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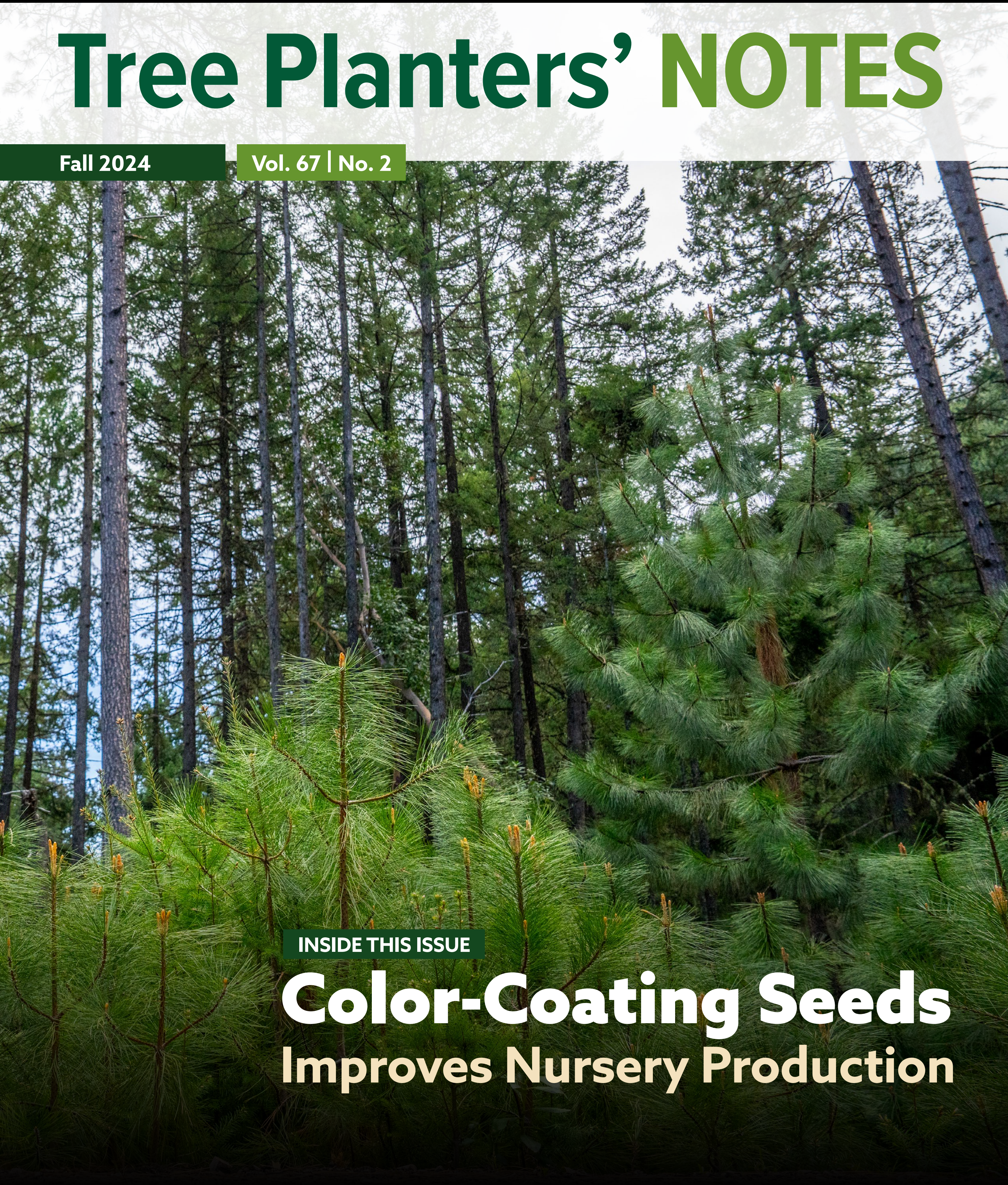

INSIDE THIS ISSUE

Color-Coating Seeds Improves Nursery Production

On the cover:
Inter-Tribal crew members in Lomakatsi's Tribal Youth Ecological Forestry Training Program conduct ecological thinning within the Ashland Forest Resiliency Stewardship Project near Ashland, OR. Photo by Preston Keres, USDA Forest Service, April 2024.

Letter from the Editor

Dear TPN Reader,

This is my first issue of TPN that I helped shepherd from review to publication as editor. Over the past year, it has been a privilege to work with authors featured in this issue and the Forest Service's Reforestation, Nurseries, and Genetic Resources (RNGR) team. As Diane shared in last issue's "Letter from the Editor," my degree is forestry but with a focus on forest management. Through my work as editor, I am learning more about the art and science of growing and planting all manner of shrubs and trees.

I intend to continue Diane's editorial philosophy over the course of future issues, welcoming all articles and working with authors to create a manuscript worthy of publication. One point that I will build upon is including an article relevant to each of the RNGR disciplines: tropical nursery, urban forestry, pest management, nursery production, etc. I want to ensure that all practitioners can learn information that is relevant to their work.

In the fall 2024 issue of TPN, many of the articles offer practical guidance that practitioners may find useful. Heitzman shares an update how black walnut that he planted 30 years ago is faring in Vermont while Kennedy reports on cold hardiness of big sagebrush seedlings, which will be useful to nurseries growing this plant for restoration projects. Witcraft, Mackey, and Khadduri describe an inexpensive method for improving the sowing of conifer and hardwood seeds with colorization, which has translated into tangible productivity at the Franklin H. Pitkin Forest Nursery and Webster Forest Nursery. Khadduri and Wightman share an analysis of paper-wrapped plugs in Pacific Northwest reforestation, and lastly, Pike et al. report on annual seedling production in the United States.

Here's to a productive 2025!

Andrea Watts

And the new plants, still awkward in their soil,
The lovely diminutives.
I could watch! I could watch!
I saw the separateness of all things.

—Theodore Roethke

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)**.

Contents

Figure 1. The 1-, 2-, and 3-year bareroot seedlings were planted in a 12 x 12 ft (3.6 x 3.6 m) grid across a 4.8-ac (1.94-ha) abandoned agricultural field and were placed within 5-foot (1.5-m) plastic tree shelters. Photo by Mark Heitzman, 1993.

Planted Black Walnut in Vermont: A 30-Year Experience

Mark Heitzman, M.D.

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Abstract

Eastern black walnut (*Juglans nigra*) is not commonly found in northern New England, however, a warming climate may be altering its ability to survive and grow in this region. In 1993, more than 1,000 commercially obtained black walnut seedlings were planted on an abandoned agricultural field in central Vermont with the goal of timber production. Subsequent management of the site was conducted according to previously established guidelines, including the use of tree shelters, herbicide control of competing vegetation, pruning, and thinning. Survival was 85 percent over a 5-year period. After 30 years, the average diameter at breast height of the trees was 10.18 in (25.9 cm) and timber form was good. With care, black walnut can be established and thrive in northern New England. A regionally adapted black walnut seed source for future assisted migration efforts is now in place.

Introduction

In the context of a warming climate, there are efforts underway in North America to extend the range of multiple hardwood and softwood species. A number of these efforts are documented in the Climate Change Response Framework (https://forestadaptation.org/) developed by the U.S. Department of Agriculture (USDA), Forest Service's Northern Institute for Applied Climate Science.

One of the goals of forest-assisted migration is to reinforce underrepresented populations currently at or near their range limit (Dumroese et al. 2015). In northern New England, eastern black walnut (*Juglans nigra*) is one such underrepresented species. Efforts to establish black walnut are currently underway in Ontario (Pedlar et al. 2023) and Quebec (Cogliastro et al. 2019, Truax et al. 2018). This brief report describes a 30-year experience with planted black walnut in central Vermont.

Site Description

In 1993, approximately 1,400 black walnut seedlings were planted on a 4.8-ac (1.94-ha) abandoned agricultural field in Barre, VT (44° N, altitude 1,100 ft (335 m)). The baseline and early-year details of this project have been described previously (Heitzman 2001). The planting site was open, west-facing, and comprised of deep silt-loam soil. Commercially obtained bareroot seedlings from New York, Michigan, Minnesota, and Pennsylvania were planted in a 12 x 12 ft (3.6 x 3.6 m) grid (figure 1).

All the seedlings were placed within 5-foot (1.5-m) plastic tree shelters. Glyphosate application via backpack sprayer was performed annually for the first 7 years. Regular pruning was and still is performed to foster good timber form (i.e., straight boles with minimal knots).

Results

Approximately 85 percent of the trees survived for the first 5 years, and mortality has since been minimal. The tree shelters effectively prevented deer browse but required considerable maintenance on this windy site. Insect damage (*Acrobasis* sp.) to terminal buds was common, as was dieback from late spring frosts, both of which have had adverse effects on timber form (figure 2).

Thinning operations in 2009 and 2019 reduced the stocking from 300 to 85 trees/ac (150 to 43 trees/ha). The average diameter at breast height (DBH) in the fall of 2023 was 10.18 in (25.9 cm), with DBH ranging between 6.8 and 15.3 in (17.3 and 38.9 cm) (figure 3). The trees began to produce a nut crop at 6 years old and have continued to do so, generally every other year. Overall, timber form is good, and the stand has some potential to be harvested for veneer.

Natural regeneration is occurring in the planting area, mainly due to caching of nuts by squirrels.

Discussion

Guidelines for the establishment of black walnut stands have long existed (Beineke 1993). This 30-year enterprise demonstrates that an approach applied successfully in other parts of the United States and Canada can also work in northern New England. The key elements for success include a good site with considerable sunlight, seedlings appropriate to the latitude, effective weed control, and prevention of animal predation. If the goal is timber production, regular pruning is essential.

Whether black walnut will be included in assisted migration efforts in northern New England remains to be seen. This project provides, if nothing else, a sizable, regionally adapted seed source for black walnut that has been selected for timber form.

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Figure 2. Black walnut terminal buds are vulnerable to late spring frosts (shown here) and insect damage. If the terminal bud dies back (left), it will resprout later in the season (right), but the timber form is compromised. Photos by Mark Heitzman, 1996.

Figure 3. This 30-year-old stand of black walnut now requires little maintenance apart from pruning and additional thinning. Photo by Mark Heitzman, 2023.

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Events and Announcements

Upcoming Nursery Conferences and Meetings

Hawai‘i Native Plant Growers’ Meeting

February 3–4, 2025, Volcano, HI
https://www.westernforestry.org/events/2025-hawaii-native-plant-growers-meeting/

Northeast and Southern Nursery Conference

July 21–23, 2025, Prairie du Chien, WI

Western Nursery Conference

September 16–18, 2025, Ashland, OR

2025 Forest Nursery Association of British Columbia Conference

September 23–25, 2025, Mary Winspear Centre, Sidney, BC
https://www.fnabc.com/

Pacific Northwest Nursery Survey

American Forests is conducting a survey to better understand the current production capacity of nurseries that serve Oregon and Washington and the challenges they might face in meeting anticipated growing reforestation demands.

Your insights can help to inform policies that may incentivize reforestation, including support for capital improvements to nurseries that may be necessary to meet reforestation goals.

We appreciate you taking the time to share your expertise. This survey should take 5–10 minutes to complete.

Thank you for your participation!

Direct link to survey: https://forms.gle/8LoPrhTZ7gdrsCA89

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.

Figure 1. Following the growing season, seedlings are moved into cold storage where they are labeled and organized. Come spring, the seedlings are removed and staged in a wax-lined cardboard box for shipping to customers. Photo by Kennedy Pendell, 2023.

Evaluating Cold Storage Effects on Big Sagebrush (*Artemisia tridentata*) Seedlings Through Seedling Quality Tests

Kennedy Pendell

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Abstract

The accumulation of chilling hours prior to cold storage and outplanting is essential for seedling cold hardiness, which allows seedlings to withstand cold temperatures. This project analyzed the effects of cold storage on outplanted big sagebrush (*Artemisia tridentata*) seedlings and performed electrolyte leakage and root growth potential tests. Big sagebrush seedlings with the highest survival had 500 chilling hours prior to cold storage, and electrolyte leakage tests showed this was a sufficient number of chilling hours for this species to become cold hardy prior to storage. Additionally, the fewer hours that big sagebrush seedlings spent in cold storage, the more successfully the seedlings grew roots in the root growth chamber. Determining the sufficient number of chilling hours that big sagebrush requires can aid nurseries in managing the storage of sagebrush, while understanding the relationship between cold storage and root growth potential can aid restoration professionals in estimating how well seedlings will grow when outplanted at restoration sites.

Introduction

Prior to European-American settlement, the big sagebrush ecosystem encompassed 156 million acres (63 million ha) throughout western North America (Boyle and Reeder 2005). This ecosystem supports 735 species (Remington et al. 2021) that are adapted to environmental conditions that include arid conditions during the summer and freezing temperatures during the winter. Currently, it is estimated only 50 percent of the big sagebrush species remain (Adler et al. 2018, Boyle and Reeder 2005). The loss of big sagebrush (*Artemisia tridentata*), an arid/semi-arid shrub, is of particular concern to range ecologists (Innes 2019).

Land use changes are the primary driver of the loss of big sagebrush ecosystems. These changes are a direct result of human activities and development and their interactions with other complex factors, such as altered fire regimes, invasive species, conifer encroachment, drought stress, and livestock grazing. Through these changes, competitive species, such as cheatgrass (*Bromus tectorum*), can become the dominant plant in this ecosystem. Given the fire-prone nature of the ecosystem, an increase in the fire frequency may limit the reestablishment of big sagebrush (Baker 2006).

Restoring big sagebrush ecosystems is a priority for organizations that include the U.S. Department of the Interior's Bureau of Land Management, the U.S. Department of Agriculture's Forest Service, the Idaho Fish and Game, and the World Center for Birds of Prey in Idaho. A primary goal of this restoration is increasing the distribution of big sagebrush across the landscape, which is accomplished through outplanting to supplement natural regeneration. Nurseries will play a crucial role in growing these seedlings, and one such nursery is the Forest Service's Lucky Peak Nursery in Boise, ID. This nursery currently produces about 2.5 million seedlings annually, which are a mix of conifer and shrub species grown as bareroot or container stock.

Lucky Peak Nursery follows the standard practice of placing seedlings into cold storage, which allows for flexibility in nursery management and plays an important role in the quality of seedlings produced (figure 1). Seedlings kept overwinter are stored in a freezer at 28 °F (-2 °C) and remain in a dormant state until conditions are favorable for outplanting (Overton et al. 2013).

However, cold storage conditions are unlike the environmental conditions that seedlings are exposed to in the field or in the greenhouse. Coolers are cold and dark, temperatures are low and constant, and there is high humidity (Ritchie 1987). When in cold storage, seedlings lose the ability to produce carbohydrate reserves through photosynthesis and instead consume carbohydrates through respiration to survive. The low temperature of cold storage reduces the rate of respiration, thereby prolonging the carbohydrate reserves and allowing the seedlings to survive longer (Ritchie 1987).

Cold hardiness is the capacity of plant tissue to withstand exposure to freezing temperatures (Herriman et al. 2012) or the minimum temperature at which a certain percentage of a seedling population will survive or withstand a given level of damage (Haase 2011). It is an essential physiological state that seedlings require to survive winter. Seedlings accumulate hardiness as photoperiod shortens, soil moisture decreases, and temperatures drop during the fall (Herriman et al. 2012). Cold hardiness can be measured by tracking photoperiod, accumulated chilling hours, or a combination of the two; chilling hours refer to the duration of time at which a seedling has been exposed to temperatures at or below 42 °F (5.5 °C) (Ritchie 2004). Federal nurseries use cold hardiness as an indicator of stress tolerance for seedlings.

Cold hardiness is critical for successful outplanting because it has been linked to higher survival and growth in the field (Haase et al. 2016). While long-term cold storage effects on seedlings have been studied for many conifer species, primarily Douglas-fir (*Pseudotsuga menziesii*) (Ritchie 1987, Simpson 1990), limited research has been conducted on the viability of big sagebrush seedlings in relation to time spent in cold storage. Measuring accumulation of chilling hours prior to placing seedlings in cold storage would give Federal nurseries a parameter to determine if seedlings are dormant and have enough carbohydrate reserves to survive in cold storage.

The chilling hour requirement for all seedlings at the Lucky Peak Nursery is 350 hours prior to cold storage (Nelson 2022, Ritchie 2004). Currently it is assumed that this requirement is the same for shrub species and other conifer species. Developing recommendations for how nurseries can prepare seedlings for cold storage may increase survival of outplanted big sagebrush and the success of restoration projects.

Methods

For this project, seedlings were sourced from the Lucky Peak Nursery. At Lucky Peak Nursery, seedlings are placed in either refrigerated storage between 33 and 35 °F (1 and 2 °C) or freezer storage at 29 °F (-2 °C). The Lucky Peak Nursery tracks seedling cold hardiness by calculating chilling hours and aims for seedlings to have a minimum of 350 chilling hours prior to cold storage to reach optimal cold hardiness (Ritchie 2004).

Plant Materials

Lucky Peak Nursery provided the seeds used for this experiment, which were collected at a site near the nursery in 2018. Seeds were sown into six Beaver Plastics Styroblocks (112 series) in March 2021. The Styroblocks were placed with another big sagebrush seedling lot for the growing season, known as a crop (figure 2). An overhead irrigation boom regularly misted the crop until germination occurred. Irrigation occurred at 70 percent of field capacity based on block weight (Dumroese et al. 2015). The crop was fertilized every three irrigation cycles with Peters Professional Conifer Finisher 4-25-35 with magnesium and YaraLiva CALCINIT 15.5-0-0 at 50 ppm.

Seedlings remained in Styroblocks until December 2021. At time of extraction, seedlings received exactly 506.4 chilling hours, exceeding the standard operational target at Lucky Peak of 350 chilling hours. Seedlings were extracted from Styroblocks and placed randomly into seedling bags in bundles of 10. Seedling bags were then placed horizontally into a lightly waxed box with a plastic box liner (figure 3). A total of 448 seedlings were extracted and placed into a freezer at 29 °F (-2 °C).

Figure 3. Once seedlings are extracted from the blocks, they are placed into thin plastic bags and packed into wax-lined boxes for cold storage. Photo by Kennedy Pendell, 2023.

Planting Site

The planting site was located at the Lucky Peak Nursery, where a small, 17-acre (6.9-ha) fire occurred in September 2020 and cleared most of the old endemic shrubs and native perennial forbs and grasses. One year after the fire, rush skeletonweed (*Chondrilla juncea*), bulbous bluegrass (*Poa bulbosa*), cheatgrass, medusa head (*Taeniatherum caput-medusae*), common storks-bill (*Erodium cicutarium*), and other invasives dominated the area. The site harbors wintering mule deer and offers habitat for ground-dwelling birds, small mammals, and predatory species such as coyotes and bobcats. These site characteristics made this an ideal location for a big sagebrush seedling survival study due to its similarities to big sagebrush restoration sites.

Figure 2. Big sagebrush crop used for this project in the greenhouse at Lucky Peak Nursery. Photo by Kennedy Pendell, 2022.

Planting

Beginning on March 21, 2022, 20 seedlings were randomly selected and pulled out of the freezer every 2 weeks and planted (table 1). To avoid root damage that could occur when the seedlings were planted, 2 days prior to planting they were placed in a walk-in cooler set to 33–35 °F (1–2 °C). In the planting site, seedlings were planted 3 feet apart in rows in a south-to-north orientation. Each outplanting had a designated row: outplanting (OP) 1 to OP17, and seedlings in each lot were numbered 1 to 20 in a south-to-north orientation. A drill with a 2-inch auger bit was used to drill the holes. Seedlings were placed in the holes with no portion of the plug still visible above the soil profile

Table 1. Dates of 17 outplantings of sagebrush seedlings, 2022

Outplanting	Date	Outplanting	Date
OP1	Mar. 21	OP10	July 25
OP2	Apr. 4	OP11	Aug. 8
OP3	Apr. 18	OP12	Aug. 22
OP4	May 3	OP13	Sept. 4
OP5	May 16	OP14	Sept. 18
OP6	May 31	OP15	Oct. 3
OP7	June 14	OP16	Oct. 16
OP8	June 27	OP17	Oct. 29
OP9	July 9		

Each planting included 20 sagebrush seedlings. The 8 months of plantings spanned both the ideal outplanting windows in the spring and fall, and the less-than-ideal time during the summer.

and soil compacted around the soil plugs to avoid air pockets and frost heaving near the roots (figure 4) (Shaw et al. 2015). The planted site encompassed 0.07 ac (0.2 ha) and included 17 rows of planted seedlings following 17 outplantings that spanned from March to October 2022.

Data Collection

Root Growth Potential

Every 2 weeks, 20 seedlings were randomly pulled from the freezer for outplanting. Two seedlings from each batch were randomly selected for testing root growth potential (RGP) and used as a control for each outplanting (figures 5 and 6). RGP is a useful indicator for seedling vigor and quality, and Lucky Peak Nursery uses this method to analyze a seedling's capability to produce new roots under ideal growing conditions.

The two seedlings thawed in a walk-in cooler set between 33 and 35 °F (1 and 2 °C) for 2 days before being placed into the RGP chamber. Seedlings were monitored over 14-day time periods. The RGP chamber stayed in a temperature-controlled building at roughly 59 °F (15 °C) for the entirety of this study. Supplemental lighting provided 10 hours of light a day to promote growth. At the end of each 2-week period, new roots greater than 0.2 in (5 mm) in length were recorded. The seedlings' RGP was rated on a scale of 0–4 using the Lucky Peak Nursery's protocol (table 2).

LT_{50} Testing and Frost Tolerance

Cold hardiness, also known as frost tolerance, is the ability of a plant to withstand freezing temperatures that can damage the plant cell tissues (Atucha Zamkova et al. 2021). The frost tolerance of seedlings can be tested using electrolyte leakage assessments. Of the available methods to conduct electrolyte leakage testing, the freeze-induced electrolyte leakage (FIEL) test was used.

FIEL testing uses seedling samples that are frozen to various decreasing freezing temperatures (Nelson 2022). At each benchmark temperature, the electrolyte concentration in the water is measured to determine the percentage of electrolyte leakage from the plant tissue. This value is used as a metric of tissue damage caused by freezing temperatures. Based on these measurements, the

Figure 4. Seedling from outplanting 3 (OP3) a few months after planting. Photo by Kennedy Pendell, 2022.

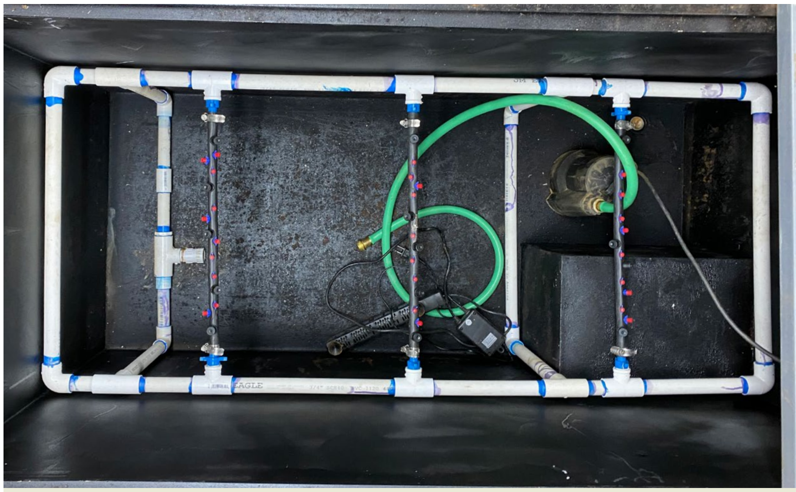

Figure 5. Root growth potential chamber used at Lucky Peak Nursery. Photo by Kennedy Pendell, 2023.

Figure 6. Seedling from OP17 in the root growth potential chamber. Photo by Kennedy Pendell, 2022.

lethal temperature for 50 percent (LT_{50}) of the population can be determined.

Samples consisted of nine replicates of randomly selected seedlings or clippings. These samples were randomly selected from when seedlings had no time in cold storage, at the time of the first outplanting, and from two outplantings in November 2022. Samples were placed in seedling bags and placed in a Styrofoam cooler with a freezer pack to maintain seedling vigor during the shipping process. Samples were overnighted to the University of Idaho's Pitkin Forest Nursery, which performed the FIEL tests immediately after arrival.

Leaves from each seedling sample were randomly selected, however, leaves with visible damage were avoided. Leaves were cut into 0.4-in (1-cm) segments and put into 20-mL vials with 10 mL of deionized water. The vials were then capped and placed into a programmable freezer set to decreasing temperatures of 19, 7, -6, -18, -31, and -40 °F (-7, -14, -21, -28, -35, and -40 °C). One sample set was removed at each temperature benchmark and set into a refrigerator to thaw at 36 °F (2 °C). Once samples were thawed, electrolyte concentration was measured with a Mettler Toledo SevenEasy conductivity meter. Next, all samples were completely killed in an autoclave followed by a secondary conductivity measurement. These two measurements were used to calculate the relative electrolyte leakage for each temperature (Nelson 2022).

Table 2. The Lucky Peak Nursery rating system for root growth potential

Index	Rating	Observation
0	Dead	No new root initiation
1	Poor	1–5 new roots at least 0.2 in (5 mm) in length
2	Fair	6–10 new roots
3	Good	10–20 new roots
4	Excellent	Greater than 20 new roots

Data derived from these tests determined the LT_{50} through plotting the index of injury against temperature and assuming a linear relationship between the two values. A lower LT_{50} value (more negative) indicates that a seedlot has higher cold hardiness. A higher LT_{50} value (more positive) indicates a seedlot has lower cold hardiness (Haase 2011). An upper threshold cold hardiness value for most conifer species is -4 °F (-20 °C), which can be assumed for shrub species like sagebrush (Nelson 2022, Simpson 1990).

To represent results from the LT_{50} tests, graphs were fitted with a sigmoidal (Gompertz) curve using SigmaPlot 14.5. The index of injury was created using direction from Flint et al. (1967) and data received from the LT_{50} tests conducted at the University of Idaho's Pitkin Forest Nursery.

$$\text{Index of injury } (T) = 100 \times (RT - R0) / (1 - R0)$$
$$RT = L1T / L2T$$
$$R0 = L1C / L2C$$

where

T is temperature

$L1T$ and $L2T$ are the initial and final leakage values for a sample exposed to temperature (T)

$L1C$ and $L2C$ are the corresponding values measured from respective control samples

Electrolyte leakage data starts at 0 percent and values are spread between 0 and 100 percent by adjusting the leakage values from totally injured samples as suggested by Lim et al. (1998):

$$\text{Percentage-adjusted injury } (T) = (\text{index of injury } [T] / \text{index of injury } [T\ lowest]) \times 100$$

where

index of injury (T) is the value obtained at respective freeze-treatment temperature

index of injury (T *lowest*) is that obtained at the lowest test temperature (-31/-49 °F (-35/-45 °C)) (Nelson 2022)

Results

The root growth observed in the RGP chamber was mixed (figure 7). For OP1, whose seedlings spent the least amount of time in cold storage, the RGP index rating was 0.5. This low RGP could be due to poor seedling health of the random samples, a malfunction of the root growth chamber water system, or even the environmental controls of the building the chamber was in. The same assumptions could be made for OP3 and OP7.

The RGP results show successful root production (aside from OP1, OP3, and OP7) until OP15. Root production of these seedlings show that when these seedlings are planted in ideal growing conditions, the seedlings should be successful in the field.

For seedlings stored for 10 to 11 months (OP15 through OP17), there was a significant reduction of root growth with half of the population not accumulating roots at all. The mortality of seedlings reached 50 percent beginning with OP15. These results suggest that seedlings can spend about 9 months in cold storage before 50 percent mortality is reached.

Staff conducted four LT_{50} tests over the course of the experiment (table 3). The first LT_{50} test was conducted on a random sample of nine seedlings from the entire seedling population on the date of extraction, and these seedlings had 506.4 chilling hours. This test resulted in the lowest LT_{50} value at -19.59 °F (-28.66 °C), indicating the seedlings had sufficient cold hardiness prior to cold storage. This value is a 2.55 °F (-16.36 °C) difference from the highest LT_{50} value, which was found for OP1 with the second test. The second LT_{50} test was conducted on a random sample from the entire seedling population at the time of OP1. This test resulted in an LT_{50} value at 9.86 °F (-12.3 °C), which indicated the seedlings did not exceed the upper threshold cold hardiness value at the time of outplanting.

On November 30, 2022, the third and fourth LT50 tests were conducted on clippings taken from OP1 and OP5. OP1 had an LT_{50} value of -9.4 °F (-23.0 °C) and OP5 had -11.99 °F (-24.44 °C). Based on these values, OP1 had less cold hardiness at the time of outplanting on March 30, 2022, than OP5 that was outplanted on November 30, 2022. OP5 had more cold hardiness than OP1 both before and after planting. However, each of these outplantings did reach the upper threshold of the cold hardiness value of -4 °F (-20 °C) (figure 8).

Table 3. The lethal temperature where 50 percent of the sampled seedlings died (LT_{50})

Test date	Outplanting (OP)	LT_{50} °C	LT_{50} °F
Dec. 8, 2021	Initial pack, no storage	-28.66	-19.59
Mar. 30, 2022	OP1 (before planting)	-12.3	9.86
Nov. 30, 2022	OP1 (after planting)	-23.0	-9.4
Nov. 30, 2022	OP5 (after planting)	-24.44	-11.99

The LT_{50} value is used to determine how cold hardy a seedling population is at the time of testing.

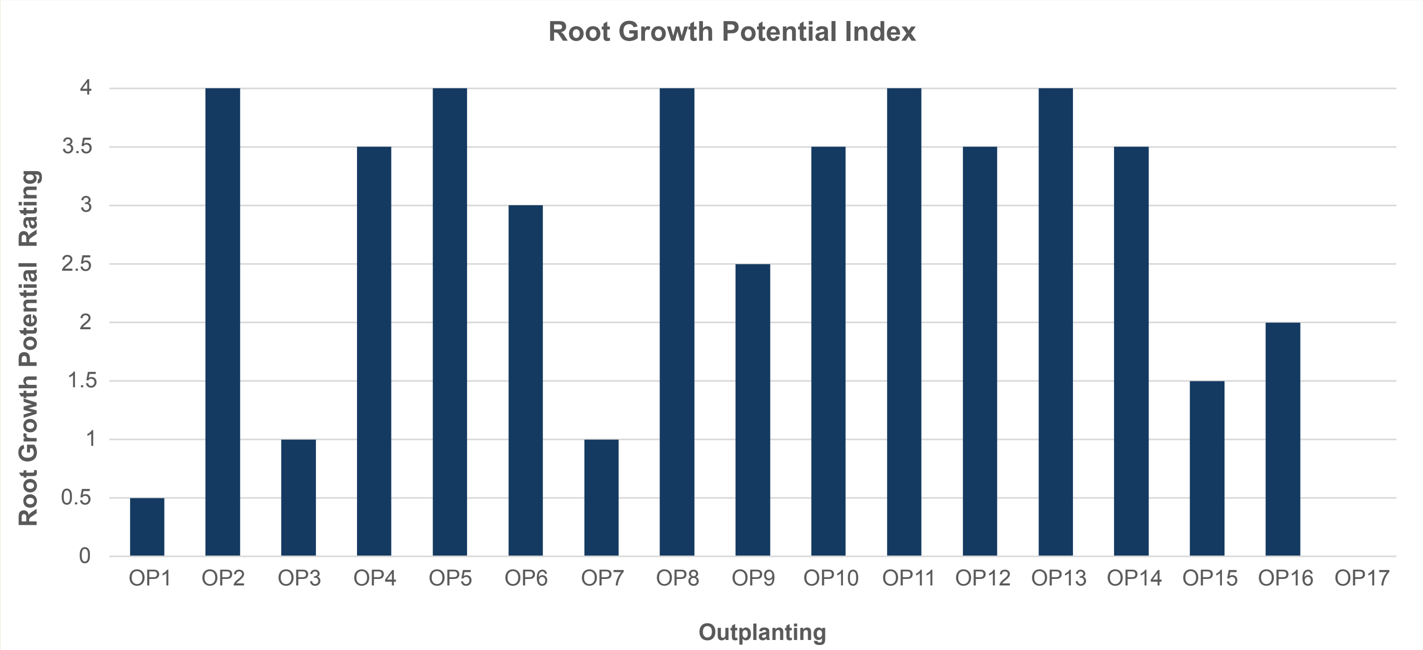

Figure 7. The root growth potential index rating for each of the outplanted seedlings. See table 2 for further details.

Discussion

This study analyzed each of the steps taken by Lucky Peak Nursery to grow big sagebrush seedlings for restoration projects and paired it with a cold hardiness experiment. Based upon the results, it is possible to develop recommendations for nursery production and outplanting.

The viability of seedlings through OP14, which occurred on September 18, shows that sagebrush seedlings can be kept in cold storage for up to 9 months and successfully survive outplanting. Apart from OP1, OP3, and OP7, 100 percent of seedlings for each outplanting produced new roots until OP15. Thereafter (OP15 to OP17), only 50 percent of seedlings produced new roots. It can be speculated from these results that the less time seedlings spend in cold storage, the higher survival rates outplantings will have if planted during ideal growing conditions. While seedlings remain viable with 9 months in cold storage, it is advised that seasonality of selected planting sites is taken into consideration, because temperature and soil moisture are still driving factors of seedling success.

Freezer conditions throughout the study did not change for these seedlings. They were kept at a constant 28 °F (-2 °C). There is always a concern for seedlings to mold when placed into overwinter storage; seedlings may also begin to grow in storage. Neither of these occurred during this study. Loss of leaf color on the seedlings did occur the longer seedlings spent in storage.

Cold hardiness testing of the big sagebrush seedlings confirmed that the seedlings were sufficiently cold hardy after 506.4 chilling hours. At the time of storage, the LT_{50} value for a given sample of the entire population was -19.59 °F (-28.66 °C). At the time of OP1, the LT_{50} value for a given sample of the entire population was 9.86 °F (-12.3 °C). This confirms that FIEL test measurements are characteristic of low LT_{50} values during a growth phase, and high when seedlings are dormant (Nelson 2022). In this study, seedlings were not placed into cold storage directly when seedlings reached 350 chilling hours. It is possible that the seedlings were sufficiently cold hardy at 350 hours, but the seedlings in this study surpassed this chilling requirement. However, this study shows that 500 chilling hours is sufficient for sagebrush seedling cold hardiness prior to cold storage.

Traditionally, LT_{50} plots should show an inflection point in the data where temperature maximum (T max) is found. The T max was not found for the first, third, and fourth LT_{50} tests. This could be due to the programmable freezer at the University of Idaho having a minimum temperature of -40 °F (-40 °C), where most reach -58 °F (-50 °C). It could also be due to the methods used to find LT_{50}, assuming that 100 percent mortality of seedlings is reached at the maximum temperature of the programmable freezer.

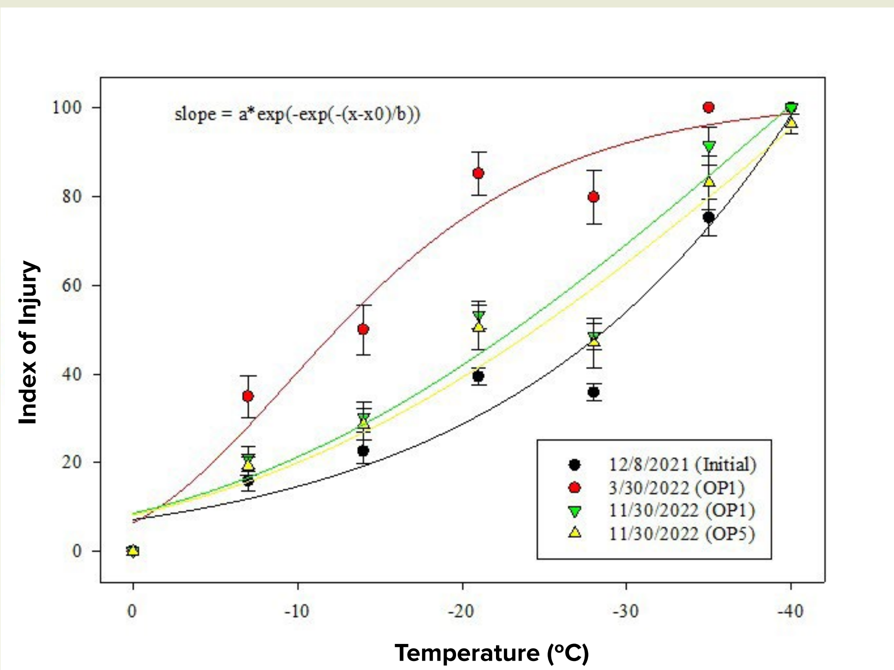

Figure 8. The relationships between temperature and index of injury (determined with electrolyte leakage) of big sagebrush seedlings at different storage dates (outplanting dates). Sigmoidal model fit is included.

Sagebrush seedling cold hardiness, which was determined by FIEL testing and finding the LT_{50}, confirmed that the seedlings were sufficiently cold hardy at the time of extraction prior to cold storage. Future studies could attempt to perform an electrolyte leakage test closer to 350 hours to further confirm that is enough chilling hours for not only conifers, but sagebrush seedlings as well.

While the LT_{50} data from this study confirm that the minimum chilling requirement Lucky Peak Nursery uses for its seedlings is sufficient, the study did not investigate how long-term cold storage affected all outplantings using this method. Further research could perform electrolyte leakage tests after storage for all outplantings. The data derived from this research could be used to analyze how cold storage influences cold hardiness of seedlings over a prolonged period. This would provide nurseries and their clients with insights on survival of sagebrush seedlings in relation to cold hardiness after cold storage.

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Figure 1. Small or light-colored tree seeds pose a challenge to sow uniformly into containers because they can be difficult to distribute evenly and are hard to see after being placed into growing containers. Photo by Jacob Witcraft, 2024.

Coating Seeds Using DayGlo Thermoplastic Pigments To Improve Sowing Distribution and Uniformity

Jacob Witcraft, Lori Mackey, and Nabil Khadduri

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Abstract

The uniform sowing of tree seeds into containers is crucial to ensure that the desired number of seedlings is produced for each respective growing season. However, very small, dark-colored, or light-brown seeds can make uniform sowing challenging. For over 20 years, the Washington State Department of Natural Resources' Webster Forest Nursery used tempera paints to remedy this issue, though the paints do not greatly increase the visibility of the seeds. A sowing trial using DayGlo brand A/AX thermoplastic pigments proved successful in increasing seed visibility. Additionally, nursery staff reported more uniform sowing and increased productivity when policing lot changes.

Introduction

The low visibility of certain seeds—especially from tree species that produce very small seeds, such as western hemlock (*Tsuga heterophylla*) and Sitka spruce (*Picea sitchensis*)—makes it difficult to evenly distribute those seeds into containers. Light-brown and darker colored seeds can look very similar to the color of growing medium, making them difficult to see (figure 1). To remedy these issues, the staff at the Washington State Department of Natural Resources' Webster Forest Nursery (Webster) have used tempera paints to color seeds for increased visibility.

Tempera paints are powdered and meant to be mixed with water, but instead Webster dusted the seeds with the powder. Unfortunately, there were some drawbacks to this method of colorization. The paint colors are faint; although they increased seed visibility, it was not as much as desired. The powdered paints also tended to clump if there was too much moisture on the seeds, which clogged the needles on the vacuum needle seeder. Tempera paints have also been reported to occasionally clog vacuum drum seeders (Rhoades 2024, Stevens 2024).

After attending a conference and networking with the University of Idaho's Franklin H. Pitkin Forest Nursery (Pitkin), Webster became aware of an alternative to coloring seeds. For nearly 25 years, Pitkin has used A/AX thermoplastic AX-11-5 Aurora Pink pigment due to its high visibility and ease of adherence to both conifer and hardwood seeds, whether dry or damp. This pigment provides vivid colorization that persists throughout the growing season on the seed coat, allowing for prolonged visibility throughout the germination process.

Methods

For the 2024 sowing season, at the suggestion of Lori Mackey, a research specialist with the Pitkin Nursery, Webster staff trialed Pitkin's method of colorizing seeds using DayGlo brand A/AX thermoplastic pigments. (Pitkin uses approximately 0.25 tsp (1.06 g) of powder stirred into a bowl of 0.5 lb (0.22 kg) of seeds to color the seeds prior to machine or hand sowing.) Mackey donated some of their nursery's AX-11-5 Aurora Pink pigment, and DayGlo provided free samples of AX-17-N Saturn Yellow and AX-15-N Blaze Orange (figure 2).

Before testing this coloring method on the smallest and most delicate seeds, Webster staff conducted a germination test of western hemlock seeds treated and untreated with the pigment. Their results showed no significant difference in germination between the colorized and the control seeds.

Webster staff used the pigments to colorize seeds of western hemlock, Engleman spruce (*Picea engelmannii*), Sitka spruce, western white pine (*Pinus monticola*), Douglas-fir (*Pseudotsuga menziesii* var. *menziesii*), and lodgepole pine (*Pinus contorta*). For each seed batch, a 1-qt (0.94-L) bucket was filled halfway full of seeds and less than 0.5 tsp (2.09 g) of pigment was placed on top of the seeds. A lid was placed on the bucket, and the seed and pigment were gently mixed. The extremely fine pigment effectively coated the seeds. There were no issues with the pigments clogging the needles on the Bouldin & Lawson (McMinnville, TN) vacuum needle seeder (figure 3). The bright colors made it much easier to verify the correct number of seeds were being placed in each cavity (figure 4).

Results

The three different colors made switching between seed lots very visual, and it was easy to ensure lots were not mixed up (figure 5). Webster contract workers shared that the colors helped them police lot changes and, overall,

Figure 2. DayGlo manufactures a range of daylight fluorescent pigments. As per the company website, the "A and AX series pigments are thermoplastic, fluorescent pigments recommended for a wide range of applications where resistance to strong solvents is not needed, including paper coatings, vinyl coated fabric, A-type gravure inks, paints, screen inks, and vinyl plastisols and organisols" (DayGlo Color Corp. [N.d.]). Photo by Jacob Witcraft, 2024.

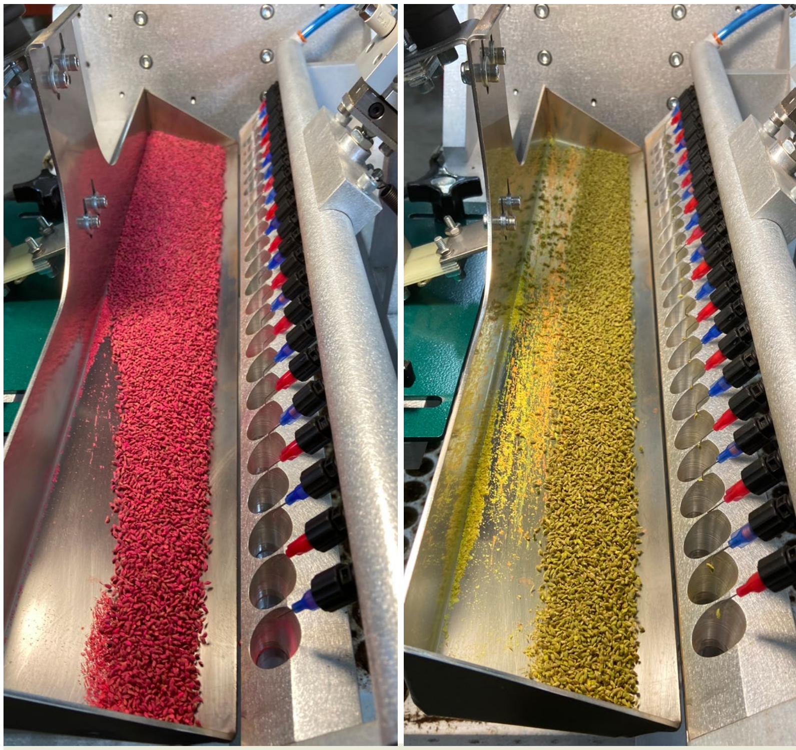

Figure 3. Prior to being sown, the seeds were processed through the vacuum needle seeder, and the additional pigment did not clog the needles. Photo by Jacob Witcraft, 2024.

Figure 4. Following sowing, the coated seeds were very visible against the planting medium. Nursery workers reported that applying colors to the different seed lots made them easier to track. Photo by Lori Mackey, 2024.

Figure 5. Contrasting colors facilitated seed lot changes. Photo by Nabil Khadduri, 2024.

greatly expedited seed checking. Webster staff found that all the colors tested performed exponentially better than the tempera paints. The orange and pink were both very vibrant colors that provided the needed contrast against the media. While the yellow worked much better than previous treatments or no color at all, Webster staff found that contrasting on the brown seeds made the color more of a greenish hue, which was not as bright as the orange or pink (figure 6).

The brighter colors helped Webster staff achieve a much more uniform distribution of seeds than sowing without colorization. The germination class counts of Sitka spruce in 240-cell containers increased more than 10 percent over the previous two growing seasons, and western hemlock germination classes increased by around an average of 5 percent.

For another sowing trial, the pigments were used to colorize seeds not typically colored due to their size, presence of resin vesicles, or seed color. Webster tested the colors on noble fir (*Abies procera*), grand fir (*A. grandis*), Pacific silver fir (*A. amabilis*) western redcedar (*Thuja plicata*), ponderosa pine (*Pinus ponderosa*), and western larch (*Larix occidentalis*) and found no ill effects on the germination or growth of any of the seeds. These results correspond to practiced applications of the pigment used at Pitkin (figure 7).

Discussion

Given the success of this trial, Webster will adopt the use of DayGlo brand A/AX thermoplastic pigments for the sowing of all seeds. The cost of these A/AX thermoplastic pigments was an estimated 50 times what the tempera paints cost for a similar weight of product. However, staff can likely use 10 times less of the pigments than the tempera paints, and the productivity savings outweigh the purchase cost.

A question remains whether the impressive visibility and longevity of the product will increase bird or other forms of animal predation. In this first season of use, Webster reports little to no loss. One seed coating website claims that bright colors may actually deter predation, particularly from birds, though this claim lacks substantiation (Summit Seed Coatings 2023). This is counter to findings that natural variation in seed coat colors serve as camouflage in native soils to limit predation (Porter 2013).

Figure 6. Difference in color between the AX-15-N Blaze Orange (left) and the AX-17-N Saturn Yellow (right) on western white pine seeds. Photo by Jacob Witcraft, 2024.

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Figure 7. Applications of the pigment to the seeds of true firs, western redcedar, ponderosa pine, and western larch have had no negative effect on the germination or growth of these seeds. Photo by Lori Mackey, 2024.

Proceedings Paper Presented at Joint Annual Meeting of the Western Forest and Conservation Nursery Association and the Forest Nursery Association of British Columbia

Portland, OR, September 19–21, 2023

All That They Are Wrapped Up To Be? How the Advantages and Drawbacks of Paper-Wrapped Plugs May Play Out in Pacific Northwest Reforestation and Restoration

Figure 1. Ellepot and other similar brands consist of a soilless medium plug contained within a paper-woven fabric, supported in a plastic container. Photo by Nabil Khadduri, USDA Forest Service, 2023.

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Abstract

Ellepot is a brand name associated with a stocktype in which plants grow in a soilless medium contained in a biodegradable, paper-based sleeve. Although this technology has existed for 30 years, recent marketing focused on Pacific Northwest (PNW) reforestation and restoration managers has led to increasing nursery demand for this stocktype. Potential advantages of paper-wrapped plugs over the current PNW standard plug produced in Styroblock containers include the elimination of difficult-to-recycle expanded polystyrene, a stabilized plug amenable to handling prior to complete root fill, early sorting of cells, ease of extraction for aggressive-rooting species at packout, and a more highly branched root architecture due to air pruning. Potential disadvantages include ongoing identification of an appropriate supporting container that balances air pruning, excess drying, and

space efficiency. Additional challenges include economic production of plugs, as well as timely plug fabrication within the relatively short windows of greenhouse sowing in reforestation. Some PNW growers already use paper-wrapped plugs based on the advantages described above. However, widespread adaptation in PNW reforestation and restoration will require (1) consistent production of a fibrous root system, (2) field trials confirming superior performance, and (3) nursery production costs justified by subsequent field performance. This paper was presented at Growing Pains: Scaling up the Reforestation Pipeline—Joint Annual Meeting of the Western Forest and Conservation Nursery Association and the Forest Nursery Association of British Columbia (Portland, OR, September 19–21, 2023).

Introduction

Since the 1970s, reforestation container nurseries in the Pacific Northwest (PNW) and British Columbia produce most seedlings in Styrofoam containers, an expanded polystyrene tray first developed in Canada (Arnott 1973, Matthews 1971). Current greenhouse production systems in the United States have commonly used the Styroblock for the last 50 years. The Styroblock system (Beaver Plastics, Acheson, AB) is generally mechanized and has a variety of sizes and shapes. Many growers are understandably reluctant to abandon a proven process that generates consistent quality seedling stock at competitive prices.

The Ellepot (Ellegard A/S, Esbjerg, Denmark) container system consists of a tube of soilless medium contained within a paper-woven fabric that is supported in plastic containers (figure 1). This technology was developed in the early 1990s, with widespread adaptation in specific sectors of the horticulture industry where a stabilized plug is specifically desired for rooted cuttings and other uses (figure 2). Blackmore Company (Belleville, MI) markets Ellepot products in North America. A similar system uses the Fibercell container that is made in Sweden and offered through Stuewe and Sons, Inc. (Tangent, OR). These two companies use the same manufacturing equipment to produce their respective container systems; the main difference is the paper types and degradation times. Growers can also purchase premade paper-wrapped plugs from companies such as OBC Northwest (Canby, OR), which licenses Ellepot machines and papers to produce plugs under the Earthpot brand.

Considerable marketing to promote the paper-wrapped plug has recently focused on PNW reforestation and restoration managers, which in turn has led to increasing demand for this stocktype from nurseries. To adopt this stocktype, growers must be convinced of seedling quality and economic feasibility to warrant a major change in production. While this article describes the Ellepot, the findings herein are likely applicable to all brands of this paper-wrapped plug container type.

Figure 2. Ellepots are primarily used in the horticulture industry where a stabilized plug is desired, such as with clonal propagation. Photo by Diane L. Haase, USDA Forest Service, 2014.

Advantages of Ellepots Compared With Styroblocks

Environmental Perception

Ellepots, while still supported in plastic containers, present an alternative to Styrofoam container propagation. The longevity of Styroblocks is 7 to 10 years, depending on number of uses, species grown, storage conditions, and exposure to the elements. Blocks are discarded as they age and become difficult to clean and sterilize (James and Trent 2005). Styrofoam is an "everlasting" product because it does not readily break down (Cansler 2018). Thus, most recycling centers and landfills will not accept Styroblocks (Landis 2011). A common site at PNW container nurseries is a growing pile of foam containers in various states of age and decay awaiting removal (figure 3).

Figure 3. Styroblocks can be difficult to recycle. Large stacks of styroblocks of various ages are a common sight at nurseries in the Pacific Northwest. Photo by Nabil Khadduri, USDA Forest Service, 2023.

Until recently, Agilyx, in collaboration with AmSty, offered a “closed loop” recycling option for polystyrene at Regenyx (Tigard, OR), which accepted dry, palletized Styroblocks at no cost. As of May 1, 2024, this program has shut down after “completion of the 5-year demonstration project” and due to the “dynamic nature of the recycling industry” (Duffler 2024). Several nurseries use a semi-portable densifier (GreenMax Intco Recycling, Ontario, CA, https://www.intcorecycling.com/) to densify blocks at a ratio of up to 90:1 (figure 4a). The resulting ingots are used in park benches, picture frames, and other products made from recycled materials. A mobile service using similar technology is offered by Mobilepoly Plastics (628–236–3168, sunny@mobilepoly.com) (figure 4b).

Stabilized Plug

Ellepots are a type of stabilized plug. Unlike a cavity with loose-filled medium, the paper-wrapped plug maintains its own structural integrity from the outset—a grower does not need to wait for roots to occupy the cavity to extract and handle the plug for sorting and sizing up. Fourth Corner Nurseries (Bellingham, WA) uses premade Earthpot paper-wrapped plugs to start material for early transplant to larger Styroblocks or to bareroot beds (figure 5). At the Washington State Department of Natural Resources’ Webster Forest Nursery, Ellepots have been used for red alder (*Alnus rubra*) propagation in large cells without transplant. The ability to sort early in the growth cycle helps overcome germination irregularity and variability in top growth. Once seedlings are sized and consolidated, a plant growth regulator is applied to the early germinating and faster growing material for a more uniform crop. This approach has resulted in a relative increase in red alder packout.

As a stabilized plug, Ellepots are particularly useful for rooted cuttings and other forms of clonal propagation or for any situation where root development tends to lag shoot growth. Green Diamond’s Korbel Nursery (Korbel, CA) uses small Earthpot plugs to establish coast redwood (*Sequoia sempervirens*) propagules before later transplant to larger Styroblock containers (figure 6).

Other stabilized plug technologies exist. Steinfeld (2004) and Landis (2007) described peat plugs bonded with polymer for use in PNW forestry. Those stock types, such as the Q plug or Excel plug (International Horticulture Technologies, Hollister, CA), reduce the container phase of plug to bareroot transplant stock types and can also be used for plug-to-plug transplants. Yet another type of stabilized plug consists of compressed peat, such as Jiffy

Figure 4. Recently introduced recycling options for Styroblocks include a semi-portable densifier (a) and a service that densifies on site (b). Photo (a) by Steven Kiiskila, Arbutus Grove Nursery, 2023; photo (b) courtesy of Eric Stuewe, Stuewe and Sons, 2024.

Figure 5. Fourth Corner Nurseries (Bellingham, WA) uses Ellepot containers to start plants for early transplant (a) to larger Styroblocks or bareroot fields (b). Photos by Kelly Broadlick, Fourth Corner Nurseries, 2022.

pots (Jiffy Products, Lorain, OH), that is expanded by the grower within a mesh wrapper.

Unlike other stabilized media products such as peat polymer or compressed peat, paper-wrapped plugs offer the grower more choices to customize media components both for in-house production and from premade production facilities.

Fibrous Root Architecture With Air Pruning

Nelson (1996) described three general categories of root systems produced in containers (figure 7). (See Grossnickle and Ivetic (2022) for an excellent literature review and indepth discussion of these root categories.) While all categories have some sort of bottom opening for drainage and root air pruning, containers producing category A root form have smooth sidewalls that tend to promote spiraling and may also have twisting at the bottom of the cavity. To combat root spiraling, containers producing category B root form have vertical structures such as ribs along the inner wall. Containers producing category C root form have lateral pruning from vertical slits or holes, copper-treated sidewalls, or mesh/paper-walled sleeves, such as Ellepots.

Figure 6. Green Diamond's Korbel Nursery (Korbel, CA) uses small Ellepot plugs (a) to establish coastal redwood propagules (b) before later transplant to larger Styroblock containers (c). Photos by Carlos Gantz, Green Diamond, 2022.

Figure 7. Containers generally produce one of three categories of root systems. Illustrations and photos from Grossnickle and Ivetic (2022), adapted from Nelson (1996).

Due to lateral root pruning, category C root systems have more second-order lateral roots than category A or B root systems, with a fibrous and horizontal root system distributed throughout the plug. Copperblocks (Beaver Plastics, Acheson, AB) achieve a category C root system through copper pruning of root tips, but Ellepots can also produce a category C root system without the effects of copper in the environment or the growing medium while also providing the benefits of a stabilized plug.

Easier Handling and Planting

The protective paper wrapping of the Ellepot can limit plug deterioration and transplant stress in both the nursery and the field. Some species may be very slow to fill a cavity and prone to lose media, especially from the top portion of the plug. Landis (2023) is exploring paper-wrapped plug production of spring-ephemeral California milkweed (*Asclepias californica*) to retain plug integrity at time of fall planting (figure 8).

Ellepots may also be useful for hot planting reforestation species. In a limited fall planting program, Washington State Department of Natural Resources starts coastal Douglas-fir (*Pseudotsuga menziesii* var. *menziesii*) and noble fir (*Abies nobilis*) in early spring to ensure extractable plugs are ready by the onset of September rains. Seedlings sown early are at risk of becoming root bound with decreasing root growth potential, especially if fall planting windows do not open (Grossnickle and MacDonald 2021). A paper-wrapped plug may allow for later sowing and complete lifting of stock in active rooting condition, even for seedlings that have not yet filled the plug. If the fall planting window is missed, air-pruning might, in theory, delay the over-development of roots when a grower must hold seedlings until spring planting.

Figure 8. Trials are underway to determine whether slow-rooting California milkweed (*Asclepias californica*) (a) will establish better in a paper-wrapped plug stock type (b). Photo (a) by Drew Farr, USDA Forest Service, 2022; photo (b) by Thomas Landis, Native Plant Nursery Consultant, 2023.

Potential for Improved Field Performance

When looking at category C root systems, some studies show that this root architecture may have higher root growth potential at the time of planting, as well as increased root growth after outplanting (Grossnickle and Ivetic 2022). However, evidence in the literature is scarce on examples of improved field survival and growth in reforestation species. In fact, several studies found no difference in field performance in the first 2 to 8 years after outplanting based on originating nursery root system (e.g., Sung et al. 2019, Jones et al. 2002).

In a summary of 10 years of work with lodgepole pine (*Pinus contorta*), Krasowski (2003) concluded that improved tree stability appears primarily due to site soil texture rather than root category originating from the nursery. In a long-term study with ponderosa pine (*P. ponderosa*), Dumroese et al. (2022) note the plasticity of roots, with genetic responses to mechanical forces such as wind direction and slope, overriding an original nursery treatment with copper root pruning 32 years earlier. Widespread adoption of paper-wrapped plugs in South America has been justified by improved survival and growth in the field (Gantz 2023). It is unclear how much of this improved field performance is due to the benefits of early plug manipulation regarding clonal propagation or the ability to outplant aggressive-growing species from seed earlier in the nursery cycle.

Drawbacks of Ellepots Compared with Styroblocks

Media Filling Efficiencies

Styroblocks are loose filled, directly loading empty container cavities from above with growing medium (figure 9); paper-wrapped plugs are vacuum loaded and require specialized equipment that requires increased monitoring and maintenance (figure 10). Vacuum loading is a comparatively slower process than loose filling. Even larger, higher throughput Ellepot machines may be unable to meet the condensed production cycles associated with short spring sowing timeframes common to reforestation and restoration nurseries in the PNW. The production of hundreds of millions of paper-wrapped plugs for reforestation in South America over the last decade may be facilitated by the distribution of plug production over several cycles per year in shorter rotation crops.

As with loose filling of containers, the physical properties of the media in paper-wrapped plugs are a critical determinant of eventual seedling quality. A dedicated staff member needs to master the art of manipulating machine vacuum controls, in combination with media texture and moisture content, to produce paper-wrapped plugs with appropriate bulk density, aeration porosity, and water-holding capacity. The operator must avoid excessively firm plugs from over compaction, while also avoiding light plugs that do not properly hold together within the paper sleeve and can result in permanent gaps in the plug.

Adjustments to Sowing and Growing Equipment and Processes

To sow a vacuum-filled plug, growers may need alternative dibbling equipment that removes media rather than compresses it. Standard dibbling in loose-filled containers may not be adequate to retain seeds. Growers may also need to adjust sowing and gritting practices so that seed

Figure 9. Styroblocks are “loose filled,” where media drops directly into empty cavities. Photo by Nabil Khadduri, USDA Forest Service, 2023.

Figure 10. Paper-wrapped plugs, such as Ellepots, are vacuum loaded, which requires more equipment to monitor and maintain. Photo by Nabil Khadduri, USDA Forest Service, 2023.

Figure 11. Smooth-walled Airtray 50-count thermoform trays (Blackmore Company, Belleville, MI) (a and b), which tapered to a narrow drainage hole, failed to improve root fibrosity in growing season evaluations of Ellepots in 2022 (c). Photos by Nabil Khadduri, USDA Forest Service, 2022.

and top-dressing material does not fall into the air gaps between Ellepots and the supporting container. Growers have also noted difficulty in transplanting germinants to empty cells. Due to the generally higher bulk density of vacuum-filled cells, germinants snap off when transplanting, precluding full occupancy of containers. A final horticultural challenge is optimization of water frequency and volume (Munroe et al. 2018, Simshaw et al. 2015). This is largely dependent on the supporting container, and the next section discusses challenges with trays trialed at Webster Nursery and other locations in the past three seasons.

Continuing Development of Ideal Supporting Container

Ironically, the most important aspect of "containerless" stocktypes such as the Ellepot is the overriding importance of the container (tray) that supports the freestanding plugs. The desired tray should meet three objectives: (1) effective air pruning to help develop a fibrous root system; (2) balance of air pruning with excessive drying of plugs; and (3) reasonable maintenance costs and similar space efficiency compared to standard containers.

Effective air pruning. The interface between the paper-wrapped plug and the container determines air pruning or lack thereof, which directly impacts the resulting root architecture. In 2022, Webster Nursery tested a thermoform Airtray 50-count container (Blackmore Company, Belleville, MI) (figures 11a and 11b). Benefits included low cost, light weight (though fragile), nesting for storage, and ability to recycle with the manufacturer after one season. Due to physical limitations in manufacturing, however, the taper of the tray meant substantial contact of the plug with portions of the sidewall and bottom of the container. This reduced air pruning, resulting in root egress mainly from the bottom of the plug (figure 11c).

In the 2023 nursery crop cycle, Webster Nursery evaluated a Proptek 32-count injection-molded tray (Blackmore Company, Belleville, MI) (figure 12). Larger vertical ribs and a greater opening at the bottom of the cell on this heavier, more durable tray were designed to increase air pruning. Lateral root egress was increased in comparison with Styroblock-grown plugs produced from the same seed lots, though there was not a consistent increase in root biomass,

Figure 12. The sturdier injection-molded Proptek 32-count trays (Blackmore Company, Belleville, MI) tested in 2023 had larger ribs and a wide opening at the bottom of the cell that improved air pruning. Photo by Nabil Khadduri, USDA Forest Service, 2023.

with variation by species tested (figure 13); results of ongoing 2024 outplant trials will be published in the future. This correlates with other comparisons of Styroblock and Proptek containers conducted at the University of Idaho (Gilgunn 2024).

Balance of air pruning and rapid drying. Air pruning may result in more rapid drydown cycles and edge drying, and a grower must adjust irrigation practices to optimize water frequency and volume (Munroe et al. 2018, Simshaw et al. 2015). In the University of Idaho trials, Gilgunn (2024) evaluated three sizes of Proptek containers, with smaller plugs in relatively open trays producing comparatively more lateral root development than plugs in larger containers. However, this resulted in significant mortality due to excessive drying.

On the other hand, where water bridged between the paper-wrapping and container sidewall, effective air pruning did not take place. In the 2024 growing season, the University of Idaho and other nurseries are testing yet another container, the new Airtray 84-count injection-molded tray (Blackmore Company, Belleville, MI) (figure 14). Concerns with edge drying persist, with rapid overall cycling of plugs translating to very frequent water application on Webster Nursery and Silvaseed Nursery demonstration containers (figures 15a and 15b).

Maintaining costs. The third objective in tray development is keeping costs in check. The first two trays described above contain a low density of cells, with at least 12–20 percent fewer cells per unit area than Styroblock containers (see figures 11 and 12). Comparatively, the Airtray 84 approaches the space efficiency of an equivalent cell count Styroblock. This is especially important in greenhouse growing, where cost per unit area is at a premium. The injection-molded trays weigh 4.6 lb (2.1 kg), considered heavy by industry standards, but they have a relatively long shelf life with easier sanitation and recycling options than Styroblocks. They also nest at 60 percent of volume, unlike Styroblocks that do not nest (Taylor 2023).

Figure 14. The new Airtray 84-count injection-molded container (Blackmore Company, Belleville, MI). With increased cell density and additional side slotting for air pruning, the goal is to produce a category C root system economically and consistently. Photo by Nabil Khadduri, USDA Forest Service, 2024.

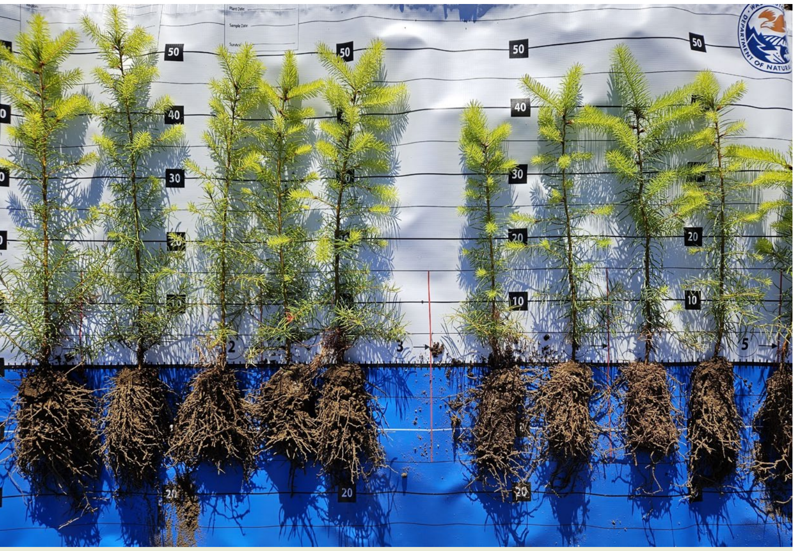

Figure 13. In 2024 field evaluations of a 2023 nursery comparison, Ellepot-produced plugs grown in a Proptek tray (left) have generally outperformed plugs grown in Styroblocks (right) in initial root growth, especially lateral root growth. Photo is of coastal Douglas-fir (*Pseudotsuga menziesii*) 7 weeks after planting. Photo by Nabil Khadduri, USDA Forest Service, 2024.

Conclusion

In the general horticulture industry, growers use paper-wrapped plugs primarily for the benefits of a stabilized plug. Accordingly, PNW reforestation growers have thus far adopted Ellepots to facilitate early sorting and sizing up in the nursery. The early extraction capabilities may also facilitate hot planting, including fall planting.

A major attraction of paper-wrapped plugs is the reduction of polystyrene-based container propagation. For widespread replacement of Styroblocks or other container types, however, three steps must be addressed. First, growers must feel confident that they can match a tray with reasonable irrigation practices to produce consistent packouts of seedlings with fibrous, category C root systems. Second, landowners need to evaluate field performance of category C and category B root systems across species and sites. Third, if trials demonstrate improved field performance of paper-wrapped-produced

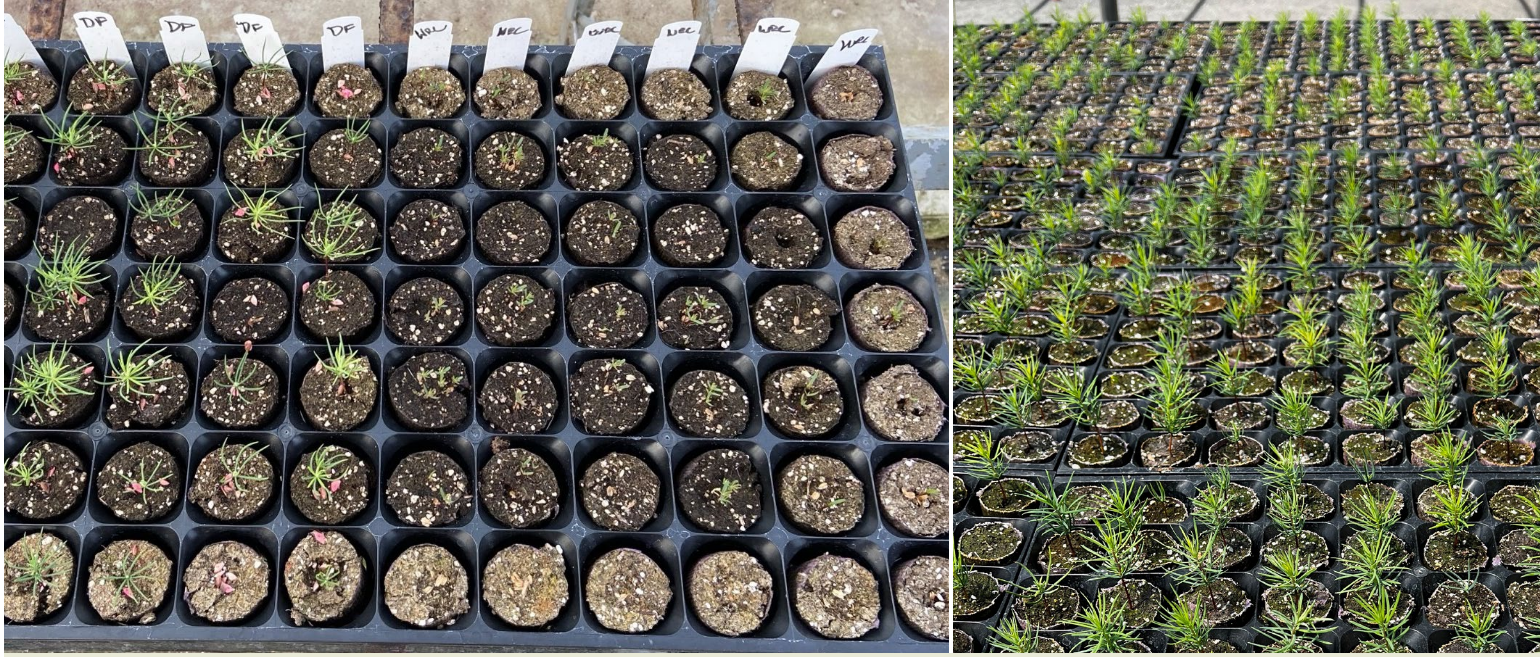

Figure 15. Webster Forest Nursery (Tumwater, WA) (a) and Silvaseed Nursery (Roy, WA) (b) have both noted edge drying and the need for frequent waterings with the new open-sided Airtray 84-count container. Photo (a) by Jacob Witcraft, Washington State Department of Natural Resources, 2024; photo (b) by Lydia Tymon, Silvaseed Nursery, 2024.

category C root systems, this outplant performance must align with nursery production costs. If category C root systems improve field performance, but paper-wrapped plug production is not economically feasible, it may be worth investigating loose-filled containers designed to air prune from the sidewalls as a Styroblock alternative.

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Forest Nursery Seedling Production in the United States—Fiscal Year 2023

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Abstract

Forest nurseries produced more than 1.27 billion tree seedlings for the 2023 planting season, including more than 38 million container seedlings imported from Canada. Approximately 68 percent of seedlings were produced as bareroot stock. Over 96 percent of the total stock grown was conifer seedlings; only a small portion (3.5 percent) of seedlings were hardwood species. Based on this total number of seedlings and estimated planting densities in each State, more than 3.7 million ac (1.5 million ha) were planted. Approximately 80 percent of production and planting occurred in the Southern States, while 14 and 6 percent were planted in the Western and Eastern States, respectively. In 2023, number of tree seedlings planted decreased in the Western and Southern States and increased in the Eastern States compared with the previous year. This decline is likely attributable to a lower-than-normal response rate to the annual data request.

Background

This annual report summarizes forest nursery seedling production in the United States, which serves as an estimate of the number of acres of forest planted per year. Prepared by the U.S. Department of Agriculture, Forest Service, Forest Inventory and Analysis (FIA) and State, Private, and Tribal Forestry, this report includes State-by-State breakdowns, regional totals, and an analysis of data trends. Support for the production of this annual report is part of FIA's mandate, as per Congress, to report on the status and trend of the Nation's forest resources.

Universities in the southern, eastern, and western regions of the United States attempted to collect data from all the major producers of forest and conservation seedlings in the 50 States. Forest and conservation nursery managers provided the information presented in this report. Because all data are provided voluntarily by outside sources and some data are estimated, caution must be used in drawing inferences.

Methodology

The Forest Service's State, Private, and Tribal Forestry Deputy Area, in collaboration with Auburn University, the University of Idaho, and Purdue University, produced the data for this report. These universities collected forest tree seedling production data directly from the forest and conservation nurseries that grow forest tree seedlings in their region of the United States (Auburn University collected from 12 States in the Southeast, the University of Idaho collected from 17 States in the West, and Purdue University collected from 21 States in the Northeast and Midwest). The estimate of planted acres for each State was calculated using FIA estimates of planting densities for the associated measurement cycle. FIA average annual estimates of trees planted are derived from permanent field plots, situated across the United States, that are sampled on a 5-, 7-, or 10-year remeasurement cycle by State.

FIA estimates of acres of trees planted by State may not correlate with those derived by nursery production surveys because FIA estimates are calculated across the measurement cycle. In addition, domestic nurseries are not asked to report shipments of seedlings across State lines; seedlings produced at that nursery are reported for planting in the State where the nursery is located. Total acres by region, however, provide a reasonable estimate for planted acreage. Data collected are reported for both hardwood and conifer species by bareroot and container seedlings produced (table 1) and by estimated acreage planted of each (table 2).

Table 1. Hardwood and conifer seedling production for each State and each region during the fiscal year 2023 planting year

State	Hardwood bareroot seedlings produced	Hardwood container seedlings produced	Total hardwood seedlings produced	Conifer bareroot seedlings produced	Conifer container seedlings produced	Conifer container seedlings imported	Total conifer seedlings produced	Total seedlings produced
Southeast								
Florida	1,111,000	60,000	1,171,000	40,349,000	1,121,000	-	41,470,000	42,641,000
Georgia	6,653,000	135,000	6,788,000	172,786,000	150,229,000	-	323,015,000	329,803,000
North Carolina	390,000	40,000	430,000	39,871,000	16,003,000	-	55,874,000	56,304,000
South Carolina	-	-	-	138,550,000	6,000	-	138,556,000	138,556,000
Virginia	2,186,000	-	2,186,000	29,860,000	644,000	-	30,504,000	32,690,000
Regional totals	**10,340,000**	**235,000**	**10,575,000**	**421,416,000**	**168,003,000**	**-**	**589,419,000**	**599,994,000**
South-Central								
Alabama	3,674,000	15,000	3,689,000	90,259,000	35,598,840	-	125,857,840	129,546,840
Arkansas	11,473,000	-	11,473,000	87,743,000	-	-	87,743,000	99,216,000
Kentucky	757,280	-	757,280	126,060	-	-	126,060	883,340
Louisiana	-	-	-	-	47,047,000	-	47,047,000	47,047,000
Mississippi	-	178,000	178,000	69,346,000	13,753,000	-	83,099,000	83,277,000
Oklahoma	280,000	4,000	284,000	452,000	323,000	-	775,000	1,059,000
Tennessee	2,164,000	-	2,164,000	2,075,000	-	-	2,075,000	4,239,000
Texas	-	-	-	59,204,000	-	-	59,204,000	59,204,000
Regional totals	**18,348,280**	**197,000**	**18,545,280**	**309,205,060**	**96,721,840**	**-**	**405,926,900**	**424,472,180**
Northeast								
Connecticut	-	-	-	-	-	-	-	-
Delaware	-	-	-	-	-	-	-	-
Maine	-	-	-	-	-	25,622,500	25,622,500	25,622,500
Maryland	987,550	-	987,550	861,925	-	-	861,925	1,849,475
Massachusetts	-	11,117	11,117	-	1,946	-	1,946	13,063
New Hampshire	24,100	-	24,100	209,100	-	-	209,100	233,200
New Jersey	28,798	690	29,488	18,310	524	-	18,834	48,322
New York	209,350	-	209,350	245,000	20,500	-	265,500	474,850
Pennsylvania	610,177	105,000	715,177	1,120,610	50,000	-	1,170,610	1,885,787
Rhode Island	-	-	-	-	-	-	-	-
Vermont	22,800	800	23,600	100	150	-	250	23,850
West Virginia	-	-	-	-	-	-	-	-
Regional totals	**1,882,775**	**117,607**	**2,000,382**	**2,455,045**	**73,120**	**25,622,500**	**28,150,665**	**30,151,047**
North-Central								
Illinois	730,100	36,177	766,277	130,000	1,117	-	131,117	897,394
Indiana	1,702,462	73,900	1,776,362	455,600	5,079	-	460,679	2,237,041
Iowa	640,775	-	640,775	227,250	-	-	227,250	868,025
Michigan	3,252,999	27,646	3,280,645	7,895,991	15,850,659	39,000	23,785,650	27,066,295
Minnesota	443,800	-	443,800	2,463,625	209,293	472,000	3,144,918	3,588,718
Missouri	916,435	-	916,435	571,850	-	-	571,850	1,488,285
Ohio	-	3,500	3,500	-	-	-	-	3,500
Wisconsin	867,063	-	867,063	2,197,802	50,000	685,000	2,932,802	3,799,865
Regional totals	**8,553,634**	**141,223**	**8,694,857**	**13,942,118**	**16,116,148**	**1,196,000**	**31,254,266**	**39,949,123**

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Table 1 Continued. Hardwood and conifer seedling production for each State and each region during the fiscal year 2023 planting year

State	Hardwood bareroot seedlings produced	Hardwood container seedlings produced	Total hardwood seedlings produced	Conifer bareroot seedlings produced	Conifer container seedlings produced	Conifer container seedlings imported	Total conifer seedlings produced	Total seedlings produced
Great Plains								
Kansas	-	20,000	20,000	-	38,500	-	38,500	58,500
Nebraska	279,810	-	279,810	573,790	1,163,694	-	1,737,484	2,017,294
North Dakota	61,350	18,656	80,006	570,860	50,466	-	621,326	701,332
South Dakota	-	-	-	-	-	-	-	-
Regional totals	**341,160**	**38,656**	**379,816**	**1,144,650**	**1,252,660**	**-**	**2,397,310**	**2,777,126**
Intermountain								
Arizona	-	-	-	-	-	-	-	-
Colorado	-	-	-	-	-	-	-	-
Idaho	1,400,000	21,070	1,421,070	4,143,574	4,985,872	6,863,370	15,992,816	17,413,886
Montana	-	35,000	35,000	-	100,000	120,710	220,710	255,710
Nevada	-	15,798	15,798	-	739	-	739	16,537
New Mexico	-	9,000	9,000	-	100,000	-	100,000	109,000
Utah	-	-	-	-	-	-	-	-
Wyoming	-	-	-	-	-	-	-	-
Regional totals	**1,400,000**	**80,868**	**1,480,868**	**4,143,574**	**5,186,611**	**6,984,080**	**16,314,265**	**17,795,133**
Alaska								
Alaska	-	-	-	-	-	203,000	203,000	203,000
Pacific Northwest								
Oregon	1,559,112	684,293	2,243,405	35,528,682	33,230,791	2,621,250	71,380,723	73,624,128
Washington	257,800	20,000	277,800	35,563,679	22,144,100	2,143,150	59,850,929	60,128,729
Regional totals	**1,816,912**	**704,293**	**2,521,205**	**71,092,361**	**55,374,891**	**4,764,400**	**131,231,652**	**133,752,857**
Pacific Southwest								
California	-	10,442	10,442	1,915,840	23,021,998	-	24,937,838	24,948,280
Hawaii	-	7,146	7,146	-	600	-	600	7,746
Regional totals	**-**	**17,588**	**17,588**	**1,915,840**	**23,022,598**	**-**	**24,938,438**	**24,956,026**
National totals	**42,682,761**	**1,532,235**	**44,214,996**	**825,314,648**	**365,750,868**	**38,769,980**	**1,229,835,496**	**1,274,050,492**

Assumptions

The following assumptions were used in compiling this report.

1. The number of seedlings reported by the participating forest and conservation nurseries was the number of shippable seedlings produced for distribution in the 2023 planting season (i.e., seedlings that were planted from fall of 2022 through spring of 2023).

Some species of forest seedlings require two or more growing seasons to reach accepted forest and conservation seedling size standards, so not all seedlings in production at a nursery at any given time are considered shippable (i.e., available for distribution). In the East and West, nurseries only reported shippable seedlings. In contrast, nurseries in the Southern States reported production numbers, however, nearly all the tree seedlings grown in this region are shippable after growing a single year.

2. All seedling production reported in this survey met the grading standards for the respective nurseries (i.e., cull seedlings were not included in the estimates).

Production estimates are often based on seedbed inventories of seedlings meeting grading standards. When nurseries ship seedlings by weight, as opposed to examining and counting each seedling, landowners and tree planters often plant every seedling that is shipped to them.

3. Seedling production data were collected from all the major nurseries that produced forest and conservation tree seedlings for the planting season.

Considerable effort was made to contact all major producers of forest and conservation seedlings (private, State, Federal, Tribal). The universities collecting the survey data reported, with few exceptions, that the major producers are included in the results.

4. All seedlings reported in this survey were produced for reforestation and conservation projects.

Some of the nurseries that participated in this survey also produce seedlings for ornamental use, Christmas tree production, or other horticultural purposes. Private nurseries were asked to report only seedling production destined for conservation and reforestation planting.

5. Forest tree seedlings remain in the general area where they are produced.

Forest and conservation seedlings are routinely shipped across State borders and at times across international borders. It is assumed that, on average, the number of seedlings imported into a State is equal to the number of seedlings exported from that State. In some States, a significant number of seedlings are produced in Canada and imported for planting in those States. Estimates of the number of seedlings shipped from Canada were obtained from Canadian nurseries that routinely export seedlings to the United States.

6. Dividing the number of seedlings shipped from forest and conservation nurseries by the average number of stems planted per acre in a specific State is an appropriate proxy of the number of acres of trees planted during the planting season (table 2).

These estimations do not include direct seeding or natural forest regeneration activities. Average tree planting acreage and densities for each State were provided by FIA.

7. Respondents to the production survey reported only hardwood and conifer trees produced.

Nurseries were asked not to include shrubs in their production estimates. Many conservation and restoration plantings include shrubs and herbaceous plants to address wildlife, biodiversity, or other management objectives. Using only tree production to estimate acres planted results in an underestimate of planted acreage where a mixed planting of shrubs and trees occurred.

Data Trends

More than 1.27 billion forest tree seedlings were planted in the United States in fiscal year (FY) 2023, a decrease of approximately 7 percent from FY 2022 and less than 1 percent lower than the 10-year average (figure 1). This decrease is likely attributable to insufficient data: all three universities conducting the survey reported a lower than usual response rate from across the entire United States. This trend was especially evident in the Southern United States where reported seedling production dropped 7 percent from 2022 to 2023 (figure 2). (Note that in the previous year's report (Pike et al. 2023), the total production for the southern region was inadvertently inflated by almost 75 million seedlings, exclusively bareroot conifers in the Southern United States. Figures 1 and 2 reflect the actual (adjusted) seedling production for the fiscal year 2022 production year.) In the Western United States, production was lower than the previous year and approximated the 10-year average. In the Eastern United States, production in 2023 was slightly higher than the previous year despite lower survey return rates.

Based on the total number of seedlings shipped and the average number of seedlings planted per acre in each State, more than 3.7 million acres (1.5 million ha) of tree seedlings were planted during the fall 2022 through spring 2023 planting season. FIA reported tree planting acres of 1.7 million acres (687,966 ha), roughly half of the estimate

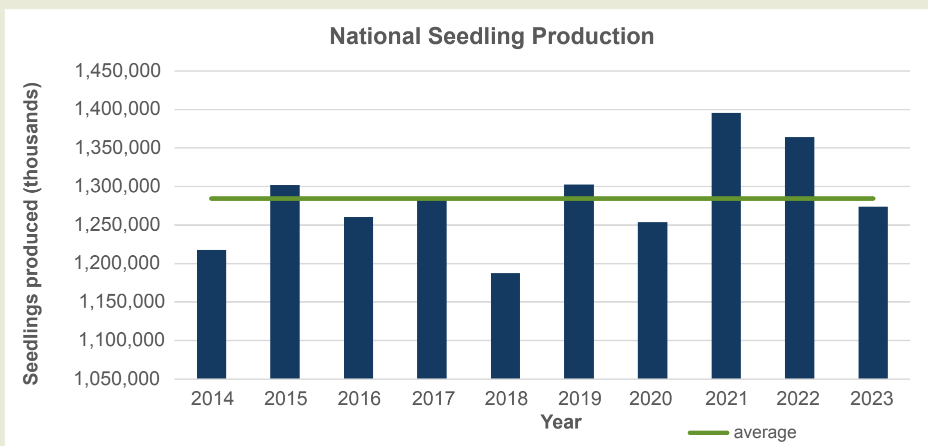

Figure 1. Total annual forest nursery seedling production in the United States for fiscal years 2014 through 2023. Data for the southern region in 2022 reflects actual numbers and are corrected from the previously published report in Pike et al. (2023). Sources: this report, Haase et al. (2019, 2020, 2021, 2022), Harper et al. (2014), and Hernández et al. (2015, 2016, 2017, 2018).

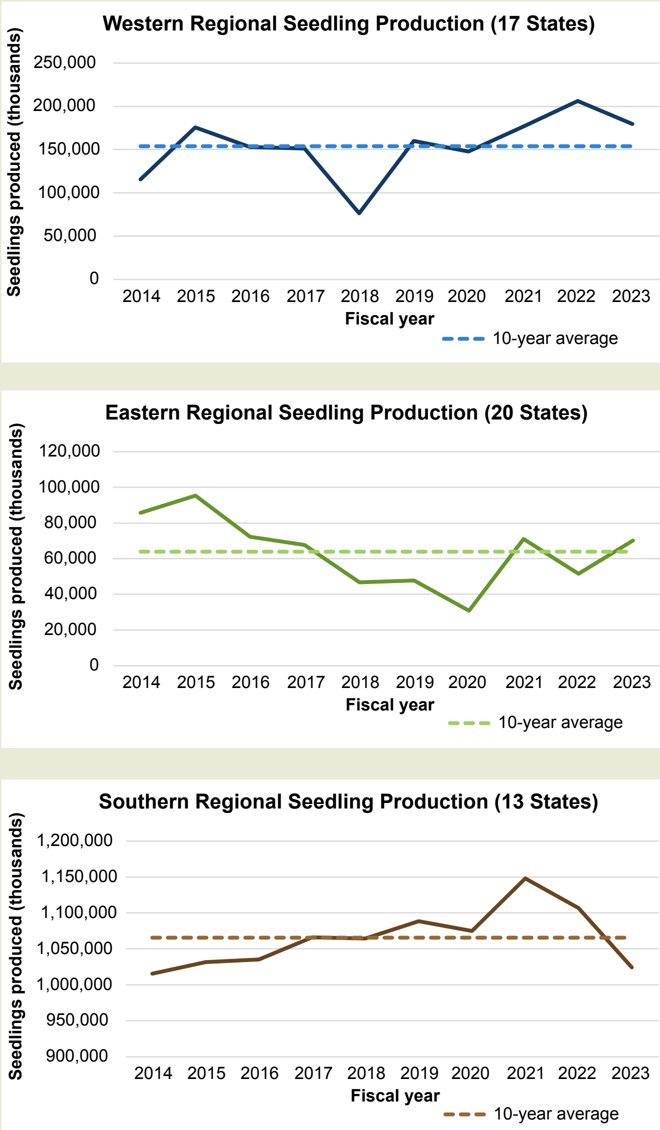

Figure 2. Annual forest nursery seedling production by region for fiscal years 2014 through 2023. Ten-year production averages are: 154,094,046 (west), 63,891,469 (east), and 1,065,549,141 (south). Ten-year averages and data for the southern region in 2022 reflect actual numbers and are corrected from the previously published report in Pike et al. (2023). Sources: this report, Haase et al. (2019, 2020, 2021, 2022), Harper et al. (2014), and Hernández et al. (2015, 2016, 2017, 2018).

derived from nursery reports, but their estimate is based on 5- 7- and 10-year cycles and includes seedlings that are grown out of State.

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Table 2. Estimated hardwood and conifer tree seedling acres planted for each State and each region during the 2023 planting year

State	Hardwood acres planted	Conifer acres planted	Total acres planted	FIA estimated acres planted
		Southeast		
Florida[1]	1,952	69,117	71,068	149,727
Georgia[1]	11,313	538,358	549,672	256,438
North Carolina[1]	717	93,123	93,840	108,826
South Carolina[1]	-	230,927	230,927	119,340
Virginia[1]	3,643	50,840	54,483	82,870
Regional totals	**17,625**	**982,365**	**999,990**	**717,201**
		South-Central		
Alabama[1]	6,148	209,763	215,911	218,711
Arkansas[1]	19,122	146,238	165,360	121,864
Kentucky[2]	1,741	290	2,031	2,034
Louisiana[1]	-	78,412	78,412	136,539
Mississippi[1]	297	138,498	138,795	133,685
Oklahoma[1]	473	1,292	1,765	26,526
Tennessee[1]	3,607	3,458	7,065	13,761
Texas[1]	-	98,673	98,673	102,489
Regional totals	**31,388**	**676,625**	**708,012**	**755,609**
		Northeast		
Connecticut	-	-	-	386
Delaware	-	-	-	-
Maine[1]	-	42,704	42,704	3,309
Maryland[3]	1,796	1,567	3,363	1,159
Massachusetts[2]	26	4	30	-
New Hampshire[2]	55	481	536	-
New Jersey[2]	68	43	111	-
New York[1]	349	443	791	3,118
Pennsylvania[2]	1,644	2,691	4,335	307
Rhode Island	-	-	-	-
Vermont[2]	54	1	55	-
West Virginia	-	-	-	-
Regional totals	**3,992**	**47,934**	**51,925**	**8,279**
		North-Central		
Illinois[2]	1,762	301	2,063	888
Indiana[4]	2,733	709	3,442	2,057
Iowa[1]	1,068	379	1,447	-
Michigan[3]	5,965	43,247	49,211	7,730
Minnesota[3]	807	5,718	6,525	12,852
Missouri[2]	2,107	1,315	3,421	267
Ohio[2]	8	-	8	1,077
Wisconsin[5]	1,084	3,666	4,750	7,487
Regional totals	**15,533**	**55,334**	**70,867**	**32,358**

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Table 2 Continued. Estimated hardwood and conifer tree seedling acres planted for each State and each region during the 2023 planting year

State	Hardwood acres planted	Conifer acres planted	Total acres planted	FIA estimated acres planted
Great Plains				
Kansas[3]	36	70	106	631
Nebraska[3]	509	3,159	3,668	-
North Dakota[3]	145	1,130	1,275	-
South Dakota	-	-	-	380
Regional totals	**691**	**4,359**	**5,049**	**1,011**
Intermountain				
Arizona	-	-	-	-
Colorado	-	-	-	786
Idaho[3]	1,421,070	29,078	1,450,148	8,326
Montana[3]	35,000	401	35,401	2,587
Nevada[3]	15,798	1	15,799	-
New Mexico[3]	9,000	182	9,182	-
Utah	-	-	-	-
Wyoming	-	-	-	-
Regional totals	**1,480,868**	**29,662**	**1,510,530**	**11,699**
Alaska				
Alaska[3]	-	369	369	-
Pacific Northwest				
Oregon[6]	6,410	203,945	210,355	120,180
Washington[6]	794	171,003	171,796	73,004
Regional totals	**7,203**	**374,948**	**382,151**	**193,184**
Pacific Southwest				
California[7]	23	45,342	45,365	26,833
Hawaii[7]	16	1	17	-
Regional totals	**39**	**45,343**	**45,382**	**26,833**
National totals	**1,557,338**	**2,216,938**	**3,774,276**	**1,746,174**

Calculations for hardwood, conifer, and total acres planted divided the production data reported in table 1 by an estimated number of stems planted per acre:

1 600 stems/acre
2 435 stems/acre
3 550 stems/acre
4 650 stems/acre
5 800 stems/acre
6 350 stems/acre
7 450 stems/acre

The Forest Inventory and Analysis (FIA) estimates for average annual acreage planted for all States are based on 5-, 7-and 10-year cycles. Cycle lengths vary by State and geographic area. Data generated by T. Ridley and A. Hartsell, USDA Forest Service, Southern Research Station, Forest Inventory and Analysis.

Support the Annual Forest Nursery Seedling Production Report

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The Forest Nursery Seedling Production report is produced annually by employees at the U.S. Department of Agriculture (USDA), Forest Service. It fulfills agency mandates to update the status and trends of the Nation's forest regeneration success and provides valuable information for nurseries and land managers. The willingness of nurseries to volunteer information on tree seedlings that they produce and sell each year is crucial to the production of this report.

The information is published annually in *Tree Planters' Notes* so nurseries and land managers can easily access the data for their own use. Summary tables of tree planting data, by State and over time, allow policy makers to view nursery production trends, which can translate into policy decisions and funding opportunities.

These trends over time have revealed the sensitivity of nursery production to conservation programs and unforeseen events unrelated to forestry, such as the USDA's Conservation Reserve Program leading to historically high demand in tree seedlings while stock market downturns can lead to sharp declines in tree seedling sales. In addition, as data are received, the National Reforestation and Restoration Directory is updated to facilitate connections between businesses, organizations, and others that support the propagation of forest and native plant materials.

The report is only as useful as the response rate to the annual survey; a low response rate may lead to misleading production numbers. Response rates have ebbed and flowed over the years—it's not a stretch to say that if forest and conservation nursery managers do not respond to the request for information, then the report could not be produced. The authors thank the nurseries who regularly respond to our annual request for information!

These data have been collected for decades by the Forest Service and were published both in *Tree Planters' Notes* and as stand-alone publications—the report has been published annually in *Tree Planters' Notes* since 2012. Prior to 2012 the report was produced sporadically and in different formats. Agency staff are currently locating all existing reports and posting them to the internet.

Safeguarding Business Confidentiality

Production data since 2012 have been procured and maintained by three universities through a contract with the Forest Service: Auburn University, the University of Idaho, and Purdue University. Data files are stored on secure folders at their respective institutions. Data are compiled by State and region and published in *Tree Planters' Notes* without differentiating between private and public sector nurseries. No questions about costs or finances are included in the questionnaire.

Over time, the agency has consistently fielded questions regarding the confidentiality of the survey and how the data are protected. These are valid concerns that likely contribute to a lower response rate. Response rates may also have decreased due to nurseries being inundated with requests for information as reforestation efforts have increased in recent years.

Streamlining the Survey

The annual information request is periodically reviewed by all three participating institutions to ensure that it is delivered consistently across all regions of the United States. Information collected relates directly to the production totals needed to generate the report. Surveys are predominantly completed online to streamline information sharing. Paper surveys are sent only if a nursery does not return the online form or if they indicate their preference for a paper survey.

The participating universities send the survey in the narrow window between wrapping up the current years' planting season and preparing for the forthcoming planting season. The report is published as soon as possible, usually within a year of the questionnaire.

Improving the Usefulness of the Forest Nursery Seedling Production Survey

As the validity of the survey depends on the response rate, here are a few suggestions to help your organization or company complete the survey.

1. Organize your production data so the report can be filled out easily by another member of your staff if necessary.
2. Designate a point of contact at your nursery to respond to the annual inquiry.
    - If the point of contact changes, send updated contact information to the Forest Service representative listed below who covers your region.
3. Share the importance of the survey with your administrative staff.
4. Ask questions if there are concerns regarding how the data will be used or maintained.
    - Please know that data privacy and protection is important to the institutions who are sending the inquiries. Reach out if you have any questions or concerns.

The forest nursery seedling production survey for the 2024 growing year will be sent out in fall 2024 (Southern United States) and early winter 2025 (Western and Eastern United States). For all regions, responses are requested within a 2-month timeframe. If you do not receive the survey, please contact the Forest Service representative in your region:

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Western States:
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Lastly, the authors recognize your contributions in supporting the ongoing reforestation and restoration work that is happening at an intensity not seen in at least a generation! Thank you for making the world a greener place.

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