the 313B stock type in the first year is statistically similar to 415B, and 415C is similar to 415D (they share the same letter), while these two groups are statistically different. The observed height of the 615A stock type in the first year is not statistically similar to the other four stock types. By year 12, the observed heights for 313B, 415C, and 415D are statistically similar to 615A or 415B, but the observed height for 415B is not statistically similar to 615A

Table 4a—Root-collar diameters in centimeters (inches) by stock type for Douglas-fir at sites 1 and 2

	Site 1				Site 2			
Stock type	After planting	1st year	3rd year	12th year	After planting	1st year	2nd year	11th year
313B	2.8 ± 0.4^{e} (0.11 ± 0.02)	4.4 ± 1.1^{c} (0.17 ± 0.04)	24.2 ± 6.4^{c} (0.95 ± 0.25)	69.2 ± 18.3^{b} (2.72 ± 0.72)	2.9 ± 0.4^{c} (0.11 ± 0.02)	5.2 ± 1.0^{c} (0.20 ± 0.04)	14.6 ± 3.1^{c} (0.58 ± 0.12)	65.0 ± 18.6^{b} (2.56 ± 0.73)
415B	3.1 ± 0.4^{d} (0.12 ± 0.01)	4.9 ± 1.2^{c} (0.19 ± 0.05)	24.8 ± 7.2^{c} (0.98 ± 0.29)	67.7 ± 24.6^{b} (2.66 ± 0.97)	3.3 ± 0.4^{b} (0.13 ± 0.02)	5.9 ± 1.3^{bc} (0.23 ± 0.05)	16.2 ± 3.8^{bc} (0.64 ± 0.15)	63.1 ± 17.1^{b} (2.49 ± 0.68)
415C	3.4 ± 0.4^{c} (0.13 ± 0.01)	5.5 ± 1.3^{b} (0.22 ± 0.05)	26.3 ± 7.2^{c} (1.04 ± 0.28)	73.9 ± 21.6^{ab} (2.91 ± 0.85)	3.4 ± 0.3^{b} (0.14 ± 0.01)	6.3 ± 1.5^{b} (0.25 ± 0.06)	17.3 ± 3.8^{b} (0.68 ± 0.15)	65.2 ± 17.9^{b} (2.57 ± 0.70)
415D	3.6 ± 0.5^{b} (0.14 ± 0.02)	5.9 ± 1.1^{b} (0.23 ± 0.04)	29.5 ± 5.8^{b} (1.16 ± 0.23)	81.2 ± 20.2^{a} (3.20 ± 0.80)	3.5 ± 0.4^{b} (0.14 ± 0.02)	6.4 ± 1.4^{b} (0.25 ± 0.05)	17.3 ± 3.6^{b} (0.68 ± 0.14)	66.0 ± 18.9^{b} (2.60 ± 0.75)
615A	4.3 ± 0.6^{a} (0.17 ± 0.02)	7.7 ± 1.3^{a} (0.30 ± 0.05)	32.9 ± 6.0^{a} (1.30 ± 0.24)	80.7 ± 20.6^{a} (3.18 ± 0.81)	5.5 ± 0.9^{a} (0.22 ± 0.03)	8.7 ± 1.7^{a} (0.34 ± 0.07)	22.5 ± 4.2^{a} (0.88 ± 0.17)	81.7 ± 20.0^{a} (3.22 ± 0.79)
p-value	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***

Table 4b—Root-collar diameters in centimeters (inches) by stock type for western larch at sites 1 and 2

	2.8 ± 0.3^{e} (0.11 ± 0.01)	5.4 ± 1.6^{d} (0.21 ± 0.06)	23.0 ± 8.3^{c} (0.91 ± 0.33)	62.0 ± 25.6^{b} (2.44 ± 1.01)	2.8 ± 0.4^{c} (0.11 ± 0.01)	6.0 ± 1.3^{b} (0.23 ± 0.05)	13.7 ± 3.1^{c} (0.54 ± 0.12)	53.1 ± 18.8 (2.09 ± 0.74)
	3.1 ± 0.3^{d} (0.12 ± 0.01)	6.0 ± 1.8^{cd} (0.24 ± 0.07)	24.8 ± 9.0^{bc} (0.97 ± 0.33)	69.5 ± 26.5^{ab} (2.74 ± 1.04)	3.4 ± 0.4^{b} (0.13 ± 0.02)	6.4 ± 1.6^{b} (0.25 ± 0.06)	15.1 ± 3.9^{abc} (0.59 ± 0.15)	66.3 ± 21.9 (2.61 ± 0.86)
	3.3 ± 0.4^{c} (0.13 ± 0.02)	6.3 ± 1.5^{bc} (0.25 ± 0.06)	25.9 ± 8.3^{abc} (1.02 ± 0.33)	73.5 ± 26.0^{ab} (2.89 ± 1.02)	3.4 ± 0.4^{b} (0.13 ± 0.01)	6.5 ± 1.4^{b} (0.25 ± 0.06)	14.4 ± 3.7^{bc} (0.57 ± 0.15)	60.1 ± 24.9 (2.37 ± 0.98)
	3.6 ± 0.4^{b} (0.14 ± 0.02)	7.0 ± 1.9^{b} (0.28 ± 0.08)	28.0 ± 9.6^{ab} (1.10 ± 0.38)	78.0 ± 29.5^{a} (3.07 ± 1.16)	3.5 ± 0.4^{b} (0.14 ± 0.02)	7.5 ± 1.7^{a} (0.29 ± 0.07)	16.9 ± 4.9^{ab} (0.66 ± 0.19)	60.1 ± 29.1 (2.36 ± 1.15)
	5.9 ± 0.7^{a} (0.23 ± 0.03)	8.7 ± 1.4^{a} (0.34 ± 0.05)	29.1 ± 9.5^{a} (1.14 ± 0.37)	78.0 ± 27.8^{a} (3.07 ± 1.09)	4.6 ± 0.6^{a} (0.18 ± 0.02)	7.8 ± 1.8^{a} (0.31 ± 0.07)	17.3 ± 4.4^{a} (0.68 ± 0.17)	55.8 ± 29.7 (2.20 ± 1.17)

Table 4c—Root-collar diameters in centimeters (inches) by stock type for western white pine at sites 1 and 2

	Site 1				Site 2			
Stock type	After planting	1st year	3rd year	12th year	After planting	1st year	2nd year	11th year
315B	3.3 ± 0.4^{d} (0.13 ± 0.02)	4.7 ± 0.7^{d} (0.18 ± 0.03)	16.1 ± 4.7^{b} (0.63 ± 0.18)	48.8 ± 21.5^{b} (1.92 ± 0.85)	3.4 ± 0.4^{d} (0.13 ± 0.02)	5.2 ± 1.0^{c} (0.21 ± 0.04)	12.2 ± 2.5^{c} (0.48 ± 0.10)	31.4 ± 12.6 (1.24 ± 0.50)
415B	3.5 ± 0.4^{cd} (0.14 ± 0.01	5.0 ± 0.7^{cd} (0.20 ± 0.03)	18.7 ± 7.2^{ab} (0.74 ± 0.28)	55.8 ± 18.1^{ab} (2.20 ± 0.71)	3.7 ± 0.6^{c} (0.15 ± 0.02)	5.6 ± 1.2^{bc} (0.22 ± 0.05)	13.4 ± 2.5^{c} (0.53 ± 0.10)	32.5 ± 10.6 (1.28 ± 0.42)
415C	3.6 ± 0.5^{c} (0.14 ± 0.02)	5.2 ± 0.7^{c} (0.21 ± 0.03)	18.4 ± 4.5^{ab} (0.72 ± 0.18)	58.4 ± 21.5^{a} (2.30 ± 0.84)	3.9 ± 0.5^{bc} (0.15 ± 0.02)	6.1 ± 1.1^{b} (0.24 ± 0.04)	13.8 ± 2.9^{bc} (0.54 ± 0.12)	38.0 ± 18.0 (1.50 ± 0.71)
415D	3.9 ± 0.5^{b} (0.15 ± 0.02)	5.8 ± 0.8^{b} (0.23 ± 0.03)	20.8 ± 5.1^{a} (0.82 ± 0.20)	63.3 ± 15.5^{a} (2.49 ± 0.61)	4.1 ± 0.5^{b} (0.16 ± 0.02)	6.8 ± 1.1^{a} (0.27 ± 0.04)	15.0 ± 2.7^{ab} (0.59 ± 0.11)	39.9 ± 12.3 (1.57 ± 0.48)
615A	4.6 ± 0.5^{a} (0.18 ± 0.02)	6.6 ± 1.1^{a} (0.26 ± 0.04)	20.5 ± 6.3^{a} (0.81 ± 0.25)	56.7 ± 17.9^{ab} (2.23 ± 0.70)	5.0 ± 0.7^{a} (0.20 ± 0.03)	7.1 ± 1.1^{a} (0.28 ± 0.04)	15.9 ± 3.2^{a} (0.62 ± 0.13)	41.5 ± 18.6 (1.63 ± 0.73)
p-value	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	0.051

Refer to the note under table 3 regarding the *a*, *b*, *c*, and d symbols.

Table 5a—Stem volume in milliliters (cubic inches) by stock type for Douglas-fir at sites 1 and 2

	Site 1				Site 2			
Stock type	After planting	1st year	3rd year	12th year	After planting	1st year	2nd year	11th year
313B	0.7 ± 0.2^{c} (0.04 ± 0.01)	2.6 ± 1.6^{c} (0.16 ± 0.10)	325.7 ± 246.5^{c} (19.88 ± 15.04)	13,792.1 ± 9,210.6^{b} (841.7 ± 562.1)	0.8 ± 0.3^{b} (0.05 ± 0.02)	4.0 ± 2.0^{b} (0.25 ± 0.12)	85.3 ± 53.3^{b} (5.21 ± 3.25)	11,738.8 ± 7,766.9^{b} (716.4 ± 474.0)
415B	0.8 ± 0.3^{c} (0.05 ± 0.02)	3.1 ± 1.9^{c} (0.19 ± 0.12)	348.3 ± 249.1^{c} (21.25 ± 15.20)	14,490.1 ± 11,641.3^{b} (884.2 ± 710.4)	1.2 ± 0.4^{b} (0.07 ± 0.03)	5.7 ± 2.9^{b} (0.35 ± 0.18)	107.3 ± 71.2^{b} (6.55 ± 4.34)	10,815.7 ± 6,745.8^{b} (660.0 ± 411.7)
415C	1.1 ± 0.3^{b} (0.07 ± 0.02)	4.5 ± 2.9^{b} (0.27 ± 0.18)	423.2 ± 320.3^{bc} (25.83 ± 19.55)	16,529.5 ± 11,163.9^{ab} (1,008.7 ± 681.3)	1.2 ± 0.3^{b} (0.07 ± 0.02)	6.3 ± 3.4^{b} (0.38 ± 0.21)	133.5 ± 77.2^{b} (8.15 ± 4.71)	11,604.5 ± 7,185.6^{b} (708.2 ± 438.5)
415D	1.2 ± 0.4^{b} (0.07 ± 0.03)	5.1 ± 2.1^{b} (0.31 ± 0.13)	517.5 ± 275.1^{b} (31.58 ± 16.79)	20,578.9 ± 11,794.8^{a} (1,255.8 ± 719.8)	1.2 ± 0.3^{b} (0.07 ± 0.02)	6.3 ± 3.7^{b} (0.38 ± 0.22)	124.1 ± 75.6^{b} (7.57 ± 4.61)	12,010.6 ± 7,657.4^{b} (732.9 ± 467.3)
615A	3.3 ± 1.0^{a} (0.20 ± 0.06)	13.6 ± 5.4^{a} (0.83 ± 0.33)	751.1 ± 394.3^{a} (45.83 ± 24.06)	20,769.4 ± 13,081.0^{a} (1,267.4 ± 798.3)	5.9 ± 2.4^{a} (0.36 ± 0.14)	20.3 ± 9.6^{a} (1.24 ± 0.59)	289.1 ± 171.6^{a} (17.64 ± 10.47)	20,805.2 ± 12,322.4^{a} (1,269.6 ± 752.0)
p-value	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***

Table 5b—Stem volume in milliliters (cubic inches) by stock type for western larch at sites 1 and 2

	0.6 ± 0.2^{c} (0.04 ± 0.01)	5.8 ± 9.0^{c} (0.35 ± 0.55)	542.6 ± 682.0^{b} (33.11 ± 41.62)	14,834.2 ± 16,528.2^{b} (905.2 ± 1,008.6)	0.6 ± 0.2^{c} (0.04 ± 0.01)	7.0 ± 4.0^{c} (0.42 ± 0.24)	101.8 ± 76.8^{b} (6.21 ± 4.69)	8,327.3 ± 6,697.4 (508.2 ± 408.7)
	0.8 ± 0.2^{c} (0.05 ± 0.01)	7.6 ± 7.7^{c} (0.46 ± 0.47)	640.5 ± 596.2^{ab} (39.09 ± 36.38)	18,439.5 ± 16,332.4^{ab} (1,125.3 ± 996.7)	0.9 ± 0.3^{b} (0.06 ± 0.02)	8.8 ± 7.4^{bc} (0.54 ± 0.45)	151.9 ± 107.4^{ab} (9.27 ± 6.55)	14,051.3 ± 11,516.2 (857.5 ± 702.8)
	0.9 ± 0.3^{bc} (0.06 ± 0.02)	8.5 ± 6.8^{bc} (0.52 ± 0.42)	644.6 ± 470.5^{ab} (39.34 ± 28.71)	20,637.9 ± 15,635.8^{ab} (1,259.4 ± 954.2)	1.0 ± 0.3^{b} (0.06 ± 0.02)	8.7 ± 7.0^{c} (0.53 ± 0.43)	119.8 ± 99.4^{b} (7.31 ± 6.06)	12,816.4 ± 13,120.3 (782.1 ± 800.7)
	1.1 ± 0.4^{b} (0.07 ± 0.02)	11.7 ± 12.3^{b} (0.71 ± 0.75)	846.1 ± 813.8^{ab} (51.63 ± 49.66)	24,609.9 ± 18,928.8^{a} (1,501.8 ± 1,155.1)	0.9 ± 0.2^{b} (0.06 ± 0.01)	12.7 ± 8.1^{ab} (0.78 ± 0.49)	197.7 ± 161.0^{a} (12.06 ± 9.82)	13,670.4 ± 14,383.9 (834.2 ± 877.8)
	6.3 ± 1.5^{a} (0.38 ± 0.09)	20.3 ± 9.9^{a} (1.24 ± 0.60)	943.7 ± 836.9^{a} (57.59 ± 51.07)	24,506.4 ± 21,858.3^{a} (1,495.5 ± 1,333.9)	2.1 ± 0.8^{a} (0.13 ± 0.05)	13.7 ± 9.1^{a} (0.83 ± 0.56)	195.2 ± 141.5^{a} (11.91 ± 8.63)	11,472.5 ± 12,339.5 (700.1 ± 753.0)

Table 5c—Stem volume in milliliters (cubic inches) by stock type for western white pine at sites 1 and 2

	Site 1				Site 2			
Stock type	After planting	1st year	3rd year	12th year	After planting	1st year	2nd year	11th year
315B	0.7 ± 0.3^{c} (0.04 ± 0.02)	2.0 ± 0.8^{d} (0.12 ± 0.05)	102.6 ± 95.6^{c} (6.26 ± 5.84)	6,423.4 ± 6,553.3 (392.0 ± 399.9)	0.9 ± 0.3^{d} (0.05 ± 0.02)	3.1 ± 1.5^{c} (0.19 ± 0.09)	44.8 ± 25.1^{c} (2.74 ± 1.53)	1,596.4 ± 2,034.3^{b} (97.42 ± 124.1)
415B	0.8 ± 0.3^{bc} (0.05 ± 0.02)	2.4 ± 0.9^{cd} (0.15 ± 0.05)	163.8 ± 274.4^{abc} (9.99 ± 16.75)	7,712.2 ± 6,629.7 (470.6 ± 404.6)	1.4 ± 0.7^{bc} (0.08 ± 0.04)	4.0 ± 2.6^{bc} (0.25 ± 0.16)	60.5 ± 32.9^{bc} (3.69 ± 2.00)	1,646.2 ± 1,438.3^{b} (100.5 ± 87.8)
415C	0.9 ± 0.3^{bc} (0.05 ± 0.02)	2.7 ±1.1^{c} (0.17 ± 0.07)	135.9 ± 87.5^{bc} (8.30 ± 5.34)	9,122.0 ± 8,349.5 (556.7 ± 509.5)	1.2 ± 0.5^{cd} (0.07 ± 0.03)	4.7 ± 2.2^{b} (0.29 ± 0.14)	68.7 ± 40.6^{bc} (4.19 ± 2.48)	3,036.7 ± 3,537.4^{ab} (185.3 ± 215.9)
415D	1.0 ± 0.4^{b} (0.06 ± 0.03)	3.6 ± 1.4^{b} (0.22 ± 0.08)	198.6 ± 134.3^{ab} (12.12 ± 8.20)	9,797.5 ± 6,574.1 (597.9 ± 401.2)	1.6 ± 0.5^{b} (0.09 ± 0.03)	6.3 ± 2.4^{a} (0.39 ± 0.14)	81.8 ± 40.4^{b} (4.99 ± 2.46)	2,759.5 ± 2,179.2^{ab} (168.4 ± 133.0)
615A	1.3 ± 0.5^{a} (0.08 ± 0.03)	5.3 ± 2.4a (0.32 ± 0.15)	220.5 ± 181.5^{a} (13.45 ± 11.08)	8,218.2 ± 6,712.1 (501.5 ± 409.6)	2.8 ± 1.1^{a} (0.17 ± 0.07)	7.6 ± 3.5^{a} (0.46 ± 0.21)	110.8 ± 65.9^{a} (6.76 ± 4.02)	3,771.8 ± 3,857.4^{a} (230.2 ± 235.4)
p-value	<0.001***	<0.001***	<0.001***	0.063	<0.001***	<0.001***	<0.001***	<0.05*

Refer to the note under table 3 regarding the *a, b, c,* and *d* symbols.

Although the stock types did not affect the survival rates, the odds of survival increased as the root-collar diameter increased in most species and years at site 2 (see figure 4) but not at site 1 (see figure 3). Despite the site indexes being comparable at both sites, the environment became harsher at site 2 than site 1 immediately after outplanting. This suggests that if the site quality or environment is unfavorable, the stock types and seedling sizes may be more important than at more favorable sites. Wightman et al. (2018) had a very different finding with coastal Douglas-fir (*P. menziessi* var. *menziessi*) where the largest stock type in their study had the lowest survival rate. They attributed this to the larger leaf area, and thus, increased evaporative demand that may increase water stress during stand establishment. However, it is also possible that the differences between these results are due to the differences in stock types tested, the sites where the seedlings were planted, and the species or variant of a species examined.

Similar to survival, each species' seedling height, root-collar diameter, and stem volume were minimally influenced by stock type over time. Sizes were statistically different for all species and metrics at the time of outplanting, except for the height of WP (see tables 3, 4, and 5). However, the effects of stock type disappeared after 11 or 12 years for some metrics of WL and WP. The most prominent trend in the results was that DF 615A seedlings remained larger than the smaller stock types 11 or 12 years after planting at both sites. This finding is similar to other studies of stock type effects on Douglas-fir (e.g., Haase et al. 2006, Haywood et al. 2012, Johansson et al. 2015, Regan et al. 2015). Comparatively, van den Driessche (1992) and Wightman et al. (2018) observed that initial differences in coastal DF at the time of planting disappeared 6 to 8 years after planting. These studies further suggest that results vary across sites, variants (e.g., coastal and interior), and stock types tested.

Regardless, findings from the current study suggest that if the objective is the largest interior DF trees in the shortest amount of time, larger stock types may be the best option. The less consistent results across sites and size metrics for WL and WP suggest that stock type selection may be less important for these species in this region; an interesting observation was the lack of differences between the 615A container and medium-sized containers (e.g., 415B, 415C, 415D), which suggests minimal gains in seedling size when using larger, more expensive stock types. It is also possible that this study did not document differences between stock types because the seedlings grown in the 615A stock type did not have enough time to reach that container's maximum capacity. These observations can help guide stock type selection, especially for large reforestation projects when maximizing nursery space occupancy and seedling quantity are considerations.

Haase et al. (2006) found that DF seedling growth rates did not differ among the stock types after three seasons of growth. However, van den Driessche (1992) showed that larger seedlings had lower mean relative growth rates than smaller seedlings, and the initial differences in performance disappeared after a 6-year period on a site in south-central Vancouver Island. Wightman et al. (2018) also reported that initial size (height, root-collar diameter, shoot and root volumes, and shoot/root ratio) differences at the time of planting disappeared after 8 years of growth, resulting in tree sizes being similar across stock types.

Although 615A seedlings had larger initial height, root-collar diameter, and stem volume, the differences lessened after 2 or 3 years and mostly disappeared after 11 or 12 years in DF, WL, and WP (see tables 3, 4, and 5). Tuttle et al. (1987) and Pinto et al. (2011) also found that site differences may play a role in the relationship between stock types and growth rates. Tuttle et al. (1987) found that the growth of loblolly pine (*Pinus taeda*) seedlings is negatively related to initial seedling height on drought-prone sites, while there was a positive relationship for favorable sites. Pinto et al. (2011) found that initial seedling traits (height, root-collar diameter, and stem volume) of ponderosa pine (*Pinus ponderosa*) lost predictive ability with time, especially on the higher quality site. That is, initial seedling traits were unable to predict long-term performance in their study. On the contrary, the absolute growth was reduced on a dryer site, but traits determined by the stock type persisted longer. In this study, because the planting years and climate conditions were different, site differences were not compared.

All these studies demonstrate that the results of growing DF in different stock types can be site specific (e.g., soil, weather, vegetation), that smaller seedlings may have better early performance on harsher sites (Wightman et al. 2018), and the initial differences may disappear over time.

WP was the slowest growing species among these three conifers. It had the lowest height and smallest root-collar diameter among the three species (see tables 3 and 4) and consequently, the smallest stem volumes (see table 5). The heights at site 1 after outplanting did not have any differences among stock types. This suggests that using a larger stock type (e.g., 615A) for WP increases the production cost without a statistical difference in survival. However, there is a potentially lower cost per established tree over the rotation of the stand due to better initial growth. This can also lead to fewer seedlings being planted per acre, better resistance to transplant stress, and a greater likelihood of achieving minimum stocking levels required by some laws in a timely manner. However, based on the results of this study, the value of using larger stock types for some species on good-quality sites with suitable environments is negligible.

The 615A stock type consistently showed larger height, root-collar diameter, and stem volume while the other four types did not show much difference across all the species. Therefore, from the cost-effectiveness point of view, if the stock types are smaller than 415D, it is best to choose the smallest one to decrease the cost and maintain the seedling performance. If larger seedlings that have better performances are preferred, the best choice is the 615A stock type. Still, the decision is subject to change depending on the species and sites and should follow the target plant concept.

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How IR-4 Can Be a Tool for Nursery Growers

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Abstract

Pesticide use is a central part of modern nursery production. Newer pesticides may be safer for the applicator, address resistance management, and better target pest species, which reduces nontarget activity and pest resurgence. However, the relatively small horticultural sector growing native plants for reforestation does not attract the level of research investment as commodity crops, and pesticide manufacturers may be unaware of what nursery managers need. IR-4 is an organization funded by the U.S. Department of Agriculture, National Institute of Food and Agriculture that supports research into pesticide use on specialty crops, with the aim of expanding legal access to useful pesticides. Research direction comes from a public workshop and growers through a needs survey and communication with regional coordinators. IR-4 also serves as a repository of information on pesticide efficacy and crop safety. These research summaries represent comprehensive and current collections of information on pesticide use and are available through IR-4's website.

History of IR-4

Founded in 1963, the purpose of IR-4 (https://www.ir4project.org/) is extending pesticide registrations from major commodity crops to minor crops that may not be included in initial labeling. The program is divided into four regions, each having a regional contact (figure 1 and table 1). The program has regional laboratories housed with academic or Federal partners.

Longstanding Environmental Protection Agency (EPA) rules require pesticide manufacturers to provide data demonstrating efficacy in controlling labeled pests and to set limits, which must be determined experimentally, for preharvest application on food crops. Some States, such as California, may also require efficacy data for ornamental crops. Additionally, manufacturers may be exposed to liability if the compound causes crop damage.

Pesticide manufacturers are often unwilling to bear the cost of generating data required by the EPA if they believe the market for the compound will not justify that cost. IR-4 funds research to support claims of pest suppression, establish timelines of compound degradation, and evaluate potential phytotoxicity. Since its inception, IR-4 has facilitated more than 75,000 registrations of pest management technologies on specialty crops.

Beginning in the 1970s, IR-4 expanded its research to nursery crops. Early work into environmental horticulture includes experiments supporting new uses of Banrot (etridiazole and thiophanate-methyl), glyphosate, Ronstar (oxadiazon), and a project to find better control for black vine weevil.

Table 1—IR-4 Regional field coordinators and contact information

IR-4 regional office	Name	Phone	Email
Western Region	Kari Arnold	(530) 574-9181	klarnold@ ucdavis.edu
	Mika Tolson (Env Hort)	(530) 752-7635	mptolson@ ucdavis.edu
North Central Region	Nicole Soldan	(517) 712-8441	schroe65@ msu.edu
Southern Region	Kristen Searer-Jones	(352) 294-3979	k.searerjones @ufl.edu
Northeast Region	Marylee Ross	(410) 742-8788 ext. 310	mross@ umd.edu

Figure 1—IR-4's headquarters is in Raleigh, NC, with regional offices located in each of its four regions.

IR-4 Resources

Resources relevant to native plant growers are found under "Environmental Horticulture" in the top menu bar of the IR-4 website (direct link: https://www.ir4project.org/ehc/). What follows is a brief overview of resources relevant to nursery growers and planters.

Crop Vignettes

For a number of commonly grown native plants, IR-4 produces crop vignettes, which include plant information, economic value, main pests, and IR-4 research.

Environmental Horticulture Research Summaries

IR-4 summarizes relevant research on pesticide use and pest control, drawing from research they fund and other work (table 2). The site organizes research summaries by an active ingredient, a group of pests, or a class of compounds. Summaries focus on crop safety (evaluating nontarget phytotoxic effects of pesticide use), control of specific pests or groups of pests, or sometimes efficacy of a class of pesticides. Many of the compounds tested are not labeled for a specificized use or may be unregistered entirely at the time of experimentation. Browse research summaries on crop safety and compound or biological efficacy at https://www.ir4project.org/ehc/environmental-horticulture-research-summaries/.

Table 2—Recent efficacy summaries

Topic	Year	Trials summarized
Nematode	2024	34 active ingredients tested against foliar and soil dwelling nematodes
Bacterial disease	2024	83 products tested against 10 bacterial species
Mollusk	2024	11 products tested against the brown garden snail
Fatty acid herbicides	2024	5 herbicides tested against 7 weeds, some of which are resistant to glyphosate
Phytophthora	2024	74 products tested against 11 *Phytophthora* species
Nutsedge and sedge	2023	28 products tested against several *Cyperus* species
Rhizoctonia solani	2023	42 products tested against *R. solani* in 15 hosts
Liverwort	2023	37 products tested for both pre and post emergent activity against liverwort
Powdery mildew	2023	28 products tested against 12 pathogenic species
Scale	2023	32 active ingredients tested against 24 scale species
Mealy bug	2023	31 active ingredients tested against 7 mealy bug species
Botrytis	2023	56 active ingredients tested against 3 species of *Botrytis*
Beetle, borer, weevil, & white grub	2022	91 products tested against adult and grub beetles and 10 products tested against clearwing borers
Pythium	2022	47 active ingredients were tested against 5 *Pythium* species
Thrips	2022	78 products tested against 5 thrips species
Fusarium	2021	40 active ingredients tested against 4 species of *Fusarium*

Trials Database and Biopesticide and Organic Database

The trials database is a finding aid to individual trials and research reports on thousands of studies. Users can filter the database by crop, plant group (e.g. narrowleaf evergreen tree/shrub or deciduous tree/shrub/vine), active ingredient, chemical group (herbicides or insecticides), or target pest, among other factors. The search results will describe general results of the trial and provide a link to more detailed results or the associated research summary. View and search the trials database at https://www.ir4project.org/ehc/ehc-registration-support-research/environmental-horticulture-database-a-2/.

IR-4 also hosts a database on biopesticides and organic compounds. Users can filter this database by crop, crop group, pest, and other variables to find alternative treatments to common pests (figure 2). This database is available at https://ir4app.cals.ncsu.edu/biopestPub/labelDb.

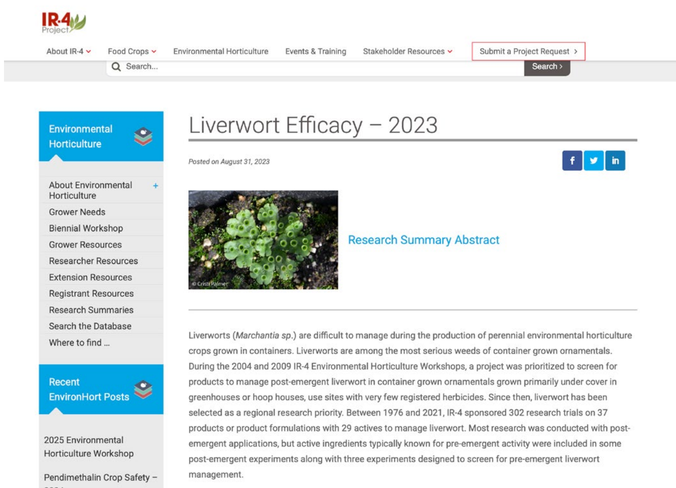

Figure 2—For specific pathologies or insects, an efficacy summary will be displayed with a link to the efficacy results.

The Environmental Horticulture Program within the IR-4 Project has conducted over 2,500 trials, testing more than 275 products on 90 native plant species. For Douglas-fir alone, IR-4 has helped get 240 new registrations or label amendments for more than 75 products.

National Needs Survey and Research Direction

IR-4 staff relies on local growers and the agriculture community to identify pest management needs for specialty crops. IR-4 sends an annual needs survey to growers requesting input on their research direction. Priorities are set at a biennial meeting using data from the needs survey and supported through direct communication with IR-4 and meeting attendance. Common recurring priorities in environmental horticulture include *Phythophora* and *Pythium,* scales, thrips, mealybugs, *Botrytis,* borers, beetles, and preemergent and postemergent herbicide crop safety.

The research request form is available at https://www.ir4project.org/ehc/ehc-registration-support-research/env-hort-grower-needs-2/#Request. A link to the ongoing grower and extension survey, which helps set research priorities, is on that same web page (https://www.ir4project.org/ehc/ehc-registration-support-research/env-hort-grower-needs-2/).

Resources Available

Staff are available to discuss pest management needs. IR-4 distributes a quarterly newsletter and shares updates on Facebook. Sign up for the newsletter at https://www.ir4project.org/about-ir4/news/registration-form/.

Address correspondence to:

Paul Rhoades, Nursery Pest Specialist, USDA Forest Service, Athens, GA 30621; email: paul.rhoades@usda.gov; phone: 208-797-0000.

Hoop And Shade Cloth System for Protecting Nursery Seed Beds

Mike Kangas, Jeff Smette, and Edwin Jacobson

Nursery and State Forest Team Leader; Nursery Manager; Systems/Irrigation Specialist; Towner State Nursery, Towner, ND

Abstract

Since 2002, Towner State Nursery in North Dakota has used a hoop and shade cloth system to protect seed beds from unpredictable weather events that occur during the growing season, such as torrential rains, severe windstorms, and hail. This system is inexpensive to build and can be customized to a seed bed's width. For other nurseries that may be experiencing (or anticipate) unpredictable weather patterns, a hoop and shade cloth system is an inexpensive solution.

Introduction

The Towner State Nursery is a conservation nursery owned and operated by the North Dakota Forest Service since 1951. The nursery produces both bareroot and container stock for conservation tree-planting practices within the region. Bareroot species produced include Colorado blue spruce (*Picea pungens*), Black Hills spruce (*Picea glauca*), Rocky Mountain juniper (*Juniperus scopulorum*), eastern redcedar (*Juniperus virginiana*), Scotch pine (*Pinus sylvestris*), ponderosa pine (*Pinus ponderosa*), and a few hardwood species.

The nursery is in north-central North Dakota, which is approximately the geographical center of the North American continent. As such, the nursery is subject to a continental climate characterized by extreme variations in temperature throughout the year, with hot summers and cold winters. During the growing season unpredictable weather events are common, such as torrential rains, severe windstorms, and hail. Such events present challenges to production of conservation seedlings—especially to recently established seed beds with vulnerable germinants.

To mitigate these weather challenges, Towner State Nursery developed a hoop and shade cloth system to protect seed beds, which has been in use since 2002.

System Description

The system is relatively straightforward and consists of hoops of curved 0.5-in (1.3-cm) aluminum conduit pushed into the ground every 10 ft (3.0 m) along the length of the 500-ft-long (152.4 m), 4-ft-wide (1.2 m) seed beds. A 6-ft-wide (1.8 m), 40-percent shade cloth (heavy-duty knitted polyethylene and polypropylene) is laid over the top of the hoops and secured into place with landscaping staples along the sides. Installation of this system over the nursery's 30 seed beds takes 6 employees approximately 16 hours (figure 1).

The hoop and shade cloth system is used on shallow-seeded species, including Colorado blue spruce, Black Hills spruce, Rocky Mountain juniper, eastern redcedar, and Scotch pine. The system is not used on ponderosa pine because this species is seeded deeper, and the nursery has not observed a benefit using the system on this species. The system has not been tested on hardwood species.

In North Dakota, seeding occurs in late June once soil temperatures warm to 65–70 °F (18.3–21.1 °C); Towner State Nursery uses a Bartschi Fobro Accord DA air seeder. The hoop and shade system is installed immediately after seeding. Once installed, the system remains over the seed beds throughout the summer. The shade cloth allows for sprinkler irrigation to be used, however, it does hamper the effectiveness of aerial applications of postemergent herbicides. To remedy this, a good chemigation prior to installation is essential. Towner Nursery fumigates fields designated for seed beds with Basamid in September the year before and a preemergent herbicide directly after seeding to suppress weeds. Staff remove the hoops and shade cloth in early October prior to frost development in the soil.

Advantages and Disadvantages

The hoop and shade cloth system used by Towner Nursery offers several benefits, including (1) creating a microclimate that moderates temperature extremes and helps retain soil moisture; (2) providing protection against severe wind events, torrential rains, and hail; and (3) deterring seed depredation from avian and rodent species

Drawbacks to the system include (1) installation being contingent on available labor, (2) the need to fabricate specialized hoops, (3) the upfront cost associated with the materials, and (4) the ongoing cost of replacing materials (shade cloths must be replaced every 20 years). Lastly, once a grower installs the system they are unable able to till or treat weeds; good chemigation prior to seeding is essential.

Summary

Towner Nursery has seen great success over the years using this hoop and shade cloth system. Once the initial investments are made to incorporate the practice, the benefits are clearly realized with greater consistency in seed bed establishment. This system has provided an essential assurance to meet production goals despite the persistent weather challenges associated with an outdoor nursery.

Address correspondence

Mike Kangas, North Dakota State University, Fargo, ND 58108; email: michael.kangas@ndsu.edu

Figure 1—Nursery employees installing the hoop and shade cloth system. Photo by Jeff Smette, 2024.

To watch the hoop and shade cloth system be installed, visit:

https://app.screencast.com/

Incorporating Native Plant Restoration Nurseries Into Public School Programs

Julie Vanderwal

Operator, Beaver Food Forest Nursery, Carlton, WA

Abstract

Cultivating the next generation of much-needed nursery workers requires investing in educational experiences that connect K–12 students to the native plant nursery industry. Coincidentally, public schools are showing increased interest in establishing nurseries on school grounds to support science, technology, engineering, and math (STEM) integration and to cultivate skills that will increase student employability after graduation. These nurseries can also be a source of native plants for local habitat restoration, further connecting students to the real-life applications of nursery operations. Nursery managers may find it valuable to partner with schools to offer guidance in establishing a native plant nursery and serve as mentors. This paper was presented at the 2024 Combined WFCNA & ICSGA Meeting held in Wenatchee, WA, on September 4–5, 2024.

Introduction

Schools with native plant nurseries allow students to discover the native plant world, which is a rewarding journey for both the students and those in the nursery field. Incorporating nurseries into public schools brings interconnected benefits, which can include giving students the real-world experience of growing plants for restoration, cultivating lifelong learners, and generating career interests and contacts. Standard career preparation programs may not highlight options such as soil scientist, restoration ecologist, or nursery pest specialist, but being exposed to the nursery field can lead to jobs for students and employees for businesses. Nurseries are also a rich environment to bring in speakers with expertise to help students solve problems and design their nurseries for success. These contacts can lead to future letters of reference for job and college applications, or even careers. Experiences in a school nursery can help students develop competencies and certifications that can build their resumes and be used for career placement or advancement.

Oroville School District, located in north-central Washington State just 5 miles south of the Canadian border, serves approximately 480 students, with about 81 percent qualifying for free or reduced lunches based on income. The district is very motivated to help students explore potential career opportunities. As a career and technical education teacher with a background in restoration

ecology, I saw an opportunity to introduce students to the nursery industry by developing a native plant nursery on the school grounds. The school district had a vision for involving students in habitat restoration and growing plants year-round in a state-of-the-art greenhouse. Their vision attracted me to become involved in building these programs into the career and technical education courses being offered.

Starting a School Native Plant Nursery

Connecting the Nursery to Curriculum

Many school administrators and teachers are pushed to capacity to meet State and Federal educational requirements in addition to the daily demands of teaching. The idea of starting a school nursery can feel daunting, particularly if it is seen as a new and additional program to create. However, the tasks necessary to grow plants support a wide variety of educational content standards and can fit well within existing courses, programs, and learning objectives.

Language arts standards are addressed when students write descriptions of a sprouting seed or how a plant grows over time. Math standards gain meaning when students create potting mixes using ratios of ingredients, calculate fertilizer application rates, and determine the volume of a growing container. Agricultural standards transform into practical skills when students handle seed to overcome dormancy. In addition to helping students master content standards, if a nursery can effectively support a school's dropout prevention program or career preparation program, a school district will likely be more receptive to investing resources and time in establishing a nursery.

Many different Next Generation Science Standards (NGSS) can be met in growing native plants, including many of the NGSS disciplinary core ideas related to structure and function, stability and change, and adaptation, as well as standards in:

- From Molecules to Organisms: Structures and Processes
- Ecosystems: Interactions, Energy, and Dynamics
- Heredity: Inheritance and Variation of Traits

Building the Nursery

When approval is granted to begin a school nursery, the next challenge is developing the nursery space. One should be prepared to work at a small scale, both in terms of space and budget; budgets are an increasing concern in schools, and there are a lot of programs and activities being cut back.

To build the Oroville School Native Plant Nursery, I sourced materials that were cost effective or could be donated by the community and modified nursery operations to accommodate a public school's limited budget and novice nursery workers. For example, I used pallets to organize the space and keep the containers off the ground for phytosanitary reasons (figure 1).

Figure 1—School nurseries are usually built on a budget, which means sourcing inexpensive materials. Stores are often willing to donate pallets. Photo by Julie Vanderwal, 2022.

To reduce the use of plastic pots, which rely on petroleum-based manufacturing, ultimately end up in landfills, and have an upfront cost of purchase, the school used donated milk and juice carton containers—an existing resource.

At the school's request, Green Okanogan, a local recycling center, asked the community not to crush the milk and juice cartons, and many people supported the school's efforts by bringing uncrushed cartons to the recycling center. After cleaning the cartons in the dishwasher, the students cut the tops off and punched holes in the bottom for drainage. The amount of labor involved in preparing beverage cartons for planting might be difficult for a commercial nursery to justify, but schools have the advantage of many hands to work on cartons during spare moments in the classroom. These cartons make great growing containers because the paper can be torn away without disturbing the root system when it is time to plant (figure 2). They also model a circular economy by reusing material prior to recycling.

Figure 2—Juice and milk cartons can serve as inexpensive pots that model reusing waste materials. Students can easily tear the paper and safely remove the seedling when it is time to plant. Photo by Julie Vanderwal, 2022.

Due to the significant time constraints of school class schedules, it is important to install automatic irrigation when the nursery is started. This is an excellent science, technology, engineering, and math (STEM) project and can be cost effective with a battery-operated timer and micro-irrigation supplies. A shade structure may be necessary depending on the climate, and schools can start off with securely anchored popup canopies, if wind conditions allow.

Others can replicate the process used to create the Oroville School Native Plant Nursery by starting small and scaling up over time as needed. A single 3- by 4-ft (0.91- by 1.2-m) pallet accommodates 100 milk cartons. Once students grow the plants successfully and everyone sees what can be learned from the process, students could add more pallets and plants, if space and class time allow. Schools may also find that staying at a micro-nursery scale is both manageable and provides meaningful work experience for students.

Nursery Management

Managing a group of students in a nursery setting requires clear roles for each student and the means to perform their tasks as independently as possible. Before the students set foot in the nursery, adult facilitators need to generate a list of every specific job that students could do and consider how an individual's strengths and areas for growth can be maximized by their specific work.

For a successful session, students should know what they are going to do before they arrive at the nursery. Just as a nursery manager may hold a morning staff meeting to assign tasks for the day, a facilitator should use time in the classroom beforehand to prepare the students.

I created a job board with sticky notes and movable clothes pins with the students' names written on them (figure 3). I would facilitate a discussion of the whole task list, which could include watering, taking soil temperatures, measuring plant growth, planting, mixing potting media, filling containers, etc. I placed the clothes pins with student names next to each task to assign jobs. Because class periods were only 46 minutes long, including taking attendance, walking to the greenhouse, cleaning up, and walking back, I found it helpful to keep students on the same jobs for the following class session as well, which would allow the group to start working more promptly the next time (figure 4).

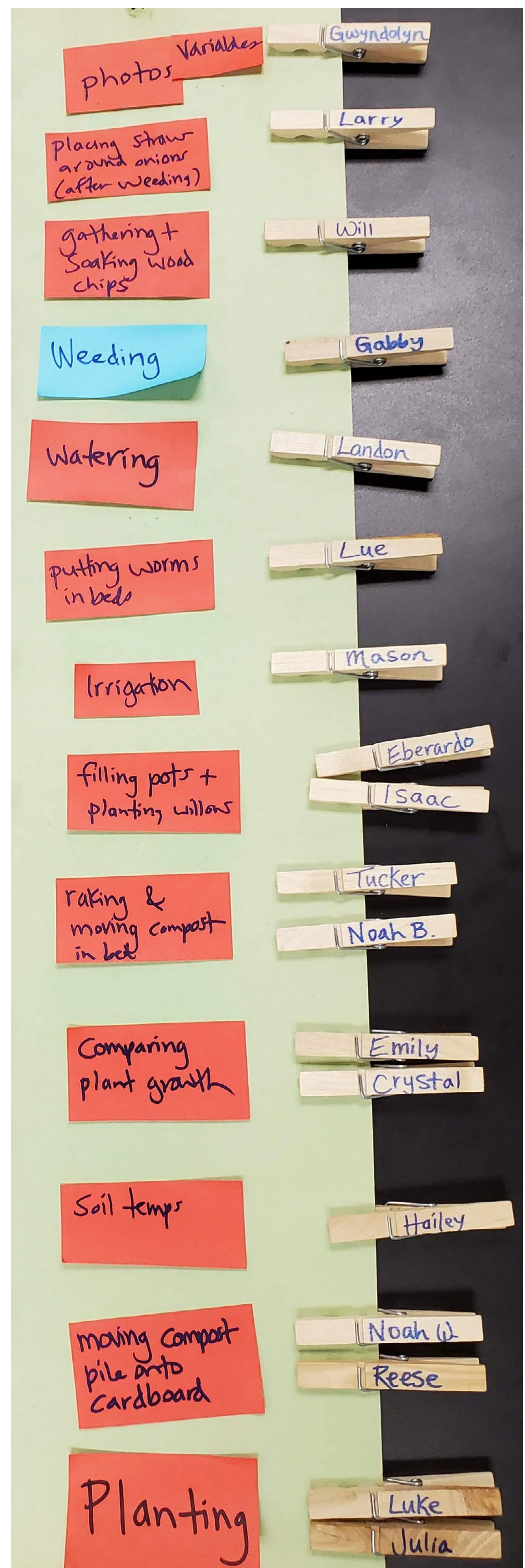

Figure 3—A school nursery has the same types of daily tasks as a professional nursery, and once trained, students can be capable of carrying out these same tasks. Photo by Julie Vanderwal, 2022.

Figure 4—Students transplant seedlings into milk and juice cartons. Photos by Julie Vanderwal, 2022.

When budgeting classroom preparation and education vs. nursery work time, efficiency is key. In a 46-minute class period, it can feel like there is only time to get started and then clean up. Tips to maximize classroom time in the nursery include:

- having an assistant prepare tools and materials beforehand,
- assigning jobs at the end of a class period (so students are ready at the start of the next class), and
- breaking larger tasks into smaller steps that can be completed in less time, but over multiple days.

Administrators can facilitate hands-on career prep experience by creating block periods so that each class period is longer. At Oroville School District, some activities like field trips are scheduled to start during the period(s) before the hosting class and can sometimes run through the advisory homeroom period after lunch to work with the students for a longer time. I had flexibility in class scheduling because the school district was very supportive of pulling students out of other classes if they kept up with their work. To provide work experience during the school day related to career areas of interest, Oroville School District developed a policy that allows for flexible class schedules for students who meet a set of high expectations for effort and achievement.

Engagement Through Tangible Connection

To spark interest and investment in growing plants, students need a tangible connection to how they benefit from plants. Few students have thought about native plants before or even know the difference between a native and an introduced species. Students are often interested in local wildlife species, particularly in rural areas. Linking native plants to wildlife survival creates tangibility that makes the native plant nursery meaningful for many students.

In Oroville, bighorn sheep (*Ovis canadensis*) cross the highway frequently. Students know and love this charismatic megafauna. Students learned that lupine species are important plants to support the bighorn sheep population, and I asked them what could be done to established lupine in an area where the bighorn sheep will graze. Students related to that need because they care about bighorn sheep, so they were invested in growing silky lupine (*Lupinus sericeus*) and velvet lupine (*L. leucophyllus*). Mule deer (*Odocoileus hemionus*) also rely on antelope bitterbrush (*Purshia tridentata*) as their primary winter forage in the area. The students wanted to plant more bitterbrush in the hills around the town for deer, which motivated them to figure out how to break bitterbrush seed dormancy. After learning about how native plants can support local wildlife species, the students became much more interested and invested in growing the plants (figure 5).

Figure 5—Bitterbrush was a native plant selected by the students to grow. This shrub is important winter forage for local mule deer populations. Photo by Julie Vanderwal, 2023.

Sterilizing Safely in a School Setting

In all nurseries, including within schools, it is important to maintain an environment that minimizes pathogen transfer between plants. However, because it is problematic for school-age students to use the nursery-standard 10 percent bleach solution, I use a solution of 3 percent hydrogen peroxide to sanitize surfaces such as pots and wood, and electric heat-treating units to sanitize tools, gloves, pots, and other materials.

Preparing pallets for growing plants— Remove all soil and organic material with a scrub brush or, ideally, a pressure washer. If scrubbed, spray the pallets with water at a high-pressure setting. Leave pallets to dry completely, preferably in the sun. When dry, saturate the pallet surface with a 3 percent hydrogen peroxide solution.

Most living organisms contain the enzyme catalase, which functions to decompose hydrogen peroxide (H_2O_2) into oxygen (O_2) and water (H_2O). Fizzing will occur as the hydrogen peroxide reacts to the catalase in microorganisms; this is a sign that the pallet is being sanitized. If fizzing persists in certain areas, spray it with more hydrogen peroxide until the fizzing stops. The absence of fizzing indicates the absence of catalase-bearing microorganisms.

A senior from Oroville Highschool was recently selected as the 2024 Washington STEM Rising Star. In her Washington STEM website video, she says:

> My STEM journey began my freshman year of high school when I joined a greenhouse management class. I started learning about complex natural systems and plant anatomy, and I fell in love with learning about the natural world. My greatest achievement in STEM was during my wildlife monitoring internship, where I implemented trail cameras to track bighorn sheep. After months of having no tangible results and just getting pictures of grass swaying and triggering the motion sensors, I finally caught pictures of a [State-managed] herd of [bighorn] sheep. It was an extremely gratifying experience, and it taught me that even though some things take time, if you stick with it, the end result will be totally worth it.

The student plans to pursue a degree in environmental science.

Integrating the Nursery Into Local Restoration

Another way to build interest and momentum for student involvement is to create field experiences that relate to growing native plants. I took students on field trips to nearby forests, rivers, creeks, and meadows to collect cuttings and seeds to bring back to the school nursery to grow. When the plants were large enough for outplanting, I identified local restoration projects where the students could install the plants (figure 6).

Figure 6—Students plant seedlings grown at the Oroville School Native Plant Nursery at a restoration site along Tonasket Creek. Photo by Julie Vanderwal, 2021.

I met with local land managers to explain our program's goals and objectives, including providing students with natural resource work experience, creating connections with local professionals, and growing native plant materials to sell to support the greenhouse program. Local Washington Department of Fish and Wildlife (WDFW) wildlife area managers and other land managers have been very supportive of this work. In one case, the Okanogan Conservation District applied for a permit on our behalf to install a streambank soil bioengineering demonstration, which included plantings. In another case, the WDFW purchased plants from our program and allowed students to install the plants. Several times, a local wildlife area manager came with us on field trips to collect cuttings.

This is the full circle of what it means to work in a nursery, and it is important to give students these opportunities.

Building a Nursery Community

When starting a nursery within a school program, a teacher or horticulturist doesn't have to build the nursery alone; there are educators and facilitators, both local and regional, who can support this work.

I started teaching during the coronavirus pandemic, which meant I taught native plant restoration remotely. Class attendance was frequently low during this time. Inviting guest speakers always increases student engagement, even in a virtual setting. Nursery specialists with the U.S. Department of Agriculture, Forest Service agreed to join my classes and speak on plant propagation, data collection, and greenhouse management. Students later had assessments to test their retention of the information. Inviting students to meet someone from the industry motivated them to join via Zoom, and class attendance was higher on these days.

Now that students and teachers have returned to the physical classroom, it is significantly easier to engage students. It's still important, however, to have a network of experts who can serve as guest speakers and resource people, whether remotely or in-person. The Washington State Department of Natural Resources, through their education and outreach program, played an important role in bringing in expertise and offering help with specific needs. At request, the program found a guest speaker who was both Spanish/English bilingual and an expert on pollinators—because one student, who spoke only Spanish, had selected to plan a pollinator garden as a supervised agricultural experience. The expert joined the class via video call to share their knowledge. Having regular help to bring in specific expertise made a huge difference in the program and created community around the work.

Finding new activities for students is important to keep them engaged in the lessons. For example, The Nature Conservancy's restoration project manager gave Oroville students a tip for processing Saskatoon serviceberry (*Amelanchier alnifolia*) seeds. She advised them to grind the seeds in a blender, with duct tape on the blades, to mimic the digestive system of a bird or bear. This became a favorite activity of the program because students loved using the blender to masticate seeds (figure 7).

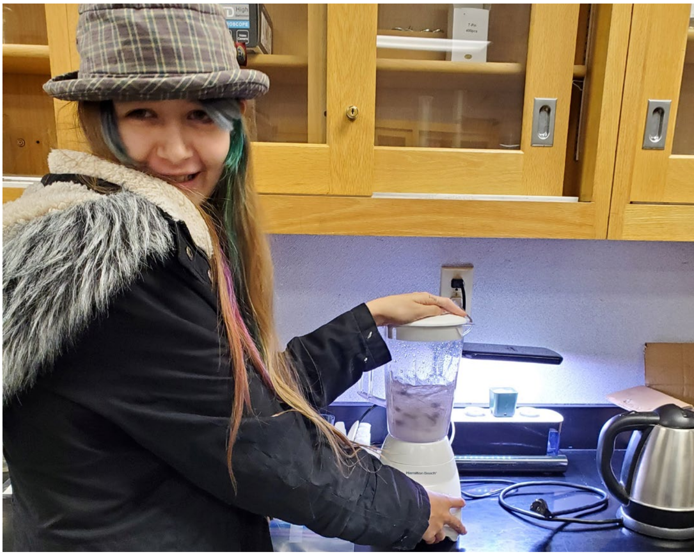

Figure 7—Finding activities that keep students engaged is an important part of running a school nursery. Masticating Saskatoon serviceberry seeds in a blender, which scarified the seeds in preparation for planting, was a popular task. Photo by Julie Vanderwal, 2022.

Building the Workforce Pipeline

Because the day-to-day operations of running a school nursery can easily take priority, it is important not to lose sight of the workforce development element, which has the potential to transform lives and helps justify funding the program. Career preparation is a cornerstone of the greenhouse in Oroville because of the goal that students graduate with skills that make them employable in agricultural and natural resource management fields.

The Washington State Nursery and Landscape Association (www.wsnla.org) has a Certified Professional Horticulturist program. With a requirement of 2,000 hours of professional experience, this program is too rigorous for most high school students to achieve. A collaboration between the association and the Oroville School District developed an entry-level certificate program that is accessible to high school students and others not yet ready or able to pursue the full Certified Professional Horticulturist program. This Level 1 Washington Certified Horticulturist program is modeled after the Certified Professional Horticulturist program.

For the Oroville school nursery, we divided the overall certificate into a series of smaller progress certificates. When a student earns at least three progress certificates, they are issued a full Level 1 Washington Certified Horticulturist certificate. Each progress certificate has a written exam and a hands-on mastery task, and the live specimen plant ID exam is shared among the progress certificates. If students decide to pursue a Certified Professional Horticulturist certificate, they will already be familiar with the exam structure.

In the nursery, students learn to master elements of the progress certificates. For example, teams of students designed irrigation systems, which is part of the irrigation progress certificate. The teams designed an irrigation system for the metal rack shelves or the pallets where the plants would grow (figure 8). Students developed written designs, constructed their systems, and then wrote about how they built the system and how it worked (figures 9 and 10). The plants were grown on the shelves and the pallets, and students compared how well the different systems functioned. Irrigation design-and-build projects touch on all aspects of STEM and provide hands-on opportunities for students to solve real-world problems.

Some of the hands-on mastery components included:

- learning to graft plants at a local apple orchard owned and operated by another teacher;
- using the Forest Service's native plant propagation protocol database (https://npn.rngr.net/propagation) to select and initiate a protocol for stratifying and germinating an assigned species of native seed; and
- accurately interpreting direction of growth in preharvested, dormant *Salix* spp. branches and accurately creating cuttings to a specific length, with angled bottom cuts and flat top cuts.

Figure 8—Teams of students designed the irrigation systems for plants to grow on metal shelves and pallets. Photo by Julie Vanderwal, 2023.

Figure 9—Students developed written plans for their irrigation systems with sketches to scale (left), constructed their systems using a variety of micro-irrigation supplies (right), and wrote a summary of how their system worked. Photos by Julie Vanderwal, 2023.

Figure 10—A student compares irrigation systems during the growing season to select which methods to replicate. Photo by Julie Vanderwal, 2023.

In the first 2 years of the certificate program, 10 students earned certificates for their resumes. Two students earned the full Level 1 WA Certified Horticulturist certificate (figure 11). One of these students was a greenhouse intern for 2 years, with the responsibility of managing the greenhouse over the summer of 2022. He completed all three progress certificates and was one of two students to graduate in 2023 with both a high school diploma and a full Level 1 Washington Certified Horticulturist certificate. He was also an intern with the nonprofit organization Conservation Northwest, working as native plant propagation coordinator for the school district. After graduating, he was hired by the Washington Department of Fish and Wildlife to work for a wildlife area manager he met on a school field trip. The resume- and contact-building opportunities from working in the school's native plant nursery proved integral for this young man's transition from school to employment.

Get Involved!

I am grateful for the people who help students and teachers because it does take a village. If you work at a nursery or are a nursery owner, your expertise is invaluable, and I encourage readers to reach out to local schools to offer support.

1. Reach out to your local school district's career and technical education program director. (Principals and superintendents are often inundated with urgent matters and may not be in a good position to fully absorb what you are offering and to respond effectively.) Ask which teachers are or may have an interest in working with plants, and ask if you can get in touch with those teachers directly.

2. Offer to come to the classroom as a guest speaker. At first, focus on planning a one-session experience with a hands-on component. This will keep things simple and allow you to make connections and get a clearer idea of who you should work with, and how receptive the school might be. Example topic: Native seed stratification. Example hands-on component: Students label zippered bags and place native seeds into a substrate like Pittmoss (a peat alternative) for refrigeration for stratification.

3. Follow up with the teachers and find out how the students liked the session. Ask if they would like to continue to work together, and whether they would be interested in growing native plants at their school.

Creating a Certificate Program in Your State

Across the United States, there are a variety of entities focused on supporting professional horticulturists. Research what organizations exist in your State and find out if they offer professional certifications. Any organization that offers professional certification is a candidate for potentially offering a high school level certification. Nursery growers can ask these organizations if they would be open to offering a certification for high school students and entry level workers, and if they have capacity to help develop one. Teachers who are already offering units on relevant topics may be able to adapt their content for a certificate program. Having support in this process from a nursery grower could be the missing piece that allows a new certificate program to be developed!

Conclusion

The K–12 experience should offer more than what is learned through worksheets—it should offer skills, contacts, and competencies that are pathways to jobs. Working in a native plant nursery at school can open doors in a student's life. Even if students decide to pursue a different career path, they will understand the role that nurseries play in restoration, reforestation, and horticulture, and can advocate for the importance of habitat restoration when collaborating with others. Schools can start a micro-nursery with very little infrastructure, and because native species are adapted to local climatic conditions, a native plant nursery can operate with or without a greenhouse.

Address correspondence to:

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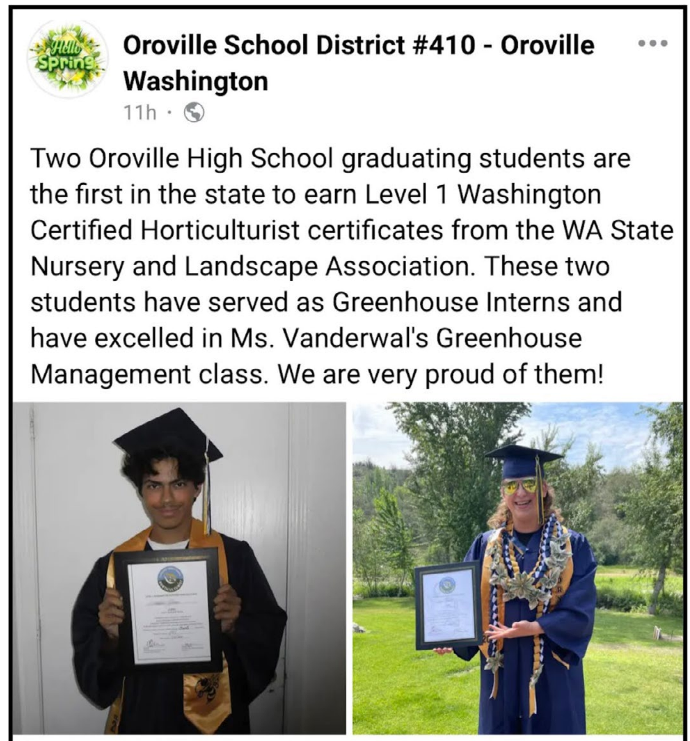

Figure 11—Following the development of the Level 1 Washington Certified Horticulturist program, two Oroville High School students successfully earned the full Level 1 Washington Certified Horticulturist certificate, while 10 other students earned progress certificates. Oroville School District Facebook post, 2023.

Content Creation for Native Plant Nurseries

Figure 1—Social media provides an open avenue to share growing techniques and experiences that might be different from what people usually expect. The growing table in the foreground was built to fit deepot tree pots (D60Ls) and accommodate 6-in (15.24-cm) drip emitter tubing. These peat-free, coir-free plants grew exceptionally well despite the commonly held belief in the nursery industry that it's not possible to successfully grow peat-free in small containers.

Julie Vanderwal

Operator, Beaver Food Forest Nursery, Carlton, WA

Abstract

Social media is a useful and relatively inexpensive communication tool that can connect the public to the role of nurseries in supporting restoration and reforestation projects. Effectively connecting with the public requires intentionality and practice, and there are best practices, just as there are in the nursery industry. This article features examples of how to create and share social media content based upon experiences of owning and operating a private nursery and managing the Oroville School District's nursery. This topic was presented at the 2024 Combined WFCNA & ICSGA Meeting held in Wenatchee, WA, on September 4–5, 2024.

Introduction

Of the daily tasks required to operate a nursery, creating social media content might not be prioritized in the face of urgent needs related to watering, weeding, and pest management. However, social media is a useful tool for connecting the public with the value of growing native plants, which can then generate more interest in native plants, plant propagation, and the many careers that go along with this work.

Fortunately, nursery work lends itself to being engaging and informative (figure 1). When creating content, it is important to be intentional but not overthink what you share. The challenge is remembering to take videos or photos of what you are doing and deciding what is appropriate to post. It's also important to consider what social media platform you are using. Instagram originally focused on photos but is now also popular for short videos up to 180 seconds long, called reels. (Stories posted on Instagram can only be up to 60 seconds long.) Facebook and Bluesky work well for sharing photos or videos, and TikTok features short and somewhat longer videos. YouTube is great for longer videos but also hosts short-form content. You can also go live on any of these platforms for longer periods of time.

Choosing Content Creators

Creating and sharing social media content is just as much of a skill as propagating seeds, raising plants, or repairing irrigation lines. Finding individuals within your operation who are passionate about social media will help build your nursery's social media presence.

For example, the Washington State Nursery and Landscape Association (WSNLA) wanted to develop their social media presence to encourage young people to consider pursuing nursery- and landscape-related careers. While collaborating on developing the Level 1 Washington Certified Horticulturist program for high school students, I offered that students could help create content for WSNLA.

I recruited an unlikely team of social media interns: students in 7th, 9th, 10th, and 12th grades. The 12th-grade student had a paid internship funded by the WSNLA, and I supervised their work. The team produced content primarily designed to test myths and tips about plant growing found on TikTok and from other sources. One of their videos addressed a TikTok video of an individual who promoted dipping a rose cutting in honey, claiming that honey works like rooting hormone. I asked the students, "Do you really think honey is a rooting hormone? Let's test it out."

The students filmed themselves dipping groups of redosier dogwood (*Cornus sericea*) cuttings in honey, commercial rooting hormone, or water, and then measured, compared, and filmed the growth a few weeks later to show the results. By creating these videos, the students contributed to the social media presence of an important organization in the horticulture field and felt part of something bigger.

Figure 2—Creating an example audience can increase the effectiveness of your social media content because it enables you to create more targeted and personalized content. Photo shared by the user on Instagram, 2024.

Identifying Your Audience

Once you know who will create your social media content, next you must identify your target audience. Does your audience already know the difference between native and nonnative plants, or is that something that you need to explain? It's surprising how many people don't realize that not all plants are native and why it matters. If your audience does know about native plants, how much do they know? And do they already care about native plants, or is this something you want to inspire?

To help picture your audience, find someone who is an example of the people you want to reach. My example audience is a person who lives in Okanogan County and operates a farm (figure 2). She cares about native plants and knows a fair bit about them. More importantly, she's a lifelong learner open to learning new ways of doing things. When filming a video, I sometimes picture myself talking to her to make the experience feel less awkward, keep my focus on the right perspective, and come across more naturally on video.

Figure 3—Inexpensive photo editing tools enable the creation of customizable images that can also be used to share information, such as this post that was shared on Instagram and other platforms. Photo by Julie Vanderwal, 2024.

Deciding What To Share

When thinking of content to share on your social media accounts, consider the goal of your nursery operation. At Beaver Food Forest, I grow beaver food for ecological restoration, and my goal is to inspire others to seek out materials and methods for growing that will support ecosystem health. The potting media I use are peat free and coir free, and I post information that explains why I take this approach (figure 3).

The content I share shows the process of growing native plants: how I grow them and what I'm learning. For example, I made 17 different potting medium recipes this growing season and made videos showing how the recipes were made and how the plants grew in different mixes. I also made a video showing the "unboxing" of my first delivery of PittMoss, which is a recycled paper peatmoss alternative. The sack was 7 feet tall, and I was very afraid that when I cut into it, the product was going to spill all over the ground. Sharing that moment of uncertainty is something

that people can relate to. The product didn't fall out and remained intact, which ended up being funny after all the precautions I had in place to catch falling PittMoss.

In my nursery, I use milk cartons because they work really well for me, and they represent the circular economy of using a waste product instead of creating something new. I made a video on turning the humble milk carton into a "double decker" deep pot that encourages a longer root system (figure 4).

It is important to recognize that not everything needs to be posted. For example, we received a delivery of a semi-truck load of biochar. The delivery went sideways because I didn't realize that the soil was very sandy in the area where I wanted it delivered. The forklift became stuck, and the tractor became stuck while trying to free the forklift. I filmed the experience but realized afterward that this didn't have to be posted. Sometimes it's better to just be grateful that things worked out okay and not turn every event at the nursery into a post.

Also, not every post needs to cover a lot of ground. You can share thoughts, moments, and glimpses of your practice, as well as occasional deep dives into topics of interest.

Figure 4—Problem solving and innovation in the native plant nursery often generate shareable social media content. Several reels on Beaver Food Forest accounts feature unconventional uses for milk and juice cartons, a free resource that anyone can utilize. Photo by Julie Vanderwal, 2024.

Creating Engaging and Consistent Content

I operate on three criteria for "postable" content: does it fit my audience, will it help me meet my goals, and will it draw the viewer in?

If you are prone to scrolling through videos on social media, after a while you see patterns of how people structure their videos—using the same hooks and formulas to make you stop and watch—and it can feel stale. However, you only have a couple of seconds to capture somebody's attention before they scroll away. Think of things that will naturally generate curiosity and make people want to keep watching. You can search online for "social media hooks" for inspiration. Avoid hooks that are manipulative or exclusive.

Here are some hooks that lend themselves to nursery content:

- Here are three reasons to (__________). Let the person know what the video is going to be about from the first moment. My "three reasons to mulch your plants with sand" video has the longest track record of all my videos, for people continuing to like and add to favorites on TikTok over time.
- "Here are five things I would do if I were starting over."
- "If you're worried that (_____________)." Example: "If you're worried that your compost from BCS Livestock might have weed seeds in it, check this out. I haven't had a single weed sprout in this pile in a whole year."
- Pose thought-provoking questions, such as "Why not use peatmoss?"
- Tips for saving time or money when growing plants: For this hook, my videos might feature how to make your own potting media, or methods I've found for doing jobs more effectively. Example: "Here's a quick hack. If you want to grow a big plant really fast, use five big, long willow cuttings and put them all into one large pot." That was a popular video.
- Reminders of what to do during each time of the year: Example: "October is a good time to make use of the natural stratification of wintertime. Plant your native seeds in containers outside and let them sit through the winter conditions, and see if they break dormancy and sprout in the spring."

Photos are a good alternative if video creation is not practical. For example, the Oroville School District uses Facebook to share posts, which are often a photo with a couple of lines of text (figure 5). When taking a photo, you want to consider the lighting and whether a reader can understand what's happening. It's not always necessary to alter the photo (i.e., apply a filter or crop). You can upload the photo directly from your phone.

Video is useful to show a task or walk a viewer through how to do something, such as how to create a custom potting mix for

riparian or upland plants. My students created a video showing their attempt to scarify Saskatoon serviceberry (*Amelanchier alnifolia*) seeds using a blender. One of my nursery's most popular reels, which has about 160,000 views, simply shows me dipping the tips of willow (*Salix*) cuttings in paint. The caption explains how latex paint color codes the cuttings by species, prevents evapotranspiration, and shows which way is up—in case I have help planting them. The music on this reel features the line, "Why do we do the things we do?" and helps generate curiosity. One of my TikTok videos—only 8 seconds long with one sentence of text—has more than 500,000 views and 2,000 meaningful comments. The majority of comments expressed genuine appreciation for what they learned, and many people said they plan to change their practices as a result of the video. Your content doesn't need to be long or complex to have an impact; and keeping your content simple makes it more feasible to post regularly.

No matter what hooks, music, or moments you decide to share, be yourself. People are drawn to authenticity—it will attract the people who are interested in what you're doing. If you are an introvert, bring that to the table, because some viewers don't want to watch someone using a lot of expressive, boisterous language.

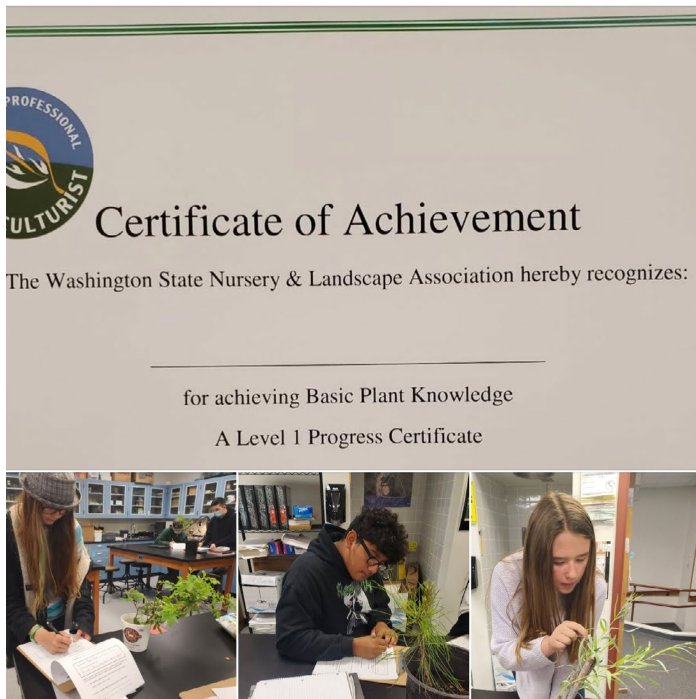

Figure 5—Facebook posts can be simple, such as a photograph with a caption or a series of photos. When posting photos of minors, a parent's or guardian's permission is required. Oroville School District Facebook post, 2022.

A companion to creating engaging content is posting regularly. If you're going to have an account on any social media platform, posting daily helps build engagement. I struggle with this because I always have multiple, simultaneous projects. I have learned that not every post needs to cover a full concept. Instead, I can post a short thought or a scenic picture of my nursery at sunset with a caption.

Collaborating with others to create social media content can increase the number of viewers seeing your content and learning about what you're doing. For example, I collaborated with PittMoss on Instagram by posting a reel about how I use their product and selecting "invite collaborators" under "tag people." Once they accepted the invitation, the reel was posted to their followers, some of whom then followed my account. The company I'm highlighting also benefits, as their followers see real applications of the product.

In another example, local agricultural producer BCS Livestock created a video describing their product, and I then stitched in my video afterward, sharing how well their compost works in our nursery. Another video collaboration was with the Western Washington University Sustainability Pathways program. Their students cleared hiking trails and salvaged native plants that needed to be removed, and I potted them in my nursery. I made a reel about the plants and invited Sustainability Pathways program to collaborate, which shared my reel to their feed (once they accepted).

Conclusion

To have a successful social media presence, you need to take moments from your daily practice and find ways to share them with the world. You have to be willing to do things imperfectly and do your best to engage your audience—all within the sideboards of being your authentic self.

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Stories and Lessons Learned From a Career in Reforestation and Restoration Nurseries

Working in the nursery industry combines a passion for growing plants with the science of understanding how plants grow—or fail to grow—and the frank realities of running a business. Those individuals whose careers span decades accumulate experience and contacts that are invaluable for the next generation of nursery staff who will continue the work of growing seedlings.

To help facilitate this transfer of intergenerational knowledge, *Tree Planters' Notes* is launching a new column that features practitioners, drawn from nonprofits, private industry, Tribes, and State and Federal agencies, whose knowledge has influenced nursery practices for the better.

The inagural column is based upon "Nursery Perspectives on Native Plant Restoration from Forest Service Lifelong Learners," which was presented at the 2024 Combined WFCNA & ICSGA Meeting held September 4–5, 2024, in Wenatchee, WA. The presentation featured Kas Dumroese, Aram Eramian, Diane Haase, and Tom Landis reflecting upon their career and lessons learned.

To view a recording of the presentation, visit https://vimeo.com/1040258199/5575493906.

Kas Dumroese

Senior Scientist, U.S. Department of Agriculture (USDA), Forest Service, retired

Dumroese worked for 17 years with the University of Idaho before transferring to the U.S. Department of Agriculture's Forest Service. As a research plant physiologist, he worked at the agency's Southern Research Station, National Agroforestry Center, and Rocky Mountain Research Station. During his time with the Forest Service, Dumroese was a member of the Reforestation, Nurseries, and Genetic Resources (RNGR) team, which produces *Tree Planters' Notes*.

What Changed During a 40-Year Career

When I started, we began thinking more and more about native plants and a little bit less about the tall, cylindrical cellulose objects (trees) that we had focused on; during this shift, the Western Forestry Nursery Association turned into the Western Forestry and Conservation Nursery Association. I've watched the decrease in the demand for bareroot seedlings and an increase in container seedlings. With that increase in container seedlings, we've gone from a couple container sizes to gazillions to work with.

Over the decades, robust programs disappeared or became smaller. For example, the British Columbia Ministry of Forests in the early 1990s had dozens of employees working solely on nursery issues; there isn't anything like that anymore. Maybe that's because we've solved a lot of our problems, because funding priorities have changed, or maybe it's for some other reason.

When looking at technology and workforce changes, I went from computer punch cards to a computer that I carry in my pocket. We have better tools to help make some informed decisions. There used to be locals who would come in to work on a packing or sowing line. A lot of this work is now contracted out.

There are also a lot of research or management topics that we don't talk about as much anymore. When I started in the industry, Fusarium root disease was a big deal. [Fusarium (*Fusarium oxysporum* f. sp. *radicis-lycopersici*) root disease can result in rotting roots, wilting, or stunted seedlings.] Some nurseries would lose half of their crop to this root disease. Now, we don't even talk about *Fusarium* anymore. Fall fertilization is another issue that we don't really discuss as much.

How I Approached Working With Nurseries

During my career with the Forest Service, I homed in on several things that influenced how I worked with nurseries. First, what's the problem, issue, or need? It helps to be curious, a good listener, and a careful observer. A lot of the topics that the Forest Service pursued, or I pursued as a researcher, came from discussions during professional meetings or casual socializing, during which issues and needs would percolate up to the top. Those would be the topics that we'd pursue because we knew those were interesting to growers.

Second, once a problem is identified, who can help with it? I've worked with nursery managers, academics across the United States, and international friends, which has really been the special part of this career. And when I found people who could help me, and whom I enjoyed working with, those were the ones who I kept pursuing. Find the people you like to work with because after 40 years, when you're reminiscing, those are the ones who will bring a little tear to your eye.

I always tried to be pragmatic too when visiting nurseries. I wanted to challenge growers who did the same practice because that's the way they've always done it. However, I also didn't want to come in as an arrogant scientist, demanding that something be "fixed" only to break a proven process. I wanted to find the balance of challenging growers to do things differently and improve, but not necessarily making a change for the sake of changing. That's been one of my mantras.

How the Forest Service Served Nurseries

It is really heartening to see the *Native Plants Journal* and the propagation protocol database (https://npn.rngr.net/propagation) being used. That was another project the Forest Service developed after hearing about the need.

When pursing a new project, I wanted to help nursery managers and restoration people. I also wanted to advance the science with my peers and advance my own career. If there were ways that we could align the needs of research, the Forest Service, and industry managers at the same time, those were really good projects.

And at the end of the day, it's important that the Forest Service shares what we've learned: We want to help nursery managers and restoration ecologists do their job better and more efficiently and get better results. This requires knowing your audience when developing training materials. Our approach spanned the lay people to the technical professionals to ensure we were hitting our target audiences with the information they need. The Forest Service also understood that these audiences have different needs of how they assimilate and put knowledge into practice. That's why we produced a Spanish version of the "Tropical Nursery Manual"—we're trying to bridge those gaps and reach particular audiences.

I've been really blessed and fortunate to visit the Forest Service Washington Office and accept awards on behalf of the Reforestation, Nurseries, and Genetic Resources team. Many of the products that team developed have been recognized for their quality by different Chiefs of the Forest Service (figure 1). That's been really a special part of my career, working with a team of folks all committed to how we can promote success in this field.

Figure 1—In 2017, the Reforestation, Nurseries, and Genetic Resources team received the Chief's Award for outstanding technology transfer nationally and internationally, which Kas Dumroese accepted on behalf of the team. Left to right: Dumroese; Deputy Chief for Research and Development Carlos Rodrequez-Franco; Associate Chief Lenise Lago; Chief Tony Tooke. Photo courtesy of Kas Dumroese, 2017.

Revisit the Past To Inform the Present

What we do is very cyclic. Every year, we always have people coming in and people retiring. We always have to keep going back to the basics that we already know and reinforcing practices when new people come in.

This also applies to management practices. Those of us who've been in the industry for a long time, we've seen things happen multiple times. If someone new announces they have the best idea ever, somebody's probably already talked about that and done the research. With access to research through the internet, there is no excuse for not reviewing past literature.

Aram Eramian

Nursery Superintendent, USDA Forest Service, Coeur d'Alene Nursery, retired

For the first 15 years of his career, Eramian worked for the Forest Service in timber, fire, silviculture, and tree improvement on the Clearwater and Idaho Panhandle National Forests. In 1992, he started his nursery career at Coeur d'Alene where he managed the Tree Improvement Program. Eramian later switched to bareroot management and went on to be the assistant nursery manager. In 2015, he became the nursery manager, a role he still holds.

Everything Old Is New Again in Native Plant Propagation

At the Coeur d'Alene Nursery, we started growing native plants because conifer production started going downhill. We thought that we were leading the charge during this time, switching to growing native plants. When Joe Myers, the former nursery superintendent, shared that the nursery grew native plants in the 1960s and 1970s, I never checked the records until I prepared for this talk. When I reviewed our annual reports from the early 1970s, we were growing bareroot native plants out in the field from 1968 to 1980. In 1972, we built our first greenhouses. In 1974, we produced 340,172 bareroot native plants outside; this year is also when we started growing native plants in containers. Old is new.

As we switched to growing native plants, we submitted propagation protocols to the *Native Plants Journal* and native plant propagation protocols database, both of which had been recently launched. Then in a file cabinet I found a document, published in 1973, that detailed cleaning methods for native plant species (figure 2). There were also stratification protocols and how they were sown into bareroot fields. The document listed many of the species that we work with now but there were some unique ones as well. We're in the process of having this document digitized and making the information available.

METHODS OF COLLECTION AND SEED CLEANING NATIVE SHRUB AND FORB SEED — Coeur d'Alene Nursery

SPECIES	METHOD OF COLLECTION	METHOD OF CLEANING
Arrowleaf balasamroot	Hand pull heads	Dewinger, gravity separator, clipper cleaner
Ash, Mountain	Hand strip into buckets or burlap sacks	Macerator or dybvig with water, float, dry, clipper cleaner
Beargrass	Hand strip	Macerator and screen
Bitterbrush	Knock off onto canvas or use portable vacuum	Dewinger, gravity separator
Blackcap	Hand pick into containers	Macerator, dry, float, screen
Buckthorn, Alderleaf	Hand pick into containers	Macerator, float, dry, clipper cleaner
Cascara	Hand pick into containers	Macerator, float, dry, clipper cleaner
Ceanothus, redstem Ceanothus, evergreen	Hand strip into containers	Dewinger, gravity separator
Chokecherry	Hand pick or beat bushes with canvas underneath	Macerator or dybvig with water, dry
Dogwood, redosier	Hand pick	Macerator or dybvig with water, float, dry
Elderberry (black & blue)	Hand pick into containers	Macerator, float, dry, clipper cleaner, gravity separator
Geranium - sticky	Hand pick	Macerator and screen
Hawthorn	Hand pick or knock from trees onto a canvas	Macerator or dybvig with water, dry, clipper cleaner
Hollyhock	Hand pick	Macerator and screen
Huckleberry	Hand pick into buckets (can use a picker)	Macerator, float, dry, separate in dakota blower
Juniper	Hand pick	Macerator, float, dry, gravity separator
Kinnikinnick	Hand pick	Macerator, float, dry, gravity separator
Lupine	Hand strip	Dry, gravity separator
Mahogany, Mtn true	Knock from bushes onto canvas or a hopper	Dewinger, gravity separator
Mahogany, curlleaf	Knock from bushes onto canvas or a hopper	Dewinger, gravity separator
Maple, Mountain	Hand strip	Rub wings off
Ninebark	Hand pick clusters	Macerator or pick off stems and screen
Oceanspray	Hand pick clusters	Separate from stems and screen
Oregon grape	Hand pick or use picker	Macerator, float off pulp and separate in dakota blower
Penstemon	Hand strip seed heads	Macerator, dry, gravity separator
Rose, woods	Hand pick or knock onto canvas or containers	Macerator or dybvig with water, dry, gravity separator
Sandcherry	Hand strip or knock off onto canvas or container	Macerator or dybvig with water, dry
Serviceberry	Hand pick or knock off onto canvas	Macerator or dybvig with water, dry, gravity separator
Snowberry	Hand pick or use picker	Macerator or dybvig with water, float, dry, gravity separator
Spirea	Hand pick	Rub off stems and screen
Syringa (mock orange)	Hand pick	Rub off stems and screen
Sumac	Hand pick or use picker	Macerator or dybvig with water and fan
Ash, green	Hand strip	Macerator, fan
Thimbleberry	Hand pick	Macerator, float off pulp and screen
Thinleaf alder	Hand pick conelets	Maceraotr, screen
Twinberry (black)	Hand pick	Macerator, float off pulp, dry and screen

CDA Nursery 1973 1 of 3 pages of treatments

ATTACHMENT NO. 1

Figure 2—In 1973, staff at the Coeur d'Alene Nursery saw value in documenting methods of collection and seed cleaning for native shrubs and forb seed. This information is still useful for nursery managers, 52 years later. Photo by Aram Eramian, 2024.

Reconsidering Planting Assumptions

With the climate shift we've seen in northern Idaho, people need to plant a little earlier than they have been. And this gets back to the statement of, "This is the way we've always done it."

In October, we've asked people, "Are you sure you want to plant right now?" They reply, "Oh yeah, I've looked at my site and it is ready to go." I then ask if they've looked at the soil, and their response is no. Soil temperature is critical because you need 40 °F (4.4 °C) or above to support root development. It takes a couple of weeks for the roots to grow and move moisture up and down the stem. If moisture's not being moved, the seedlings will dry out; come spring, there will be a bunch of dead seedlings. This also applies to spring planting. When planting dormant seedlings, it takes a little while to wake up. If it stays cold, they'll remain dormant.

We get a lot of requests for sowing conifer seed directly on a site. One memorable example is when a team tried to sow whitebark pine (*Pinus albicaulis*) seed—all they did was feed the rodents. About 10 years ago, another researcher suggested planting whitebark seed coated with cayenne red pepper, which the rodents seemed to really like. He had one site that was successful, which everyone focused on, but they did not pay attention to the failures. The success rate for direct-sowing conifer seed is very low, especially for whitebark pine. That's why it is important to look at the literature and see what happened across the range where direct seeding of conifer seed is being applied.

Our clients own their seed; we are just responsible for maintaining the proper storage conditions to ensure viability. Whitebark seed is expensive to collect, and as a nursery manager I feel a personal and professional obligation for the seed to produce seedlings.

The Importance of Engaging With Clients

I've learned over time that "Please" and "Thank You" go a long way. And "Yes" means "Yes," and "No" means "Maybe," and you need to ask the question in a different way.

Despite being part of a Federal agency, the Coeur d'Alene Nursery does not receive congressional funding; it depends on the customers who do business with us, so our focus is on customer service. If nobody grows with us, the nursery doesn't exist. If a client calls and asks if I have a minute to chat, I say, "Yes."

Because we are customer-service focused, it's important to keep customers engaged. I ask questions about how the stock type is working for them, because, as I tell our customers, "If we're giving you a stock type that's not working, you must tell us. We don't want to take your money and just keep doing the same thing repeatedly."

Like what Kas said earlier, if I ask a customer why something is being done a certain way and the answer is, "That's the way we've always done it," I stop and ask why. We should all be learning.

Diane Haase

Western Nursery Specialist, USDA Forest Service, retired

Haase's career includes 20 years as the associate director of the Nursery Technology Cooperative at Oregon State University and 15 years as the western nursery specialist with the Forest Service. She produced dozens of publications, presentations, meetings, workshops, and conferences, and served as the editor of *Tree Planters' Notes*.

Recruiting the Next Generation—Then and Now

Twenty-five years ago, while at Oregon State University, I made a radar graphic of the different careers in forestry to show that nobody thought much about nurseries because we were off the radar. If you asked somebody the top 10 things that come to mind when thinking about forestry, they would likely list wildfire, recreation, or timber harvests but not nurseries or seedlings. I convinced four nurseries to offer paid summer internships, and went to horticulture, forestry, and botany classes to give my spiel of how great a job it is to work in nurseries. We had zero applications.

In the last few years, we now are definitely on the radar (figure 3)! There are so many national and international programs with lofty, unprecedented goals for forest restoration. Some of these goals have deadlines by 2030, which is a little ambitious, but at least they're out there.

My advice is to leverage this current enthusiasm, attention, and funding because who knows how long it's going to last. Be vocal about what we do. Those of us who work in nurseries tend to be introverted. We chose to work with plants, not people. Nonetheless, it's important to be vocal and to talk to the right people and make sure they understand what we do. The people who are making decisions usually know nothing about plants.

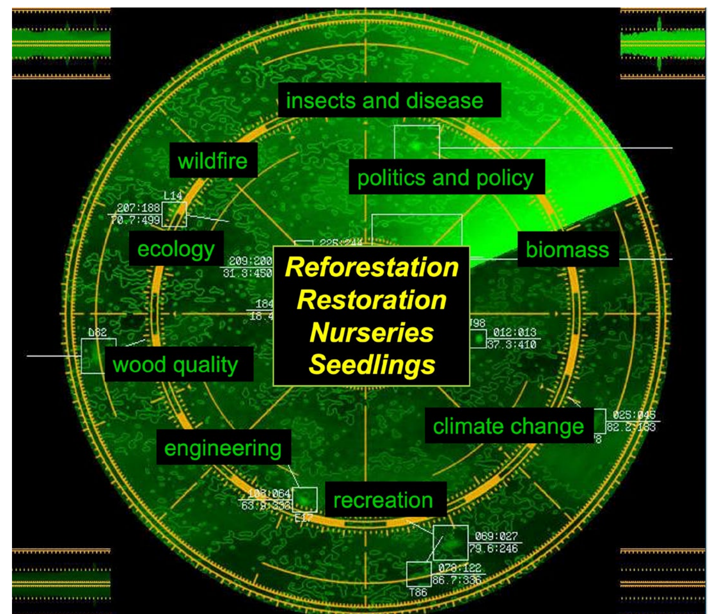

Figure 3—To convey the reality that nurseries were not thought of as a forestry-related career, 25 years ago, Diane Haase developed a radar graphic of forestry career options that didn't include nurseries or seedings. Now, with the focus on reforestation and the seedling pipeline, developing a nursery career pipeline is a priority. Image by Diane Haase.

Reconsidering Planting Assumptions

When I was at Oregon State University, we did a lot of research on fall planting. We looked at the gradient of soil moisture and temperature, as well as locations from the coast to inland and into the valley. Planting began in August and ran through January. The seedlings planted in August closest to the coast did amazing because there was plenty of soil moisture. But beginning in October, the soil temperatures became colder and

the days shortened. We couldn't capture that benefit of fall planting, however; it was very site dependent. The further inland, the plantings in August had 100 percent mortality. Re-creating the planting on the east side also resulted in high mortality.

A Nursery's Role in the Reforestation Pipeline

There's a lot of talk about the reforestation pipeline. I am really happy to have had a part in writing a paper on the reforestation pipeline that got a lot of attention (Fargione et al. 2021). In the paper, we addressed each part of the process: seed, nursery, outplanting, and postplanting (figure 4). I will point out that it really should be called the "restoration pipeline" because this process is relevant to every kind of planting project, no matter what species are being planted or how big the project is.

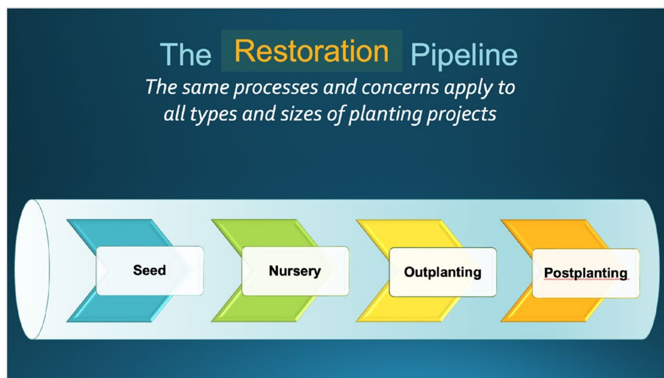

Figure 4—One of Diane Haase's accomplishments is her work to characterize the reforestation pipeline and the need to address each part of the pipeline when it comes to reforestation. Image by Diane Haase.

The one thing that is an issue with the pipeline is the huge focus on nurseries. If you're in the nursery, maybe you don't think that's such a bad thing. However, the focus is all about nursery capacity and the need for more seedlings. But, if we do not have the seed to grow those seedlings or the people to put them in the ground, what's the point?

We need all the parts of the pipeline in balance, with field performance as the ultimate goal. Whether you are working in the nursery or collecting seed, the metrics can't solely focus on pounds of seed collected, or number of seedlings produced, or number of trees in the ground. The metric needs to be the number of surviving and thriving plants. We can't just plant and walk away.

I see this "plant and walk away" approach with both forestry and native plant restoration projects, especially grant-funded projects. Over the course of a 3-year grant, the organization does the project planning, plants the plants, does a survey, and then the grant ends. After that, there is little attention to how the plants grow or survive in the long term.

To balance all the parts of the pipeline requires communication. Because there are so many people at every stage of that pipeline, you need to talk to each other regularly. This challenges the introvert aspect of us plant people, but communication is important. Nurseries should visit field sites; field people should visit nurseries.

Revisiting Previous Research

There's value in revisiting research because the climate is different, stock types are different, and restoration goals are different. A researcher asked me about doing a shading experiment, using inverted cups to shade seedling stems as they did in the 1960s and 1970s. I encouraged him to conduct the experiment because we have different stock types and different problems. The results showed there really wasn't much of a difference, likely due to it being a small-scale study (Vetter and Haase 2021).

Regardless, we should always be asking: Can we learn something new given the changes in industry goals and in the environment?

Tom Landis

Owner, Native Plant Nursery Consulting, Medford, OR

Landis started his career with the Forest Service on the Modoc National Forest. From 1974 to 1980, he was a plant pathologist in Denver and then the assistant nursery manager at Mt. Sopris Nursery in Carbondale, CO. From 1980 to 2004, he served as the western nursery specialist for the Forest Service in Denver and later in Portland, OR.

Finding My Path to Nurseries

I graduated with a Bachelor of Science from Humboldt State University and received a Master of Science and a Ph.D. from Colorado State University. When I finished my Ph.D., I wanted to work for the Forest Service but had no idea in what capacity. I was hired as a plant pathologist and started working with nurseries. One of my first tasks was problem solving. A nursery would call up and say, for example: "We're having a problem with weeds." In one case, I had to recommend methyl bromide fumigation because the weed problem was so bad; you literally couldn't see the seedlings in the field.

Then I was hired as assistant nursery manager at Mt. Sopris Nursery. I thought, "Man, this is really great!" That's when the lights went on and I realized what I wanted to do with my career: work in a nursery. Luckily, 3 years later, Mt. Sopris expanded to have a container program. I applied for the assistant nursery manager and got it. In 1980, I accepted a position as the western nursery specialist, based first in Denver, and then Portland. The two things that the Forest Service nursery program focused on were problem solving and technology transfer.

Being Responsive to Management Needs

When I started, many of the problems in our bareroot nurseries involved soil, such as soil compaction (due to the equipment use) and soil lifting. I worked with nurseries to hold trainings on soil management plans and then develop a map to categorize

each field in terms of its soil characteristics and what might grow best. Since I'm not a soil scientist, I needed some help. My colleague, Don Boyer, was the regional soil scientist in the Pacific Northwest; he understood soils and loved talking about them. When we'd visit a nursery, we would go out and dig a soil pit where he would explain the soil profile. All the employees really appreciated his down-to-earth perspective.

One of my jobs was to identify new technology. On a field trip in British Columbia, a group of us were visiting greenhouses, one of which grew tomatoes. The plants were trellised, with LED lighting going down between the trellises and all the way to the lower part of the plant. I thought, "Wow, how would that apply to our forest and conservation nursery?" So, I started doing research and wrote an article for my "Forest Nursery Notes" newsletter.

Because every nursery is different, I tried to stress "concepts, not cookbook." The "target plant concept" came from prescriptions for reforestation sites back in 1980s (figure 5). Another concept that I used was identifying factors that limit plant growth and keep them from reaching their genetic potential. All plants are limited by environmental factors, such as water or nitrogen availability. When I developed the "Container Tree Nursery Manual," I organized it around limiting factors and started with water and mineral nutrients, which were the questions I received the most.

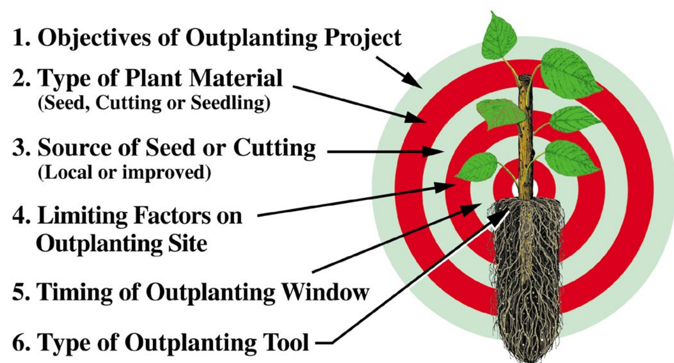

Figure 5—Once a concept applied to tree seedlings grown in nurseries to determine suitability for planting at a site, the target plant concept is now applied to all plant material that will be outplanted. Image courtesy of Tom Landis.

The Origins of the Intertribal Nursery Council

When I hosted the annual nursery conferences, Tribal members would often attend but they always sat in the back. When I asked how they liked the meeting, they would say, "It was good." I got the feeling that the Forest Service wasn't serving this group very well.

In 2000, I held a nursery meeting in Durango, CO, and afterwards, there was a 1-day meeting just for Tribal members. That first year, cultural barriers made things a little awkward; I wanted to find a Tribal member to lead the meetings. Luckily, I found Jeremy Pinto who has done an excellent job of leading the Intertribal Nursery Council for the past 20 years.

The Value of Published Literature

When I started working with nurseries, I became isolated from the latest published research because I couldn't go to the library and look things up—this was well before the internet! Because of this, I started a quarterly newsletter called "Forest Nursery Notes," which highlighted new nursery research that I thought people would be interested in.

One question I received was from a Christmas tree grower who wanted to know what was causing his trees to have corkscrew roots. I didn't know the answer and put the question on the backburner. Then a couple years later while reviewing a 1958 issue of *Tree Planters' Notes*, I found an illustration of corkscrew roots (figure 6). It was caused by repeated frost heaving because the soil had no snow cover or mulch. The lesson is to consult published literature—even sometimes going way back—and the answer just might be there.

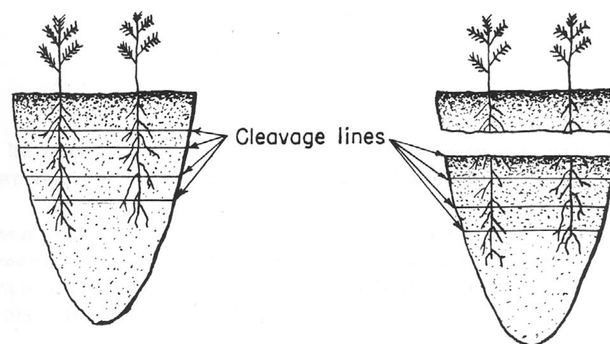

Figure 6—An article published in 1958 in *Tree Planters' Notes* explained the physical process for how trees developed corkscrew roots and answered a question that Tom Landis received decades later from a Christmas tree grower on why his trees had corkscrew roots: it results from repeated frost heaving. Image taken from *Tree Planters' Notes*, 1958.

Assisted Migration

During the question-and-answer portion of the presentation, the panelists were asked their thoughts on assisted migration. Here's what they had to share.

Kas Dumroese

We need to be cautious about how far we are transferring plants outside their seed zone. The best advice I heard was staying on the fringes of the seed zone and not get too far outside of it. We don't know the full plasticity of a lot of our species or what their limits are. Fortunately, most of the discussion, particularly in the literature, we're not talking about long-distance movements of material but tweaking plantings within either the current range or within a more appropriate range; for example, a southern source to a northern source. There's compelling data out from British Columbia about moving western larch (*Larix occidentalis*). Assisted migration is a cautious approach.

If you have an endangered plant and are worried about losing it on the landscape, there are climate model tools that estimate what the climate will be in the future. You can then find sites that have or are projected to have that climate in the future. Make some educated movements of material rather than willy-nilly decisions.

While we are gaining traction in assisted migration, we still have a long way to go. In the last decade, there's been a shift from talking about the pros and cons of assisted migration to getting results and evidence. This provides managers with concrete information about moving things and timing. There's still much to learn—so stay tuned.

Aram Eramian

I don't know enough about what variables are factored into decisions for assisted migration, but I follow the research because I'm curious about the outcome. Our clients make the decisions of what species to plant on their sites. From the nursery's perspective, we grow what our clients order, however, we already learned some things when looking at past reforestation activities in the 1920s and 1930s. Following the 1910 fire, we did a lot of moving of trees species around in the region, and it had to do with the availability of seed. At that time, we did not have the information we have today about seed zones, but we did the best we could to reforest.

One example was ponderosa pine (*Pinus ponderosa*), sourced from the Black Hills of South Dakota, the Bitterroot National Forest, and Wenatchee, WA. These sources were planted all over northern Idaho. The trees grew like weeds for about 50 years and then died because of root disease. Ponderosa pine doesn't normally die from root disease, but these sources were off site and not adapted to local conditions.

There was also experimental planting with hardwoods. There is a drainage outside of Wallace, ID, named Experimental Draw where hardwoods were planted. One guy found a red oak (*Quercus rubra*) in the St. Joe country (Idaho) during a stand exam; he knew it was a red oak because he went to school in the Midwest and keyed it out. Sequoias (*Sequoiadendron giganteum*) were also planted, and Japanese larch (*Larix kaempferi*) was planted on the Lolo National Forest. Eastern white pine (*Pinus strobus*) was also planted in northern Idaho in the 1930s but it did not survive. So, to put it simply, we have learned from our past.

We are very fortunate to have well-defined seed zones for all the conifer species we grow. We have been also working to define seed zones for native species. Where assisted migration takes us in the future will be interesting to see.

There's a lot of things that make me stare at the ceiling at 2 in the morning. How we proceed with assisted migration sometimes makes me do that but most of time, it's having to do with nursery management.

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