Tree Planters' Notes

United States Department of Agriculture
Forest Service

Spring 2017
Volume 60, Number 1

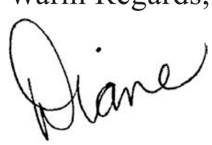
Dear TPN Reader

I'm pleased to bring another issue of *Tree Planters' Notes* to you. As with all issues, this one is filled with practical information to support your work in reforestation, restoration, conservation, research, gardening, and other purposes.

This issue includes six articles: Pettersson et al. (page 4) gives a brief history of Fraser fir cultivation and the influence of Phytophthora root rot on planting practices. Hawkins (page 12) describes a mechanical seeder developed for achieving target sowing rates for small-seeded acorns and other hardwood species. In a different type of article, my colleagues and I (page 16) provide practical guidelines for planning and executing successful conferences, meetings, and workshops. Hoffman et al. (page 28) present results from a study to examine effects of the type and intensity of artificial lighting on cottonwood and willow cuttings. Keyes and Brissette (page 37) describe their experiment to compare effects of seedling container types on production efficiency of curlleaf mountain mahogany. Gagnon and DeBlois (page 44) show that foliar application of urea, especially with a surfactant, can rapidly increase nitrogen concentration in jack pine seedlings.

I wish you all a pleasant 2017 field season!

Warm Regards,



Diane L. Haase

***Tree Planters' Notes* (TPN) is dedicated to technology transfer and publication of information relating to nursery production and outplanting of trees and shrubs for reforestation, restoration, and conservation.**

TPN is sponsored by the Cooperative Forestry Staff of the U.S. Department of Agriculture (USDA), Forest Service, State and Private Forestry Deputy Area, in Washington, DC. The Secretary of Agriculture has determined that the publication of this periodical is necessary in the transaction of public business required by law of this Department.

Editor: Diane L. Haase

TPN accepts both technical and research articles; each is reviewed by the editor and/or anonymous referees. Please see the Guidelines for Authors at the end of the journal for details about editorial policy, formatting, style, and submission. Guidelines can also be accessed on line at http://www.rngr.net/publications/tpn/author_guidelines.

Web site: http://www.rngr.net/publications/tpn

E-mail: DLHaase@fs.fed.us

Printed on recycled paper.

Spring 2017

The Heart of the Tree

by Henry Cuyler Bunner (1855–1896)

What does he plant who plants a tree?
He plants a friend of sun and sky;
He plants the flag of breezes free;
The shaft of beauty, towering high;
He plants a home to heaven anigh;
For song and mother-croon of bird
In hushed and happy twilight heard—
The treble of heaven's harmony—
These things he plants who plants a tree.

What does he plant who plants a tree?
He plants cool shade and tender rain,
And seed and bud of days to be,
And years that fade and flush again;
He plants the glory of the plain;
He plants the forest's heritage;
The harvest of a coming age;
The joy that unborn eyes shall see—
These things he plants who plants a tree.

What does he plant who plants a tree?
He plants, in sap and leaf and wood,
In love of home and loyalty
And far-cast thought of civic good—
His blessings on the neighborhood,
Who in the hollow of His hand
Holds all the growth of all our land—
A nation's growth from sea to sea
Stirs in his heart who plants a tree.

Contents

SEE PAGE 21

SEE PAGE 41

Influence of Phytophthora Root Rot on Planting Trends of Fraser Fir Christmas Trees in the Southern Appalachian Mountains

Martin Pettersson, John Frampton, and Jill Sidebottom

Graduate Research Assistant, Department of Forestry and Environmental Resources, North Carolina State University (NCSU), Raleigh, NC; Professor, Department of Forestry and Environmental Resources, NCSU, Raleigh, NC; Mountain Conifer Integrated Pest Management Extension Specialist, Mountain Horticultural Crops Research and Extension Center, Mills River, NC

Abstract

The Southern Appalachian Mountains are home to the attractive Fraser fir [*Abies fraseri* (Pursch) Poir.] that began to be cultivated for Christmas trees in the 1950s. Today, 5 to 6 million trees are harvested annually in this region, yielding a wholesale value of more than $100 million. Since the 1960s, however, Phytophthora root rot has been a problem for Christmas tree production in this region. This article gives a brief history of Fraser fir cultivation and how Phytophthora root rot has influenced planting practices. It also presents the results from surveys of Christmas tree growers about planting trends and their perspectives of the Phytophthora disease problem. Even though most growers have shifted from using locally produced bareroot seedlings to out-of-State-grown planting stock, Phytophthora root rot continues to have a major impact on Fraser fir plantations, and new *Phytophthora* species have recently been found on Fraser fir.

Introduction

The Southern Appalachian Mountains are home to one of the largest Christmas tree production regions in the United States. Collectively, North Carolina, Tennessee, and Virginia account for 17 percent of the 309,363 acres (125,195 ha) of the Nation's land used for Christmas tree cultivation (USDA NASS 2014). North Carolina is the second-largest producing State, annually harvesting 5 to 6 million trees that produce a wholesale revenue of more than $100 million (Napier and Sidebottom 2011). Fraser fir (*Abies fraseri* [Pursch] Poir.) is the main species cultivated in the region, where it naturally grows in a small number of island-like populations on high ridges, mostly above 4,250 feet (1,300 m) (Busing et al. 1993). Christmas tree production sites are generally below the natural elevational range of Fraser fir, down to about 3,000 ft (910 m). Fraser fir has beautiful dark green foliage, a pleasant aroma, and excellent post-harvest needle retention that have made it highly desirable as a Christmas tree (Chastagner and Benson 2000).

Fraser Fir Planting Stock—The Early Years

The Fraser fir Christmas tree industry in western North Carolina and surrounding States began in the 1950s when the Toecane Ranger District of the Pisgah National Forest opened up portions of the Roan Highlands for the harvest of fir boughs and cut trees. Due to the superior quality of Fraser fir as a Christmas tree, growers became interested in planting them, which required a supply of seed and seedlings. Seed was collected primarily from Roan Mountain along the North Carolina-Tennessee border. Growers also lifted ("pulled") wild seedlings ("wildlings") or collected seed from other wilderness areas with, and sometimes without, permission. For instance, in the 1956–1957 planting season, the U.S. Department of Agriculture (USDA) Forest Service permitted the Haywood County 4-H Council to lift Fraser fir seedlings from thick natural reproduction under a virgin fir stand near Burnsville to use as planting stock. Landowners in the Mount Rogers area in Virginia also pulled Fraser fir seedlings and sold them (Sidebottom 2011).

In 1955, the North Carolina Forest Service agreed to produce Fraser fir seedlings. To hasten production, these were originally gathered as wildings from natural stands, primarily near Mount Rogers, VA. The climate at the two nurseries used initially—Holmes State Nursery near Hendersonville and Ralph Edwards Nursery in Morganton—was too warm to produce good-quality Fraser fir. Therefore, the North Carolina

Forest Service established a seed orchard and a seedling production facility at the Linville River Nursery near Crossnore (Avery County) and began seedling production there in 1968 (Sidebottom 2011).

Fraser fir seedlings were also available from commercial nurseries in other States as early as the 1960s. Fraser fir seedlings were advertised for sale in what became the American Christmas Tree Journal (produced by the National Christmas Tree Association) from at least two nurseries in Pennsylvania and one in Maine. Even with these sources, limited seedling supply would plague the developing Fraser fir industry through the 1970s. The main limiting factor for Fraser fir Christmas tree production in western North Carolina during the 1970s was the lack of Fraser fir stock ready for field planting. Because of this insufficient supply, extension programs and North Carolina Christmas Tree Association meetings focused on teaching growers how to grow their own seed in beds and to line-out transplants. As a result, this practice became widespread in the region (figure 1). Simultaneously, in 1977 and 1978, five contractors lifted 1.5 million wildlings from Roan Mountain. The number of wildlings taken from Roan Mountain remained high through 2000, with about 500,000 seedlings pulled each year (Sidebottom 2011).

Emergence and Spread of Phytophthora Root Rot

As Fraser fir planting in the region expanded during the 1960s and 1970s, growers began to recognize a number of disease and insect problems. Particularly challenging was Phytophthora root rot, a disease first reported on Fraser fir in 1963 on nursery seedlings in Penrose (Transylvania County, NC). *Phytophthora cinnamomi* Rands was identified as the causal agent (Kuhlman and Hendrix 1963). *Phytophthora* are fungus-like organisms belonging to the class Oomycetes (water molds). *P. cinnamomi* is exotic to the region, originating from Southeast Asia, where it was first described from cinnamon plants in Sumatra (Zentmyer 1988). It is believed to have been brought into the United States through southern ports during the 1800s or earlier on exotic plants destined for gardens of antebellum estates (Crandall et al. 1945). A map published in 1945 (Crandall et al.) showed the observed range of root rot caused by *P. cinnamomi* on American chestnut (*Castanea dentata* [Marsh.] Borkh.) and chinkapin species (*Castanea* spp.) and clearly demonstrates that this pathogen had been introduced into the Southern Appalachian region well before the start of the Fraser fir Christmas tree industry.

Phytophthora root rot affects all sizes and ages of Fraser fir. Symptoms include flagging of lower branches, stem cankers or cambial lesions with distinct borders, foliar chlorosis, reddening or browning of needles, diminished growth, and wilting of new growth, as well as darkened, sloughing, and necrotic roots (figure 2). Dying roots

Figure 1. Starting in the mid-1970s, extension programs focused on teaching Christmas tree growers how to sow their own Fraser fir seed in bareroot beds and to line-out transplants. (Photo courtesy of James McGraw, North Carolina State University, retired, Jackson County, NC, 1970s)

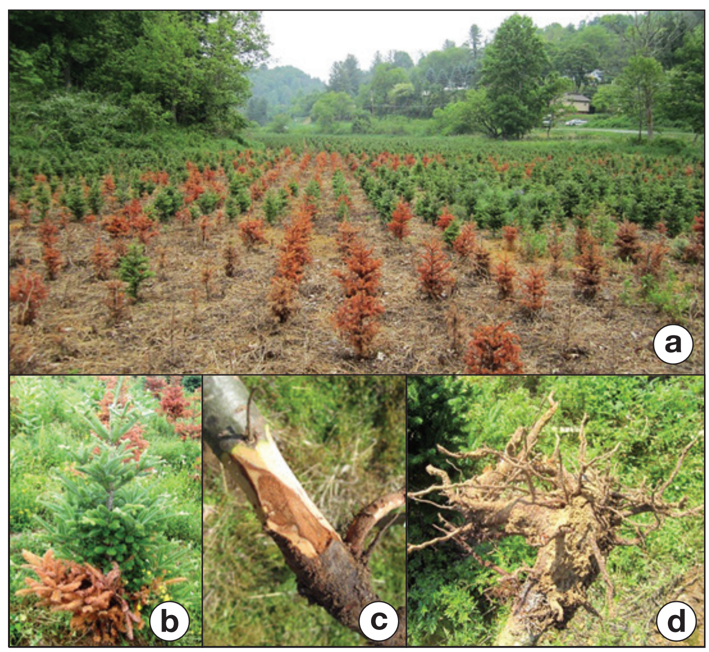


Figure 2. Phytophthora root rot inflicts a significant economic impact on the Fraser fir Christmas tree industry of the Southern Appalachian region. Characteristic symptoms of Phytophthora root rot on Fraser fir include: (a) tree mortality, (b) flagging of basal branches, (c) cambial stem lesion with distinct borders, and (d) heavily infected root systems with sloughing necrotic roots and absence of fine roots. (Photos by Martin Pettersson, 2015)

and girdling stem infections result in decreased water and nutrient translocation and often lead to a weakened tree and eventual death (Chastagner et al. 1995, Chastagner and Benson 2000).

Phytophthora species can rapidly spread in saturated and waterlogged soils or by splashing rain, subsurface water flow, and run-off water. Heavy rains and flooding conditions accelerate the spread. In addition to water movement, *Phytophthora* species can be introduced into new fields by infected planting stock, contaminated agricultural tools, vehicle tires, field workers' shoes, and animals. In nurseries, *Phytophthora* species can infect all plants if the irrigation water is taken from contaminated streams or surface water and not sterilized or filtered prior to use. Irrigation and rain can splash contaminated soil from one infected seedling onto surrounding seedlings, which may also become infected. In the nursery, seedlings experience optimal conditions (i.e., they grow in well-drained, nutritive soils, under optimal temperature), and therefore may be less prone to display disease symptoms, especially when dormant. Furthermore, fungicides do not always kill *Phytophthora* species, so that diseased plants are often not recognized until they have been lifted and planted in the field.

Two investigations of the incidence of Phytophthora root rot in Fraser fir Christmas tree plantations in North Carolina suggest that this disease is common in the region. The first study was conducted in 1972 and average disease incidence due to *P. cinnamomi* in 14 Fraser fir plantations in 5 counties in western North Carolina was reported to be 9.6 percent (range = <1 to 90 percent)(Grand and Lapp 1974). In a more recent study, conducted in 1997 and 1998 (Benson and Grand 2000), the average disease incidence was similar (9 percent; range = 0 to 75 percent) in 58 Fraser fir plantations sampled in the same 5 western North Carolina counties. As in the earlier survey, all isolates from the field sites were identified as *P. cinnamomi*, except for one isolate of an unidentified *Phytophthora* species. In the more recent study, nursery transplant beds were also sampled and had a mean disease incidence of 2 percent (range = 0 to 12 percent). In addition to *P. cinnamomi*, *P. cactorum* (Leb. and Cohn) Schröeter, *P. dreschleri* Tucker, and an unidentified *Phytophthora* species were found on Fraser fir seedlings sampled in the nursery transplant beds.

In 2014, another study conducted across the Southern Appalachian region revealed that the diversity of *Phytophthora* species in Fraser fir Christmas tree plantations had increased (Pettersson et al. 2016). Six *Phytophthora* species were isolated from infected roots sampled from 82 sites in 13 counties (North Carolina, Tennessee, and Virginia). While *P. cinnamomi* remained the most prevalent species isolated (70 percent), *P. cryptogea* Pethybr. & Laff. was relatively common (23 percent). Additionally, one or two isolates of four other species were found: *P. citrophthora* (R.E. Sm. & E.H. Sm.) Leonian, *P. europaea* Hans. & Jung, *P. pini* Leonian, and *P. sansomeana* Hans. & Reeser.

Fraser Fir Planting Stock—Shift to Out-of-State Sources

As regional Christmas tree growers became more knowledgeable about the distribution and occurrence of Phytophthora root rot, they wanted to reduce the risk associated with contaminating clean fields with diseased planting stock. Growers gradually stopped producing their own planting stock or buying from local sources and began to import out-of-State sources of planting stock. Often seed was provided to the contracted out-of-State grower. This trend is revealed in the results of pest management surveys conducted during 1995 to 2014 by the North Carolina Cooperative Extension Service (table 1).

Table 1. Summary of responses concerning planting stock from four pest management surveys conducted by the North Carolina Cooperative Extension Service between 1995 and 2014. Respondents could select multiple choices so responses do not total 100 percent (Sidebottom, unpublished data).

Survey choices	1995	2001	2007	2014
	(percent of respondents)			
Grew seedlings in outdoor beds	23.0	24.4	32.8	17.0
Didn't set Christmas trees this year in the field	5.3	30.7	28.2	30.0
Seedlings grown out of State in outdoor bed	Not Asked	14.8	24.8	59.0
Seedlings grown by NC grower in outdoor beds	Not Asked	27.4	15.1	14.0
Seedlings grown by NC Forest Service	34.2	19.0	14.0	3.0
Seedling source was Roan Mountain wildlings	14.0	10.2	6.3	3.0

NC=North Carolina

During the period of these surveys, the USDA Forest Service began limiting the number of wildlings removed from Roan Mountain, or in some years, not allowing removal of any wildlings. The survey results reflect this trend by the decreasing proportion of growers using wildlings from Roan Mountain from 1995 to 2014 (table 1). The USDA Forest Service is currently involved in a 5-year process of developing a long-term management plan for the Roan Mountain area of the Pisgah National Forest. Because of concerns with threatened and endangered species in the spruce-fir ecosystem, wild seedlings from Roan Mountain may not be available to the Christmas tree industry in the future.

Natural events also contributed to the shift toward the use of out-of-State planting stock. In September 2004, remnants of Hurricanes Frances and Ivan dropped record rainfall amounts across the region resulting in excessive soil moisture and flooding. The following spring, Phytophthora disease was widespread in Christmas tree plantations and the Linville River had spread *Phytophthora* inoculum through some fields of the State-run nursery. Ultimately, this nursery ceased production of bareroot Fraser fir seedlings and began producing a much smaller volume of containerized seedlings. The use of seedlings grown by the North Carolina Forest Service decreased from 34.2 percent in 1995 to 3 percent in 2014. Many growers found out-of-State contracting to be more reliable at the time when the local nurseries were in crisis.

2015 Survey of Planting Trends and Phytophthora Root Rot

In spring 2015, a survey was conducted at five different Christmas tree grower meetings in western North Carolina to determine how many growers use out-of-State Fraser fir seedlings and for how long they have done so. A total of 89 growers from 13 counties took the survey. Twenty-two of the growers had Christmas tree farms in more than one county, resulting in 123 farms from North Carolina, Tennessee, and Virginia included in the survey (figure 3). Most of the surveyed farms

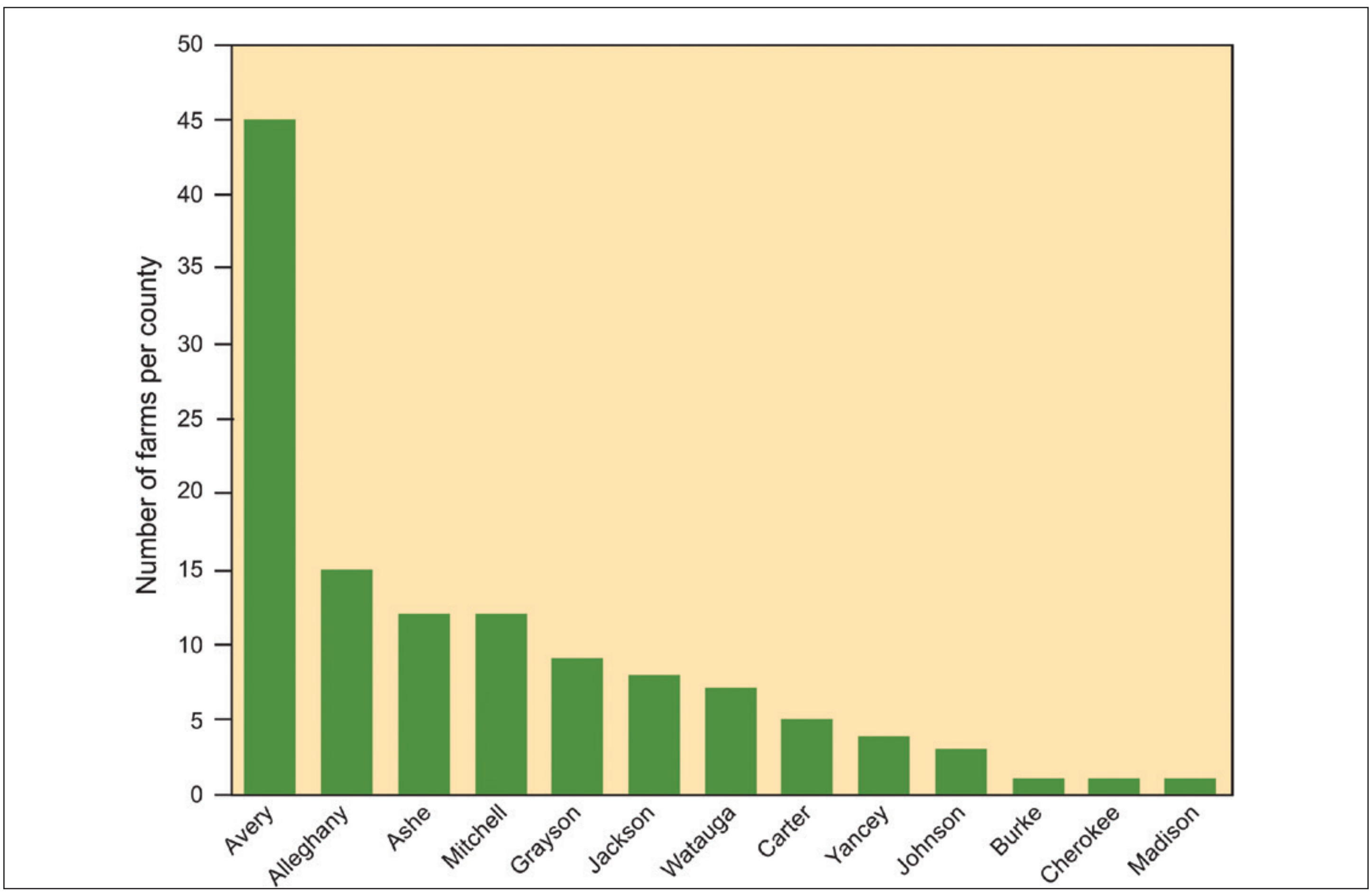


Figure 3. A total of 89 Christmas tree growers from 13 counties participated in a 2015 survey conducted in western North Carolina. Twenty-two growers included in the survey had Christmas tree farms in more than 1 county resulting in 123 farms from North Carolina, Tennessee (Carter and Johnson Counties), and Virginia (Grayson County).

were located in Avery County, NC. Of the growers surveyed, approximately 88 percent reported that they had Phytophthora root rot causing mortality in their Christmas tree fields. That is approximately 18 percent higher than what was reported in the 2006 North Carolina Christmas Tree Pest Management Survey.

On average, 64 percent of all growers surveyed were using out-of-State material (figure 4), with larger scale growers more likely to do so (figure 5). About 83 percent of the surveyed growers with more than 50 ac (>20.2 ha) of Christmas tree production were using out-of-State Fraser fir planting stock and 46 percent of these growers were purchasing seedlings from more than one State. Seventy-one percent of growers with 10 to 50 acres (4.0 to 20.2 ha) and 29 percent of growers with less than 10 ac (<4 ha) were using out-of-State planting stock. The out-of-State Fraser fir planting stock was bought from Oregon (41.2 percent), Washington (18.6 percent), Pennsylvania (17.5 percent), Michigan (17.5 percent), and Maine (5.2 percent). Clearly, a variety of locations produce the out-of-State material being planted in the Southern Appalachian Mountains.

More than half (57 percent) of the out-of-State planting stock purchased by the surveyed growers was bareroot seedlings. About 27 percent of surveyed growers purchased bareroot transplants that had been started in containers (plug+1) while only 16 percent purchased containerized seedlings grown exclusively in a greenhouse. Twenty-one percent of the growers responding to the survey reported using more than one type of planting stock.

Of the growers using out-of-State Fraser fir planting stock, 30 percent perceived an increased incidence of Phytophthora root rot in their fields since they began using out-of-State material, 47 percent said that the incidence of Phytophthora root rot had not changed, and 18 percent said that the incidence had decreased in their plantations (5 percent did not respond to this question).

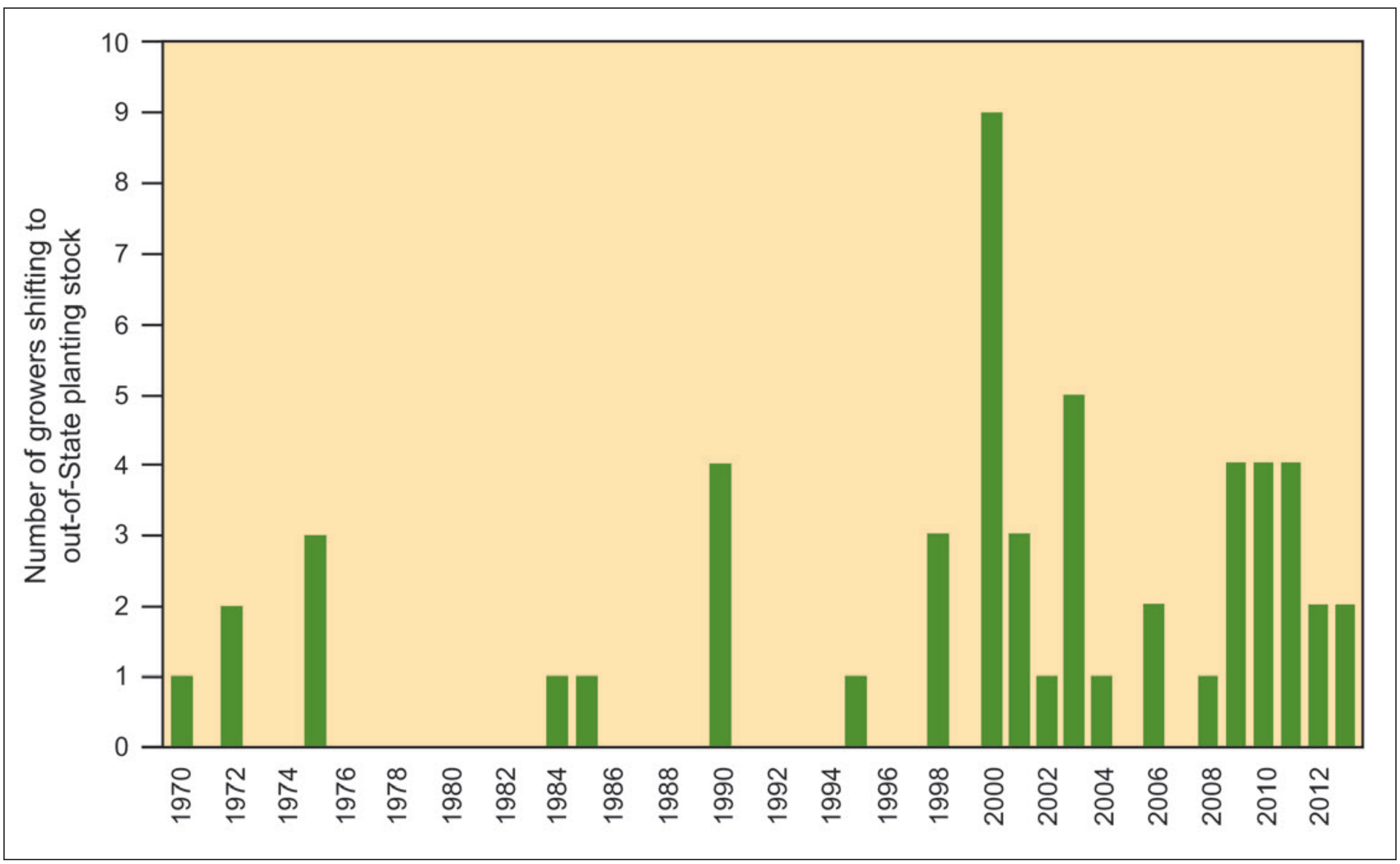


Figure 4. Christmas tree growers surveyed in western North Carolina (n=89) steadily shifted from locally produced Fraser fir planting stock to out-of-State stock starting in 1970, with the shift accelerating around 2000.

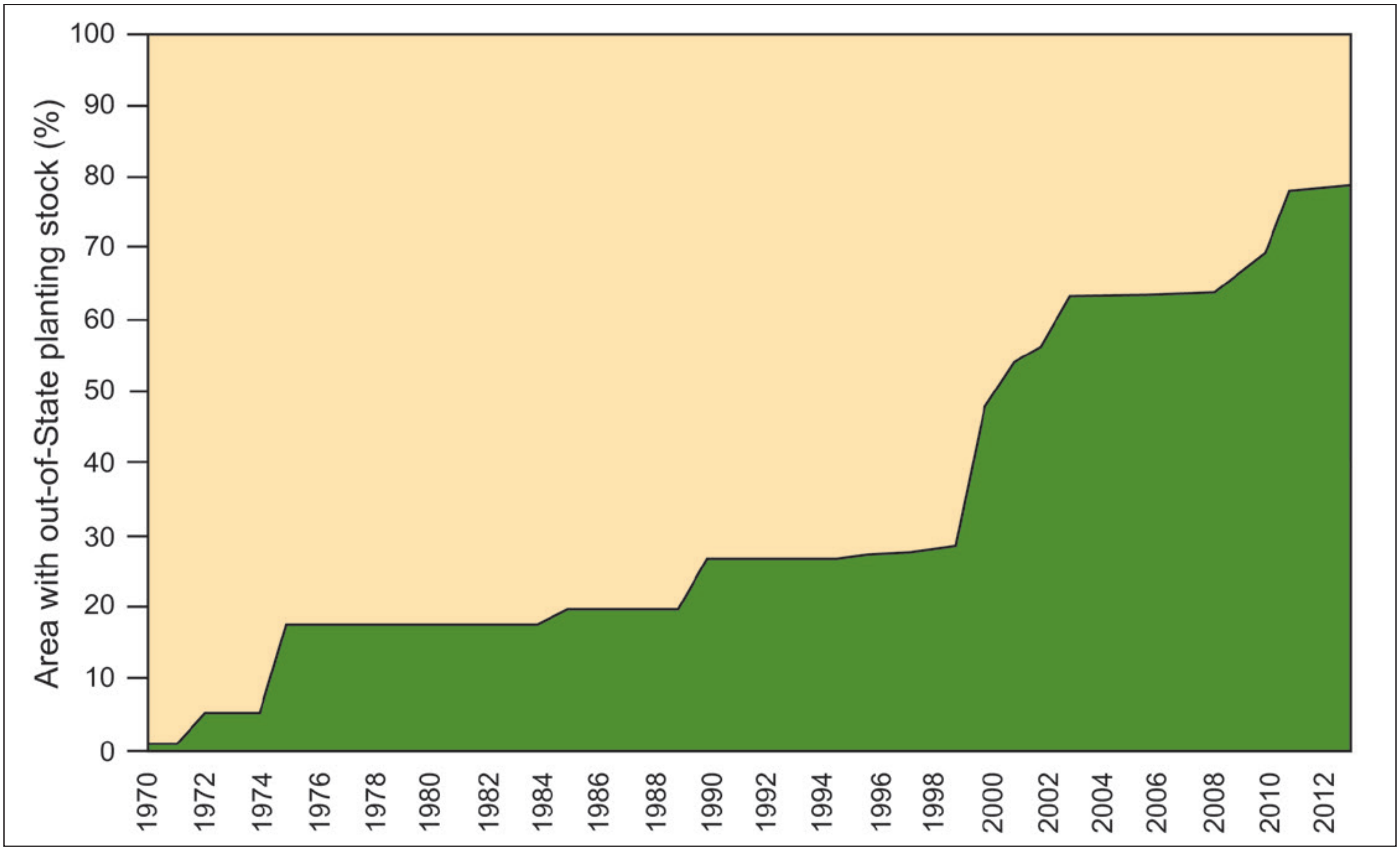


Figure 5. Over a 43-year period (1970 to 2013), 64 percent of Christmas tree growers surveyed in western North Carolina shifted from using locally produced to out-of-State planting stock. Because growers with more land were more likely to shift, about 80 percent of the land base managed by the surveyed growers was planted with out-of-State planting stock by 2013.

Perspective

Almost since its inception, the Fraser fir Christmas tree industry of the Southern Appalachian region has been afflicted by Phytophthora root rot. Although there is evidence that this exotic pathogen had previously been introduced into the region, undoubtedly the industry has contributed to its spread, especially through the movement of infested plant material. Once infested, land remains unsuitable for Fraser fir cultivation indefinitely. As Christmas tree growers understood the problem, they shifted toward importing out-of-State material to reduce the risk of contaminating sites with *Phytophthora* species, so that today only a small portion of Christmas tree plantations is regenerated with locally produced planting stock. Despite pursuing this strategy, Phytophthora root rot remains a menace to the regional Fraser fir industry. Most growers switching to out-of-State material perceive that their Phytophthora root rot problems have either stayed the same or increased since switching.

Of particular concern is the increased risk of introducing new *Phytophthora* species via importation of seedlings from bareroot nurseries and nurseries where containerized plants have been transplanted into outdoor beds. Most *Phytophthora* species are harmful plant pathogens that can cause serious and unpredictable, ecological and economic damage when they are introduced to a new environment. The Southern Appalachian climate, with its relatively warm soil temperatures and plentiful rainfall throughout the year, enhances the chance of survival and dissemination of many *Phytophthora* species. Further, the coexistence of multiple *Phytophthora* species in overlapping geographic areas increases the risk of another bleaker problem—a hybridization event from which a more virulent race could evolve (Érsek and Nagy 2008).

The number of *Phytophthora* species isolated from Fraser fir in the Southern Appalachian region has recently increased and *P. cryptogea*, in particular, appears to have rapidly spread (Pettersson et al. 2016). Regions from which Fraser fir planting stock is imported (the Pacific Northwest, Great Lakes, and Northeast) are known to have different *Phytophthora* species afflicting fir, including *P. cryptogea* (McKeever and Chastagner 2016). For example, much of the planting stock (approximately 60 percent) used in the Southern Appalachians is produced in the Pacific Northwest where at least eight *Phytophthora* species have been reported to cause mortality in fir Christmas tree fields (Chastagner et al. 1990, 1995; Chastagner and Benson 2000). While most of these *Phytophthora* species have not yet been found in the Southern Appalachian region and there is no direct evidence that species have been introduced from other regions, vigilance is warranted because the nursery trade is known to contribute to the introduction and dispersal of plant pathogens (Jones and Baker 2007, Brasier 2008, McKeever and Chastagner 2016). Once introduced and dispersed in a new region, *Phytophthora* species have proven to be nearly impossible to control.

Christmas tree growers must be watchful to detect symptomatic plant material prior to and after planting. Symptomatic seedlings should be discarded; the cost of planting stock is inconsequential compared to the cost of losing Fraser fir production on a site due to the introduction of *Phytophthora* species. Today, suspect plant material can be evaluated with easy-to-use kits designed for rapid field-diagnosis of *Phytophthora* species. The North Carolina State University Cooperative Extension Service has been training regional Christmas tree growers on how to use these kits. Symptomatic seedlings may also be sent to a plant disease clinic for further verification and possible *Phytophthora* species identification. Growers must also employ good sanitation practices to prevent *Phytophthora* species spread from infested areas via equipment, vehicles, boots, water drainage, and other means.

Recently, a number of regional Christmas tree growers have begun greenhouse production of containerized Fraser fir seedlings. This movement is in its infancy and involves much experimentation with cultural aspects such as media, containers, lights, irrigation, etc. The results have been variable but some attempts are clearly on the path to achieve economically viable production systems. These efforts are encouraging and may provide a route to minimize the introduction of additional *Phytophthora* species to the region while also providing local income and reducing the cost of planting stock.

Although the use of genetically resistant material could offer a reasonable solution to this intractable problem, Fraser fir is generally highly susceptible to Phytophthora root rot and no useful level of resistance has been identified to the most prevalent species in the region, *P. cinnamomi* (Frampton and Benson 2012). Growers in the region commonly plant known infested areas with other species that have greater tolerance or resistance: eastern white pine (*Pinus strobus* L.), Canaan fir (*A. balsamea* var. *phanerolepsis* Fern.), Nordmann fir (*A. nordmanniana* (Steven) Spach.), and Turkish fir (*A. bornmuelleriana* Mattf.). Compared with Fraser fir, however, these species are generally less valuable as Christmas trees, and they sometimes succumb to Phytophthora root rot—especially on infested sites with poor drainage. Some growers in the region are piloting a more costly but effective strategy: the deployment of Fraser fir grafted onto rootstock of momi fir (*A. firma* Sieb. and Zucc.), the most Phytophthora-resistant fir species (Hibbert-Frey et al. 2010, Frampton et al. 2012). There is a need to evaluate the resistance of alternative Christmas tree species to the newly found *Phytophthora* species in the region, as well as to develop Phytophthora-resistant Fraser fir, either via genetic engineering (faster development but controversial) or a hybridization and backcross program (long-term development).

Phytophthora species will no doubt continue to plague the Fraser fir Christmas tree industry of the Southern Appalachian Mountains. Nonetheless, vigilance and the pursuit of a variety of amelioration strategies may help to reduce its future impact.

REFERENCES

Benson, D.M; Grand, L.F. 2000. Incidence of Phytophthora root rot of Fraser fir in North Carolina and sensitivity of isolates of *Phytophthora cinnamomi* to metalaxyl. Plant Disease. 84(6): 661–664.

Brasier, C. 2008. The biosecurity threat to the UK and global environment from international trade in plants. Plant Pathology. 57(5): 792–808.

Busing, R.T.; White, P.S.; MacKenzie, M.D. 1993. Gradient analysis of old spruce-fir forests of the Great Smoky Mountains circa 1935. Canadian Journal of Botany. 71(7): 951–958

Chastagner, G.; Riley, K.; Hamm, P. 1990. Susceptibility of *Abies* spp. to seven *Phytophthora* spp. Phytopathology. 80(9): 887.

Chastagner, G.A.; Benson, D.M. 2000. The Christmas tree: Traditions, production, and diseases. American Phytopathological Society. DOI:10.1094/PHP-2000-1013-01-RV. http://www.apsnet.org/publications/apsnetfeatures/pages/christmastree.aspx. (September 2016).

Chastagner, G.A.; Hamm, P.B.; Riley, K.L. 1995. Symptoms and *Phytophthora* spp. associated with root rot and stem canker of noble fir Christmas trees in the Pacific Northwest. Plant Disease. 79(3): 290–293.

Crandall, B.S.; Gravatt, G.F.; Ryan, M.M. 1945. Root disease of *Castanea* species and some coniferous and broadleaf nursery stocks, caused by *Phytophthora cinnamomi*. Phytopathology. 35:162–180.

Érsek, T.; Nagy, Z. Á. 2008. Species hybrids in the genus *Phytophthora* with emphasis on the alder pathogen *Phytophthora aln*i: a review. European Journal of Plant Pathology. 122(1): 31–39.

Frampton, J.; Benson, D.M. 2012. Seedling resistance to *Phytophthora cinnamomi* in the genus *Abies*. Annals of Forest Science. 69(7):805–812.

Grand, L.F.; Lapp, N.A. 1974. *Phytophthora cinnamomi* root rot of Fraser fir in North Carolina. Plant Disease Reporter. 58(4): 318–320.

Hibbert-Frey, H., Frampton, J.; Balzich, F.A.; Hinesley, L.E. 2010. Grafting Fraser fir (*Abies fraseri*): Effect of grafting date, shade, and irrigation. HortScience. 45(4): 617–620.

Jones, D.; Baker, R. 2007. Introductions of non-native plant pathogens into Great Britain, 1970–2004. Plant Pathology. 56(5): 891–910.

Kuhlman, E.G.; Hendrix, F.F. 1963. Phytophthora root rot of Fraser Fir. Plant Disease Reporter. 47(6): 552–553.

McKeever, K.M.; Chastagner, G.A. 2016. A survey of *Phytophthora* spp. associated with *Abies* in U.S. Christmas tree farms. Plant Disease. 100(6): 1161–1169.

Napier, A.S.; Sidebottom, J.R. 2011. North Carolina Christmas trees by the numbers. https://christmastrees.ces.ncsu.edu/christmastrees-nc-christmas-trees-by-the-numbers/. (April 2016).

Pettersson, M.; Frampton, J.; Rönnberg, J.; Shew, H.D.; Benson, D.M., Kohlway, W.H.; Escanferla, M.E.; Cubeta, M.A. 2016. Increased diversity of *Phytophthora* species in Fraser fir Christmas tree plantations in the Southern Appalachians. Scandinavian Journal of Forest Research. DOI: 10.1080/02827581.2016.1265144.

Sidebottom, J.R. 2011. History of the North Carolina Christmas tree industry. https://christmastrees.ces.ncsu.edu/christmas-trees-history-of-the-north-carolina-christmas-tree-industry/ (April 2016).

USDA National Agricultural Statistics Service. 2014. 2012 Census of Agriculture, Cut Christmas Trees: 2012 and 2007. United States, Summary and State Data No. Volume 1, Geographic Area Series, Part 51. U.S. Department of Agriculture, Washington, DC: USDA, National Agricultural Statistics Service. 695 p.

Zentmyr, G.A. 1988. Origin and distribution of four species of *Phytophthora*. Transactions of the British Mycological Society. 91(3): 367–378.

Development of a Mechanical Seeder for Sowing Small-Seeded Oak Species

Bob Hawkins

Nursery Program Supervisor, Indiana Division of Forestry, Vallonia, IN

Abstract

This article describes a mechanical seeder designed at Indiana's Vallonia State Tree Nursery to achieve target sowing rates for small-seeded acorns. This seeder can also be used for other hardwood species with similar-sized seeds. Using the seeder has helped achieve desired seedbed densities, thereby reducing cull percentages.

Introduction

The Indiana Division of Forestry's Vallonia State Tree Nursery, located about 80 mi (130 km) south of Indianapolis, grows bareroot seedlings for reforestation, mine reclamation, and wildlife enhancement for citizens of Indiana to purchase at low cost (Hawkins and O'Connor 2011). We grow a selection of 35 to 40 native hardwood species well adapted to Indiana's climates. Seed size varies significantly among these species. This size variation makes it difficult for a single mechanical seeder to effectively sow seeds for every hardwood species at the seeding rates necessary to reach our target seedbed densities.

The most difficult seeds for us to control sowing densities when using our mechanical seeders are the small-sized acorns such as pin oak (*Quercus palustris* Münchh.), cherrybark oak (*Q. pagoda* Raf.), shingle oak (*Q. imbricaria* Michx.), black oak (*Q. velutina* Lam.), and chinkapin oak (*Q. muehlenbergii* Engelm.). There are few affordable hardwood seeders on the market that can handle a variety of seeds of this size. Several options exist for small tree and shrub seeders. Because the bareroot nursery industry is small, however, production of these machines is limited, making them very expensive to produce or purchase. Therefore, individuals from within the Vallonia Tree Nursery workforce designed and assembled a new, in-house seeder (figure 1) to help us achieve our desired sowing rates for small-sized acorns. The cost to build this seeder was approximately $5,500 (2005 pricing). This cost covered all parts, steel, and materials but did not include any labor expenses used in building the seeder.

Figure 1. Seeder developed at Indiana's Vallonia State Tree Nursery to achieve target sowing rates for small-seeded acorns and other species with similar-sized seeds. (Photos by Bob Hawkins, 2016)

Mechanical Seeder for Small-Sized Acorns

We designed our new seeder based on a multitude of ideas from other seeders used or developed by the nursery, as well as planters used in crop production. A roller, mounted at the front of the seeder, rolls over the formed bed and levels it as much as possible (figure 2). We wanted each seed to be picked up and dropped in the soil, much like corn or soybeans when they are sown. We modified finger pick-up units (P/N AA60535, John Deere Company, Moline, IL)(figure 3) to pick up small acorns individually from seed boxes (P/N BA28955, John Deere Company, Moline, IL) filled with seed (figure 4). Using these adapted finger pick-up units results in good density control by enabling each seed to be placed in the seedbed individually instead of 4 to 5 seeds at a time, which causes a clumping effect.

Floating double disk openers (P/N 121-782L, Great Plains Manufacturing, Salina, KS) open the soil in the seedbeds to the desired sowing depth (figure 5). Various pressure adjustments on the disk openers can be made to sow seed to the target depths. An individual riding the seeder and monitoring the seeding operation can make these adjustments during sowing (figure 6). The more pressure adjusted to these openers, the deeper the trench made for the seed. As seed is sown, a press wheel follows to

Figure 2. Roller mounted on front of seeder to assist with leveling the seedbed. (Photo by Bob Hawkins, 2016)

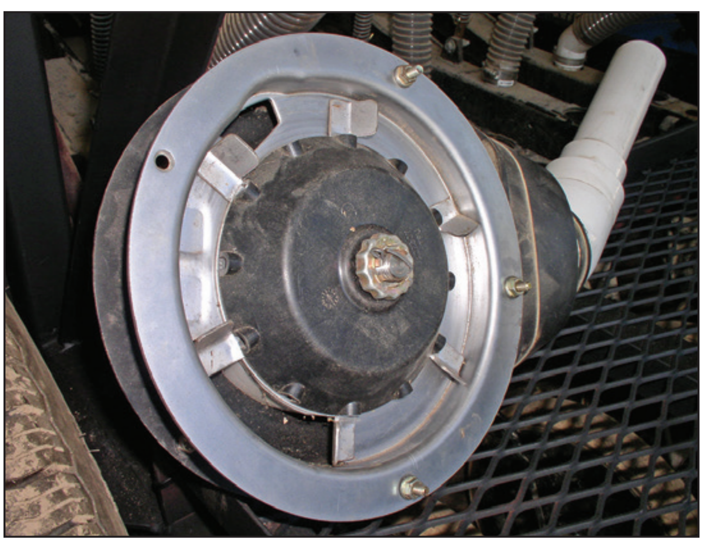


Figure 3. Modified finger pickup units used to grab individual seeds for placement in the seedbed. (Photo by Jeannie Redicker, 2012)

Figure 4. Seed boxes loaded with oak seed. (Photo by Jeannie Redicker, 2012)

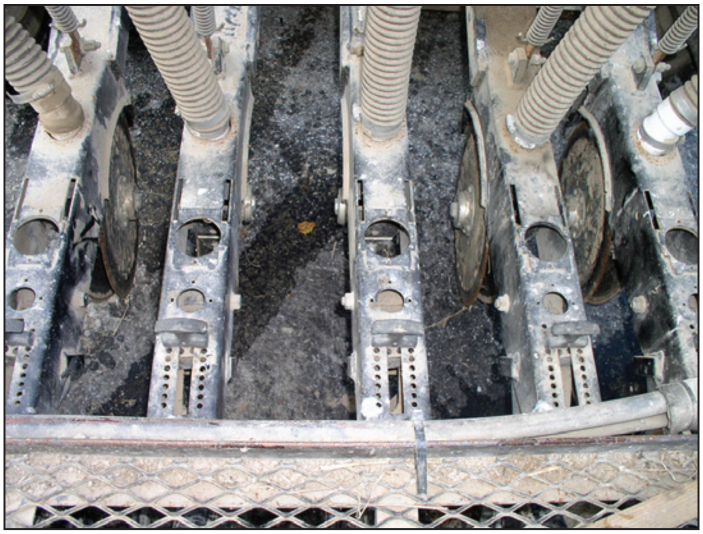


Figure 5. Double disk openers used to open soil in seedbed. Various pressure adjustments can be made as to the depth of the trench desired for the seed. (Photo by Bob Hawkins, 2016)

Figure 6. An operator riding on the seeder can monitor and adjust speed and density. (Photo by Jeannie Redicker, 2012)

Figure 7. Press wheels used to secure seed into seedbed while covering seed with soil. (Photo by Jeannie Redicker, 2012))

Figure 8. Speed-O-Meter used to control the speed of the seed pickup. (Photo by Bob Hawkins, 2016))

secure seed into the depressed seedbed (figure 7). Once seed is sown, a heavy drag pulled over the top of the seedbed drags soil on top of the seed and fills the trench. In most cases, seed flows well from the seed boxes. Occasionally, however, a wooden stick is needed to poke seed down in the box and assure proper flow and disbursement.

A chain-driven system turns the finger pick-up units. A Speed-O-Meter (P/N 01010, Micro-Trak Systems Inc., Eagle Lake, MN) is used to control how fast these units turn and how quickly seed is picked up and dropped in the seedbed (figure 8). The speed of the chain can be altered by adjusting a hydraulic flow line to allow more revolutions (increased seed drop) or fewer revolutions (decreased seed drop).

The individual riding the seeder and monitoring the operation can adjust the hydraulic fluid flow using a lever on the seeder. We reach our target sowing density by adjusting the chain speed and the speed of the tractor. All sowing calibrations are made based on a tractor speed of 1 MPH in the field. Seed is collected for 1-minute increments and weighed to determine necessary adjustments for achieving target sowing rates for each hardwood species.

We have also used this seeder design to sow other species with similar seed sizes, including American plum (*Prunus americana* Marshall), persimmon (*Diospyros* virginiana L.), hazelnut (*Corylus americana* Walter), and de-winged seeds of sugar maple (*Acer saccharum* Marshall). We have had very good success calibrating and using this seeder to obtain the desired densities and germination rates for all these species. This seeder has greatly helped reach our desired seedbed densities (figure 9), thereby reducing the number of cull seedlings when grading and processing these seedlings for sale. The importance of seedbed density cannot be understated. By controlling seedbed densities, a more uniform, higher quality seedling will be produced for outplanting (figure 10).

Figure 9. Typical seedling spacing reached from use of this seeder. (Photo by Bob Hawkins, 2016))

Figure 10. One-year-old oak seedbeds planted with this seeder. (Photo by Bob Hawkins, 2016)

REFERENCES

Hawkins, B.; O'Connor, P. 2011. Tree planting in Indiana. Tree Planters' Notes. 54(1): 10–14.

Tips for Executing Exceptional Conferences, Meetings, and Workshops

Diane L. Haase, R. Kasten Dumroese, and Richard Zabel

Western Nursery Specialist, U.S. Department of Agriculture (USDA), Forest Service, Portland, OR; Research Plant Physiologist, USDA Forest Service, Moscow, ID; Director, Western Forestry and Conservation Association, Portland, OR.

Abstract

The three of us, combined, have organized or attended more than 500 events, including meetings, conferences, workshops, and symposia, around the world. After participating in so many events, we concluded that a guide for hosting a successful event is greatly needed. Too often, an event is negatively affected by preventable issues, such as poor planning, a terrible venue, unskilled speakers, ineffective moderators, bad food service, or technical difficulties. In this article, we provide practical guidelines for planning and executing smooth-running, well-received events.

Advance Planning

Advance planning is the most important part of hosting a successful event. For small (20 to 60 people), somewhat informal events, 3 to 6 months is usually adequate. For larger events, allocate 12 to 18 months to minimize stress, delegate necessary tasks, and give speakers adequate preparation time. Although our focus for most of this article is on big events, the tips we provide apply to smaller events as well.

The event must include current, relevant information with great appeal to your intended audience. Therefore, identify the need(s) to be addressed, the event objectives, and the target audience. Once a topic area is selected, send out emails or postcards to solicit comments and suggestions from likely attendees (through individual contacts, professional lists, or attendees at previous events with a similar audience). Although only 10 to 20 percent of possible attendees are likely to respond, their input about specific hot topics and potential speakers is invaluable.

Schedule your event for dates that do not conflict with another event in the same or associated field, and do not coincide with the busy season for the intended audience. Remember to avoid spring break for public schools. An event duration of 2 or 3 days is usually the most appealing. Ideally, schedule Tuesday, Wednesday, and/or Thursday, reserving Monday and Friday for travel.

Choose a venue within a short distance from a major airport for regional, national, or international events. Unless a remote location provides something critical to the event (e.g. field tour stops significant to the event's objective), choose a moderate- or large-size city. This provides more options for overnight accommodations, venues, and catering. In addition, people are more likely to attend an event where they can also visit other points of interest.

Delegation of responsibilities is paramount. Depending on the size and scope of the event, tasks, such as collecting registration fees, advertising, ordering food, inviting speakers, editing the proceedings, getting handouts printed, conducting a field tour, reserving rooms, operating the computer and projector, and others may be handled by a few or many individuals. Volunteers are commonly used, especially if their registration fee is reduced or waived; make sure their task is well defined and of manageable size and commitment.

Venue

Ensure the venue is comfortable so that listening to presentations is enjoyable. Always inspect potential facilities in advance to confirm optimal comfort and lighting. The best venues are university or hotel facilities that are specifically designed for professional events. Many venues waive room rental fees if food and beverage expenses meet a minimum, contract-specified amount.

Ideal meeting rooms have comfortable, preferably padded, chairs with plenty of leg room and adequate space for personal belongings (figure 1). Tables should have sufficient space to take notes and set a beverage. A pitcher of water, glasses, and a bowl of hard candies at each table is a nice touch. Those candies are great for staving off hunger pangs before lunch or staying alert at the end of the day. The room should be warm enough that people do not need to wear a coat but not so warm that they are sleepy or sweating. Make sure the room will not be disturbed by distracting sounds; ask about pending construction plans and other groups that may be sharing the site. Networking during breaks is one of the most important parts of any event, so ensure ample space is available for people to mingle and chat. Consider proximity of the venue to eating establishments or shopping in order to keep attendees happy during free time.

The front of the room (i.e., speaker and screen) must be visible to the entire audience. Adjustable, easy-to-use lighting is essential. Dimming lights, preferably in the front of the room only, allows images on the screen to be clear and bright while providing adequate light for people to take notes and see the speaker. Make sure windows can be fully shaded so that projected images can be seen.

If the event requires multiple rooms, ideally all rooms should be in the same building. Strive to make movement from one room to another as simple and direct as possible. If additional buildings or long distances are unavoidable, provide clear maps in the registration packet and allow adequate time for folks to navigate from one place to the next. Each meeting room should have a sign posted outside the room with the daily agenda for that particular meeting room. Each meeting room requires a moderator to keep everything running smoothly.

Speakers

Selecting speakers can be a challenge; consider their expertise and their style. A good start is to obtain suggestions through a postcard and/or email solicitation, online surveys, and consultation with colleagues. Ideally, every speaker will be well prepared, clear, informative, concise, and engaging. The audience appreciates those who are relaxed,

Figure 1. Event venues should be comfortable and spacious with good control over lighting. (Photo by Diane L. Haase, 2016)

lively, and even humorous. Unfortunately, it is difficult to know speaking styles ahead of time, and some speakers may be relatively dry and dull. These speakers, however, can still be quite positive to the event if their presentation content is timely and relevant to the attendees.

An especially popular or notable speaker may be designated as the "keynote"—someone who presents a broad overview and/or insightful reflection on the event's focus. Some events have multiple keynote speakers to kick off each day or section of the agenda, while others do not have a keynote at all. A keynote speaker should only be included if you are confident of the speaker's message, delivery, and appropriateness.

Invite speakers as early as possible. An email invitation is fine; make sure to give a brief description of the event, including target audience, dates, location, and what is expected of them (e.g. presentation length, proceedings paper, biographical information, etc.). Either ask potential speakers to present on a specific topic or provide them some suggested areas based on the focus of the event and their expertise. In addition to inviting speakers directly, a "call for speakers" can identify potential candidates. Keep in mind, however, that respondents to the "call for speakers" may be new to their field or still in graduate school. While many respondents will have excellent presentations and cutting-edge information to share, some may be inexperienced in public speaking. To ensure that the event content is rewarding for attendees, invite a solid base of speakers in addition to those who volunteer.

Maintain contact with speakers. Use regular reminders, initiated well in advance, to keep them focused on deadlines for submitting a brief biography, handout materials, or a proceedings manuscript. Additionally, give speakers guidelines for developing and formatting their presentations. These guidelines should include using fonts that are universal to most computers, text and graphics that are large enough for the audience to see, an emphasis on results rather than methods, and avoidance of slides saturated with text or graphics. Remind speakers that the agenda will be strictly adhered to and encourage them to practice their presentation so that it is within their allotted time and reserves at least 3 to 5 minutes for audience questions.

The Agenda

The agenda should begin with an introduction from one of the event organizers. This should include a welcome to the attendees, reiteration of event objectives, description of necessary logistics (safety, event timeframe, location of restrooms/meeting rooms/meals/field tour), and a request to turn off cell phones. Speaker time slots can range from 20 to 50 minutes depending on the speaker's request, the number of speakers, and the overall time available (figure 2).

Day 1

8:00	Continental breakfast
8:30	Welcome and introductions
8:40	Speaker #1
9:15	Speaker #2
9:50	Speaker #3
10:25	Break
10:50	Speaker #4
11:25	Speaker #5
12:00	Lunch
1:00	Field tour
6:00	Evening social/dinner

Day 2

8:00	Continental breakfast
8:30	Speaker #6
9:05	Speaker #7
9:40	Speaker #8
10:15	Break
10:50	Speaker #9
11:25	Speaker #10
12:00	Lunch
1:00	Speaker #11
1:35	Speaker #12
2:10	Speaker #13
2:45	Adjourn

Figure 2. Sample agenda for a 2-day conference with 35-minute speaker slots, a field tour, and an evening social event.

Because listening to presentations for a full day can be mind numbing, do not schedule exceptionally long days. When a day is long, people tend to leave early, which is unfair to end-of-the-day speakers. Generally, 9 a.m. to 4 p.m. is ideal and allows commuter time. To reduce the duration of sitting, subdivide days to include a poster session, a field trip, or an interactive activity such as a brainstorming/discussion or a hands-on session. Many events have a morning of formal presentations followed by an afternoon in the field. Consider ending the final day a bit early to accommodate travel needs.

Order speakers strategically to best capture the audience's attention. For example, group speakers who have similar topics and intersperse the most interesting speakers (hot topic areas or dynamic presentation styles). Because 25 percent or more of your audience often departs during the last break of a multiday event, plan your concluding session carefully to include popular topics or speakers to keep the audience's attention (and attendance) for the entire event.

Schedule morning, lunch, and afternoon breaks to avoid having attendees sit for more than 2 hours at a time. One primary function of an event is the opportunity for networking. Therefore, allow adequate time for folks to interact with colleagues whom they may not see often. Schedule breaks for 30 minutes and lunches for 60 to 90 minutes. Generous break times also build in flexibility; if the agenda falls behind, the break or lunch can be shortened accordingly to get back on schedule. Conversely, if a speaker fails to appear, breaks can be extended. It is best, however, to start breaks within 5 to 10 minutes of their scheduled time to ensure the caterer is properly prepared. The audience greatly appreciates staying on schedule, so that should be a primary goal.

Make a plan for getting people to return after breaks. Often, people are so engrossed in their break-time conversations that it is difficult to get them back to their seats and resume the program. Yelling, whistling, or flashing lights can get the crowd's attention. One of the most effective ways we have found is to walk through the break area ringing a hand bell. Handing out a door prize at the beginning of a new session can also encourage attendees to return promptly (see Raffles and Contests later in this article).

Food

Good food is a must. There is nothing like a poorly done food service to elicit dozens of unhappy comments on the feedback forms.

Provide food and beverages about a half hour before the event begins each morning. This can range from a hearty breakfast buffet to a simple array of fruit, bagels, and pastries. Beverages, including caffeinated, noncaffeinated, and sugar-free choices (coffee, tea, soda, and water), should be available at each break. A light snack of fruit or cookies during the break is also nice. Provide recycling options and consider "green" products (e.g., a dispenser of cold water rather than bottles of water).

Arrange an appetizing lunch unless circumstances (e.g., a field trip) dictate a box lunch. A hot, buffet-style meal is usually best (figure 3). Serve from both sides of a table, or set up a second or third table, so that everyone has his or her food within 15 minutes. A meal served at the tables can be nice, but it is important to minimize

Figure 3. A tasty buffet lunch that can be served to all participants within 15 minutes is an effective and popular meal service for events. (Photo by R. Kasten Dumroese, 2016).

the wait time so that some diners are not starting dessert while others are still waiting for their salad. All menus should include vegetarian and gluten-free options. Make sure to provide plenty of fruits and vegetables in addition to choices for heartier appetites. And, do not forget dessert. Carefully consider the merit of a luncheon speaker; most attendees enjoy networking during professional events and lunches are a great time for conversations.

If lunch is "on your own," allow a minimum of 90 minutes. Provide a map of nearby restaurants along with a brief description of the cuisine and price range. Check with restaurants beforehand for discount coupons or special rates for attendees.

Advertising, Registration, and Budget

Ideally, the conference agenda should be finalized at least 3 months ahead of time. Post it on a Website along with registration information, maps, hotel suggestions, and any other information that can assist people planning to attend the event. Keep all posted information up to date and ensure that it prints well in black and white. In addition, a registration brochure can be mailed to various professional lists. Sending an announcement to related professional groups and asking them to include it in their newsletter, Webpage, or calendar of events can also reach more potential attendees.

Many factors influence the registration fees. The most important factor to consider is ensuring that the anticipated revenue will cover all costs (venue rental, food, handouts, technical equipment, name badges, etc.). A two-tiered structure of early and late (25 to 35 percent higher) registration fees will encourage most attendees to register by the early date and thereby provide event organizers with a fairly accurate headcount for planning purposes. Waiving or reducing registration fees for speakers is a justifiable courtesy given the time they spend to prepare their presentations. Moreover, consider covering speakers' travel expenses, including local accommodations, for those who travel long distances or have limited travel funds. Additionally, consider rewarding the planning committee, volunteers, speakers, and students with complimentary or reduced registration fees.

Sponsors/exhibitors usually receive one or two registrations with their sponsor/exhibitor fee, and spouses are usually charged only for meals or optional field trips in which they participate. Plan the budget, meals, and travel accurately by including all paid, reduced-fee, and complimentary registrants in the registration database. The database may need a separate section for optional event revenue, such as that for evening banquets or field trips. Decide in advance if partial registrations will be accepted for a multiday event and ensure the registration person knows how to handle requests from people who wish to attend only a portion of the event.

An accurate, up-to-date, and on-demand registration database is vital to pre-event decisions on food, bus transportation, handout materials, and room setup. It is worthwhile to hire a service to process registrations because starting from scratch will take an inexperienced person considerable time and energy. A number of online services offer registration systems. Your registration system is essentially a data collection and accounting spreadsheet. In addition to name and contact information, be sure to include optional events, meal preferences, and specifics for the name badge, such as chapter or State society. Attendees will want the option to register online, over the phone, via surface mail, or by fax. They will also want to use credit cards, checks, or purchase orders, and a few will ask to be invoiced after the event. Accurate accounting is essential to determine who has paid and whose registration fees are still outstanding. Confirming registration with an email is inexpensive and timely; receipts may be sent or provided during registration. You or your registration service should expect a variety of questions regarding lodging, program, venue, and payments. List only one phone number for any questions on the registration form and other materials.

Revenue sources include registration fees, sponsorships, and exhibitor fees. Base the anticipated revenue on a lower-than-expected attendance number to protect the event from losses if economics, weather, or other factors put a damper on registration numbers. (Do not forget to include the complimentary or reduced-fee registrations in the estimates.) While past event attendance may provide some guidance in estimating future attendance, base the event budget on conservative estimates of attendance and associated expenses. This is particularly true in estimating sponsorship support, which can be unreliable.

Expenses fall into two categories: fixed and variable. Fixed expenses can include brochure design and printing, Webpage management, postage, speaker travel/honorarium, registration services, credit-card bank fees, room rental, and audiovisual equipment rental. Variable expenses are those that fluctuate with attendance and include meals, breaks, buses for field trips, event souvenirs, tables for exhibitors, and printed handouts. The largest expense by far is for food and beverages. Be sure to account for any gratuity and taxes; these can add 25 percent to the listed price of meals and breaks, and sometimes to the rental costs of audiovisual equipment and rooms.

Technical Equipment

Prepare the principal computer and projector at least an hour before the first presentation each day. A complete backup system is always a good idea. Nowadays, nearly all speakers use PowerPoint® for their presentations. Although speakers may provide a PowerPoint® file of their presentations ahead of time for handouts, they are likely to make last-minute revisions and bring a new version the day of their presentation on a USB (Universal Serial Bus) flash drive (also called a thumb drive or memory stick). Assign an experienced person to load speaker presentations and operate the computer during the event. A good practice is to rename files, usually by the speaker's last name, as they are uploaded to the desktop, so that they can be located easily. Ensure the computer has the latest PowerPoint® software and an array of fonts. Before the actual presentation, always open the file to ensure the fonts and graphics display properly. Position the computer (or a second monitor) so that it faces the speaker; even if the screen is several feet away, it can help cue the speaker so that he or she does not need to turn away from the audience to look at the projected image. Have a remote for the computer so the speaker can easily advance the presentation (figure 4). Low-cost USB remotes work well and usually have a laser pointer built in (if not, provide a separate laser pointer). Keep extra batteries ready.

Wireless microphones are best. Most speakers like to wander rather than be tied to a podium or microphone stand, and stationary microphones must be repeatedly raised or lowered. Position the wireless microphone on the speaker's shirt about 6 in (15 cm) below the chin so that it picks up the voice clearly and the volume does not fade if the speaker turns his or her head from side to side (figure 4). Have a spare microphone and batteries on hand.

Figure 4. Wireless microphones and computer remotes with laser pointers are useful tools for speakers to deliver their presentation smoothly. (Photos by Diane L. Haase, 2016)

Moderators

The role of the moderator is to introduce speakers, keep the event running on time, and facilitate questions following a presentation. Select moderators with the same care used to select speakers. A good moderator is comfortable in front of a crowd and, perhaps most importantly, assertive enough to keep speakers on time. Usually, one moderator serves per topic area or session. Provide moderators with a brief biography of each speaker they will introduce and encourage them to read the bios ahead of time and confirm each speaker's name pronunciation. In addition, moderators should instruct speakers as needed on the proper use of the microphone and remote controls, and remind speakers to repeat all questions asked of them.

Typically, the moderator welcomes and briefly introduces each speaker. During each presentation, the moderator needs to be in position to clearly signal the speaker about remaining time. An effective signal is holding or waving a series of signs (5 minutes, 3 minutes, ONE minute, STOP) until the speaker acknowledges it. Another useful tool is to set up a monitor facing the speaker and use a simple countdown display to indicate how much time remains for the presentation (figure 5). If necessary, moderators may need to speak assertively to the speaker. Immediately after the 1-minute warning, the moderator must begin moving toward the speaker; this technique is usually quite effective in getting the speaker to wind up the presentation. If necessary, the moderator may need to interrupt, ask the speaker to be available at the next break for any questions, and state that it is time to continue forward with the agenda.

Following the presentation, the moderator can call for questions if time allows, reminding the speaker to repeat any questions into the microphone so the whole audience knows what was asked. If time has expired, the moderator must resist the temptation to take "just one question" to be polite, but instead request that the audience meet with the speaker during the next break. Invariably, that "just one question" takes more time than expected and throws the schedule even further off.

Name Badges and Handouts

Upon arrival, attendees will seek a registration table where they can get their name badge and other event materials. Ensure good signage at the venue entrance to direct all participants to the registration table and meeting space(s). Online meeting supply companies

Figure 5. Keeping to the agenda schedule is important. One effective tool is a monitor with a countdown timer facing the speaker to notify him or her how much of the allotted time remains. (Photo by Diane L. Haase, 2016)

provide a variety of name badge sizes and styles. The name badge should be very easy to read. Ideally, the first name occupies a line by itself in a very large, bold font (easily visible, even from 5 ft [1.5 m] away), with the last name below it in slightly smaller font, and the affiliation and location in a still smaller font (figure 6). The purpose of the name badge is identification; it is not an advertising platform. Keep event logos or company icons to a minimum so the attendee's name is most prominent. Identify speakers, moderators, exhibitors, and sponsors on the name badge by using different colors, ribbons, or a banner of text. Name badge holders are available in pin-on, clip-on, and hanging formats. Everyone can wear the hanging name badges, whereas the pin-on tags can damage clothes and attire may not provide a suitable place for clip-on tags. At the end of the event, provide a box for people to recycle their name badge holders for use at a future event.

Many event attendees appreciate having a handout to follow during presentations and for future reference. One effective format is a paper copy of the speakers' presentations in a bound booklet. This requires obtaining the speakers' files 2 to 3 weeks before the event, which also helps ensure speakers are prepared for the event. Inevitably, most will make revisions after providing the file for the handouts, but the versions are usually similar enough for the audience to follow along. Remind speakers that the file will be used for the event's handout and encourage them to make figures legible when printed in black and white. To save paper and reduce bulk, ask the speakers to omit slides that have only photos (unless they are critical to the presentation and will print well), and make sure to print the slides 6-per-page and double-sided. Even with this format, enough room is available in the margins for taking notes. Another option for a handout booklet, instead of printed presentations, is to include a 2- to 3-page summary from each speaker. Arrange the speakers' handout materials in the same order as the presentations in the agenda.

Figure 6. Name badges should be easily read, even from afar, with the first name in a large, bold font followed by last name, affiliation, and location. Refrain from cluttering the tag with logos and conference names.

The handout booklet should start with the agenda, followed by the materials from each speaker, and include lists of speakers, attendees, and exhibitors along with their contact information, as well as maps of the venue area, field tour locations, and nearby points of interest. Number the pages and include a table of contents. Be sure to acknowledge any sponsors and individuals instrumental in making the event successful. Print more books than registered attendees to accommodate any walk-ins and attendees who want to take additional copies to their office. Multiple-day events will require even more additional books, because people will lose their books or leave them in their hotel room and will stop by the registration desk to pick up a copy for that day.

Optional Activities

Concurrent Sessions

Concurrent sessions are an attractive option for accommodating more speakers and topics. Two concurrent sessions, however, means more planning and resources, and twice the technical equipment, speakers, moderators, room rentals, etc. Three concurrent sessions requires three times the resources, and so on. Fewer concurrent sessions are better than more sessions. When offering concurrent sessions, attendees will only have an opportunity to hear half, or even less, of the speakers. If the event will genuinely be enhanced by featuring concurrent sessions, it is extremely important to keep the sessions exactly on time and provide adequate time between presentations for attendees to move to another session. Assertive moderators are absolutely critical to keep to the schedule. Ideally, hold concurrent sessions in the same building and provide attendees a very clear map to aid them in locating each session.

Panels and Open Discussions

Panels or discussion sessions are occasionally a valuable tool to cultivate interactive dialog among the event participants but they can be dismal failures if the audience participation is low, or if one or two people dominate the discussion. Panels operate best with 3 to 5 people from diverse backgrounds with knowledge of the topic and clear understanding of the expectations for the session. Select panelists with the same rigor as that used for speakers. Each panelist can give a brief introduction of his or her experience and perspective—but prevent introductory comments from becoming a full-blown presentation. After the brief introductions, open the floor to questions and comments from the audience. In a large venue, either strategically place stationary microphones or circulate people with microphones to ensure that everyone can be heard; if microphones are unavailable, remind the responding panelist to repeat the question.

Discussions and brainstorming can be a great method for problemsolving or determining future directions. Designate a note taker. While it may seem ideal to hold discussions at the end of the day, that may result in minimal participation because people are tired and many will likely leave early. For optimum results, hold these sessions during the peak of the event to capture people when they are most thoughtful, enthusiastic, and alert.

Field Tours

Field tours may be optional before or after the event with an additional fee, or may be included as part of the event. Either way, field tours require some important logistical planning but can greatly complement an indoor session. One good format is to have speaker presentations in the mornings followed by afternoon field tours. Another option is to have an all-day field tour on the second day of a 3-day event. Inform participants ahead of time regarding the possible activities, weather, and terrain so they can dress accordingly.

Transportation depends on the number of people, the route to the tour stop(s), and available parking. Carpooling saves money but is only effective for smaller groups with tour stops within a small radius of the starting point. Buses or vans can be rented. If using a bus, check the route in advance for adequate clearance, parking, and turnaround areas, and, immediately before the trip, check the route for construction or other situations that could cause disruption. With buses or vans, ensure that ample bathroom facilities are available. If someone will present any information while enroute, make sure the bus is equipped with a microphone.

Avoid these two common, but unsuccessful, field tour formats: In the first, the tour guide gives a brief overview and then stays in one location endlessly entertaining questions, usually by just a few participants. Meanwhile, most of the group wanders bored and aimlessly, or clusters in groups to chat. In the second, the guide gives a brief overview then sends participants on a "self-guided tour." This format works sometimes, but too often the participants are left on their own for too long and wander around waiting to leave or cluster in groups to chat rather than learning much from the tour stop.

A successful field tour has several informative stops and keeps participants engaged and active (figure 7). Provide participants concise handouts describing the key points of each stop. Make sure the person presenting information is selected well in advance and is prepared, enthusiastic, and perhaps even amplified with a microphone or bullhorn. At each stop, keep the group moving to sustain interest and provide a comprehensive overview of that particular location; this should be impressed upon everyone involved with planning and conducting the field tour. Make sure each stop has a definite visual reason to be included in the field tour (i.e., the visuals need to match the speaker's message). A field tour with a few quality stops is best; too many stops can quickly get a field trip off schedule because attendees move slowly on and off buses. Build some wiggle room into the field tour schedule because these stops often take longer than expected. Attendees will never complain if the tour arrives back at the starting point ahead of schedule. Provide refreshments, particularly for trips during hot weather. Also, consider frequency and availability of restrooms, proximity to noisy equipment (including the buses) that could make hearing difficult, availability of shade or shelter depending on the weather, and accessibility for attendees.

Evening Activities

The most common evening activities are an ice-breaker registration the night before an event begins, a happy hour among the vendor exhibits, a dinner at the venue, or a catered dinner/happy hour at a nearby place of local/historical interest. An evening session is a great

Figure 7. The best field tour format keeps the participants moving and engaged. (Photo by Diane L. Haase, 2016)

opportunity for socializing and networking, giving out awards/recognitions, or holding a fundraiser (such as a silent auction). Additionally, it offers a perfect platform for a unique presentation or entertainment, such as music and dancing, interesting speakers telling of their ventures abroad, or someone from the local community talking about the history and lore of the area. The evening activity can be optional with an extra fee or can be built into the cost of the registration (with an extra fee for family members not attending the sessions). Be careful, however, to leave some free time during the event; attendees often want time for a private dinner with a colleague.

Posters and Exhibitors

Posters or vendor exhibits, either in the back of the room or in a separate area, are a great supplement to speaker presentations because they provide an opportunity for others to present information about research, projects, and products. Include a one-page abstract about each poster in the handout and the proceedings as well. Usually vendors are charged for booth space and therefore expect to be located in the main meeting room, an adjacent room where breaks occur, or in the public area near the registration desk. Some events also include time in the agenda for each vendor to talk briefly (2 to 4 minutes) to the group about their product or service. Sessions with food and beverages specifically set to highlight the posters or the vendors encourage attendees to take time to view these features of the event.

Speaker and Participant Gifts

Speaker gifts are a nice gesture if the budget allows, but not a necessity. The same is true for attendees. While speaker gifts may be more substantial, attendee gifts are often printed with the event's logo or are representative of the local area, such as items donated by the local tourism agency or by local businesses. Imprinting logos takes time, so plan ahead. Consider the volume, weight, and character of the items, especially for speakers and attendees traveling by air—a good rule is to ensure that all gifts meet Transportation Security Administration requirements for carry-on items.

Raffles and Contests

Even if the moderators are doing a good job of keeping speakers on time, the event can be delayed if attendees are difficult to round up following breaks.

One effective strategy is to hold a raffle a few minutes before the end of each break. Provide each attendee with a raffle ticket at registration and require attendees to be present to win. (Note: raffle tickets must be free to avoid likely State licensing requirements.) If vendors provide prizes, they receive some advertising and the raffle does not add cost to the event. Another fun element to incorporate into an event is a contest. For example, a "seedling beauty contest" was held at a reforestation event.

Feedback

Whether or not you plan to host another event, obtaining feedback from attendees is always useful. Provide a form with the handouts. The form should be just one page and include questions to stimulate the best feedback such as: Which topics/speakers did you find most useful? Which topics/speakers do you wish had been included? Other comments? Ratings (e.g., scale of 1 to 5) for the venue, food, etc. can be used. Having moderators remind attendees a few times throughout the event increases the likelihood of people returning the forms. Some events now use online surveys; these services summarize responses, but the probability is low that attendees will remember to do this after the event.

Documentation

Assembling a group of expert speakers in one place at one time is often worthy of documentation beyond the event's handout, depending on the level of effort and resources available. Documentation results in a compilation of timely and relevant information that will reach an audience beyond those who attended the event.

The most basic, and simplest, documentation is a hardcopy or USB flash drive of the speaker abstracts and presentation materials provided to all participants during registration. Speakers' presentations, either just their PowerPoint® or perhaps video of the talk, can be posted at the event's Website or on YouTube.

Additionally, and requiring more effort and resources, event organizers can request that speakers provide manuscripts for inclusion in published proceedings or a special issue of a professional journal. To accomplish this, it is critical to provide speakers with a deadline months ahead of time and then be very persistent. Even so, half or more of the speakers will likely miss the deadline by a few weeks or a few months. (Build plenty of wiggle room into the timeline so stragglers can still be included in the publication.) Some may never submit a paper. Provide specific guidelines to the speakers regarding length and formatting. A proceedings editor (or two or three) should read through the manuscripts to check for typos, inconsistencies, grammar, or errors. If needed, the editor can work with each author to make necessary revisions. Printing and mailing the proceedings to each event participant needs to be included in the event's budget (unless other funding is available or the proceedings will be distributed in another manner). Extra copies can be made available for sale and/or electronic copies posted online. Often, partnering with a government agency or university can facilitate printing and distributing proceedings. If manuscripts are expected to be of high caliber, an alternative is to work with an editor of a professional journal toward production of a special issue based on the event. Most journals require a review process that can improve papers significantly, give them greater credibility, and assist speakers with professional advancement.

Conclusions

Executing a "successful" meeting hinges on the audience having a positive perception of the event. The audience expects the event to run smoothly. Although unavoidable problems will likely arise, careful planning and attention to detail will help circumvent most minor and major pitfalls. Plan to be flexible during the event; remember that although you may be aware of meeting problems or issues, if the audience does not see or experience the problem, it is irrelevant. By following our tips toward executing a successful event (use the checklist in table 1), you should have a smoothly run, interesting, and informative event with maximum satisfaction and comfort for the organizers, speakers, and attendees.

Table 1. Check list for executing an exceptional event.

Exceptional Event Check List

Plan 6-18 months in advance

- Determine the event's objective and target audience
- Choose the event date(s), location, and venue
- Solicit suggestions for topics and speakers
- Delegate responsibilities

Venue

- Select an appropriate size for presentations and breaks
- Ensure comfortable seating and space to take notes
- Ensure adequate lighting
- Locate in close proximity to airport, accommodations, public transportation, and restaurants

Speakers

- Include speakers well-known for their expertise and/or presentation style
- Invite early to give adequate preparation time
- Decide whether or not to have a keynote
- Provide detailed guidelines, clear deadlines, and regular reminders

Agenda

- Arrange topics and speakers for maximum audience attention
- Schedule adequate breaks to allow for networking
- Provide assorted drinks and snacks during breaks
- Plan tasty meals with vegetarian, gluten-free, and healthy options; service must be timely

Budget and Advertising

- Advertise 3 to 4 months before the event—online, professional lists, registration brochure, etc.
- Set registration fees to ensure adequate revenue to cover fixed and variable expenses
- Consider waived or reduced fees for speakers, volunteers, and students
- Develop or hire a registration process that is reliable, accurate, and up-to-date

During the Event

- Provide each attendee with a legible name badge, event booklet, maps, etc.
- Have reliable technical equipment with back-up: laptop, wireless microphone, extra batteries
- Assign moderators to introduce speakers and keep on schedule

Optional Activities

- Carefully plan concurrent sessions, panels, and discussions must be carefully planned for optimum effectiveness
- Ensure field trips should have adequate transportation and engaging, interesting stops
- Provide evening banquets and presentations
- Offer presentations and/or vendor exhibits to enhance the event
- Supply speaker gifts, raffles, contests, and goodies for attendees
- Gather feedback from attendees to use for future events
- Post presentations online, publish proceedings, or ask speakers to submit papers for a special issue of a professional journal to have a broader impact

Response of Standard Eastern Cottonwood and Novel Black Willow Clones to Artificial Lighting

Alexander Hoffman, Joshua Adams, Mohammad M. Bataineh, Benjamin A. Babst, and Andrew Nelson

Graduate Research Assistant, School of Forestry and Natural Resources, University of Arkansas at Monticello (UAM), Monticello, AR; Assistant Professor of Silviculture and Genetics, School of Forestry, Louisiana Tech University, Ruston, LA; Assistant Professor of Forest Health, School of Forestry and Natural Resources, UAM, Monticello, AR; Assistant Professor, School of Forestry and Natural Resources, UAM, Monticello, AR; Assistant Professor of Silviculture, Department of Forest, Rangeland, and Fire Sciences, University of Idaho, Moscow, ID

Abstract

Dormant hardwood cuttings provide convenient propagation material for various forestry applications. The success of these applications, however, depends on achieving high survival of outplanted rooted cuttings. The type and intensity of artificial lighting during nursery production may affect subsequent field performance of rooted cuttings. Dormant hardwood cuttings of eastern cottonwood (*Populus deltoids* W. Bartram ex Marshall) and black willow (*Salix nigra* Marshall) were exposed to low-intensity wide-spectrum fluorescents, low-intensity LEDs (light-emitting diodes), and high-intensity LEDs for 33 days. Biomass partitioning did not differ among light treatments but root, shoot, and total biomass were higher for black willow compared to eastern cottonwood. For eastern cottonwood, light treatments had no significant effect on net photosynthesis-light response curves, although low-intensity LEDs tended to have the highest shoot-root ratios and maximum photosynthesis. Photosynthetic parameters were not measured on black willow. LEDs' specific light spectrum capabilities and efficient energy production may be a practical, cost-effective tool for improving outplanted seedling quality. Additional research is warranted.

Introduction

Poplars (*Populus* spp.) and willows (*Salix* spp.) grow rapidly, propagate readily, and are relatively easy to use in tree breeding and biotechnology programs. Because of these characteristics, these species are attractive candidates for short-rotation plantations around the world (Isebrands and Richardson 2014). These plantations can be cultivated to provide fuelwood, pulpwood, bioenergy, and biomass on marginal lands that are generally undesirable for agricultural use (Isebrands and Karnosky 2001, Rousseau et al. 2012, Volk et al. 2011, Zalesny et al. 2011). The common production system for these trees is through unrooted shoots from a stoolbed nursery, where stools (i.e., stumps) are maintained to produce fresh shoots (FAO 1980, Stanturf et al. 2001). These shoots are excised (i.e., cuttings) and directly outplanted or further developed in outdoor nursery beds or indoor greenhouse beds/containers for 1 to 2 years to develop rooted dormant sets (Isebrands and Richardson 2014). Rooted cuttings' root and shoot systems are commonly trimmed to ease transportation to planting sites, balance above- and below-ground biomass, and reduce planting stress (DesRochers and Tremblay 2009, Grossnickle 2005). Planted poplar and willow rooted cuttings need to be vigorous to outgrow competing vegetation, since they are shade intolerant and accordingly prone to stress from competition.

Proper site preparation (e.g., herbicide, disking, and ripping) in conjunction with pre-planting trimming is critical to maximize cutting growth and survival after outplanting (Dickmann and Stuart 1983, FAO 1980, Stanturf et al. 2001). Survival and growth of planted cuttings has been associated with planting depth, genetics, shoot-root ratios, and cutting length and diameter, which correspond to the amount of stored nutrients and carbohydrates (Burgess et al.1990, Farmer 1970, Robison et al. 2006, Schuler and McCarthy 2015, Stanturf et al. 2001, Woolfolk and Friend 2003, Verwijst et al. 2012, Zalesny et al. 2011). However, poor planting site conditions, such as well-drained sand, poorly drained silty clay loam, and poorly drained loam soils can diminish seedling survival (Baker and Broadfoot 1979, Dickmann and Stuart 1983, Stanturf et al. 2001).

Artificial lighting technologies to induce favorable seedling biomass partitioning (e.g., high root biomass) and physiology may enhance competitive potential of rooted cuttings on poor sites, thereby reducing the need for competition control and increasing first-rotation yields (Ceulemans et al. 1996, Kuzokina and Quigley 2005, Rousseau et al. 2012). Supplemental lighting has long been utilized within commercial greenhouse production environments where lower light conditions limit plant production (Heuvelink et al. 2006). Currently, high pressure sodium (HPS) lamps are the most common source for supplemental lighting because of their ability to efficiently produce light (Ieperen and Trouwborst 2007). White fluorescents have also been used successfully as supplemental lighting, especially for inducing rooting of cuttings (Cavusoglu et al. 2011). Light emitting diodes (LEDs) were originally investigated in the late 20th century to determine their potential as lighting systems for space-based plant growing systems (Bula et al. 1991). Early work focused on several food crop species such as wheat, radish, spinach, and lettuce (Goins et al. 1997, Yorio et al. 2001). As LED research developed, other applications, such as plant tissue culture and horticultural, were quickly realized (Tennessen et al. 1994). The high intensity and specific light spectrum that LEDs offer may help stimulate favorable stock material characteristics, such as adequate leaf area and root formation (Morrow 2008).

The objective of this study was to examine the effect of different artificial lighting treatments on growth and physiological performance of two species of dormant hardwood clonal cuttings. An established standard eastern cottonwood (*Populus deltoides* W. Bartram ex Marshall) clone (ST-66) was selected to contrast with the novel black willow (*Salix nigra* Marshall) clone (BRZ 3-4). We hypothesized that, while both species show fast growth characteristics, black willow's exceptional rooting capacity (Rousseau et al. 2012) would produce higher total biomass with lower shoot-root ratios in the short run compared with the eastern cottonwood. We also hypothesized that use of LEDs would result in differential biomass partitioning of cuttings as compared to that observed under wide spectrum fluorescents.

Methods

Study Species

Eastern cottonwood clone ST-66 was established as a superior clone during late 1960s clonal trials performed by the U.S. Department of Agriculture, Forest Service's Stoneville, MS, office (Mohn et al. 1970). ST-66 was a male clone originally collected from Issaquena County, MS, that exhibited below-average straightness, relatively large branch formation, and relatively late leaf-off dates. In further testing, ST-66 cuttings had a first-year survival of 93 percent, a 5-year height of 17.9 m (58.7 ft) on a silt loam site and 9.9 m (32.5 ft) on a sharkey clay site, and an average 5-year diameter-at-breast-height of 20.6 cm (8.1 in) on the silt loam site and 10.2 cm (4 in) on the sharkey clay site (Mohn et al. 1970). Black willow BRZ 3-4 is a novel clone that is being examined as a component of a new initiative towards black willow biomass production within the lower Mississippi River Alluvial Valley region (Rousseau et al. 2012). The BRZ clone's origin is within the Brazos Rivers collection site in eastern Texas (Rousseau 2016).

Cuttings Preparation and Light Treatments

Cuttings of eastern cottonwood clone ST-66 and black willow clone BRZ 3-4 were collected from a 1-year-old, coppiced, stoolbed orchard in Stoneville, MS, during late winters of 2013 and 2014. All cuttings were transferred on ice to the University of Arkansas at Monticello and placed in cold storage (4.0°C [39.2°F]) to prevent premature bud break or adventitious root initiation. In early spring 2015, 27 ramets of each clone were taken out of cold storage, rinsed with tap water, and trimmed to 20 cm (7.9 in) in length. Eastern cottonwood cuttings midpoint diameters averaged 1.3 ± 0.04 cm (mean ± SE; 0.51 ± 0.02 in) and black willow diameters averaged 1.5 ± 0.05 cm (0.59 ± 0.02 in). Each cutting was vertically placed, bud tips pointed up, in ~8 cm (3.1 in) of ddH20 for ~48 hours to promote rooting (Desrochers and Thomas 2003, Schaff et al. 2002). All 54 cuttings were planted individually in 950 ml (1 qt) Mini-Treepots™ (Stuewe and Sons, Inc., Tangent, OR) containing, hard-packed, EarthGro® topsoil (Scotts Miracle-Gro Company, Marysville, OH). The Mini-Treepots were placed in 3.28 L (3.47 qt) growing trays (figure 1). Three Mini-Treepots™ of each species were placed in each of nine growing trays.

Figure 1. Hardwood cuttings of ST-66 eastern cottonwood and BRZ 3-4 black willow in 950 ml Mini-Tree pots, randomly distributed within 3.28 L growing trays, and assigned to low-intensity fluorescents, low-intensity light-emitting diodes (LEDs), or high-intensity LEDs for 33 days. (Photo by Alexander Hoffman, 2015)

Growing trays were randomly assigned to one of three light treatments (table 1), for a total of three replicates per light treatment. Water was added to each growing tray daily to ensure adequate water supply to cuttings throughout the observation period. Temperature was maintained at 21°C (70°F) and no fertilizer was added.

Light treatments were selected to compare high- and low-light intensity LEDs with a reference low-intensity white fluorescent. Higher light intensity was achieved by shortening the distance between the cuttings and the LED light source. At the start of the experiment, light intensity was measured above each cutting using a quantum flux meter (Apogee Instruments, Inc., Logan, UT) and checked regularly thereafter to ensure desired light intensities were present within each light rack. Three independent light racks were arranged to prevent overlap among treatments and were randomly assigned to one of the light treatments (table 1). Light photoperiod was 16 hours per day.

Measurements

The experiment was conducted for 33 days. Cuttings grown under fluorescents and high-intensity LEDs grew tall enough that they came into direct contact with their respective light sources after approximately 21 days. After 33 days, lights were turned off and racks were covered with breathable black mesh to bring all sprouted cuttings to a photosynthetic steady state before measuring. Cuttings were kept in this state for ~18 hours, and then a portable photosynthetic system (LI-6400 XT, LI-COR, Inc., Logan, NE) coupled with a leaf chamber fluorometer was used to measure photosynthetic parameters of each plant's highest positioned, fully mature leaf that produced an adequate amount of leaf surface area (at least 2 cm^2, [0.31 in^2]). Black willow cuttings within all light racks produced ample aboveground biomass but inadequate leaf surface area and were therefore not measured for photosynthetic parameters.

Table 1. Mean photosynthetically active radiation (PAR) intensity and standard deviation (SD) for each light treatment

Light rack	Light source	Light intensity (µmol m-2 s-1 ± SD)
1	Six Osram Sylvania GRO-LUX wide spectrum 40 W tubes.	83.78 ± 10.87
2	Two Tesler 120 W 4:1 red (630 nm) to blue (430 nm) diode rectangular indoor LED grow lights.	161.67 ± 33.74
3	Two Tesler 120 W 4:1 red (630 nm) to blue (430 nm) diode rectangular indoor LED grow lights	87.5 ± 12.18

Photosynthesis measurements were obtained through a LightCurve auto program (6400-01, LI-COR Inc., Logan, NE), which exposed each leaf to a series of declining photosynthetically active radiation (PAR) intensities (2,000, 1,500, 1,000, 800, 500, 250, 100, 50, 25, and 0 µmol m^{-2} s^{-1}). At each PAR intensity, the cuttings' net photosynthesis (µmol CO_2 m^{-2} s^{-1}) was recorded to construct a net photosynthetic light-response curve (rate of photosynthesis per irradiance level; P_N/I) for each plant. Measurement intervals were 120 to 200 seconds. A matching infrared gas analyzer parameter of 50 µmol CO_2 was used in conjunction with a CO2 mixer that kept an internal chamber CO_2 concentration of 400 mol(CO_2).mol(air)$^{-1}$ (6400-01, LI-COR Inc., Logan, NE).

Recorded photosynthesis values were analyzed using the Lobo et al. (2013) Microsoft Excel Macro. The macro utilized a solver function to perform P_N/I curve construction using nine of the most frequently employed P_N/I curve models, including versions of the rectangular hyperbola Michaelis-Menten, nonrectangular hyperbola, exponential, and Ye models. All nine models were fit to the net photosynthetic light response datasets and compared in terms of goodness of fit, which showed the exponential model as an optimal model. Further exploration showed that the exponential model's fit to net photosynthetic light curves at a maximum PAR value of 1,000 µmol m^{-2} s^{-1} produced the highest r^2, and lowest sum of square error (*SSE*) values.

The maximum net photosynthetic rate ($P_{N\,(Imax)}$), 95 percent light saturation point ($I_{sat(95)}$), light compensation point (I_{comp}), and photosynthetic efficiency ($\varphi_{\,(Icomp\text{-}I200)}$) were calculated from the exponential macro model for each cutting.

Immediately following each cutting's net photosynthetic rapid light curve measurements, all aboveground biomass (i.e., shoot) was clipped, bagged, dried at 65 °C (149 °F) for 72 hours, and weighed. All root material was trimmed, bagged, labeled, and placed into cold storage until all samples were collected. To ensure finer root samples were collected, each pot's residual soil mixture was washed in a GVF Hydropneumatic Elutriation System (Gillison's Variety Fabrication, Inc., Benzonia, MI) which utilized air and water to float the roots and other organic matter out of the soil samples and onto a mesh screen. A 540-micron mesh was used to separate the roots from water exiting the extraction system. All the collected washed root segments were then combined with their respective sample bags, which were then dried at 65°C (149°F) for 72 hours. The dried root material was weighed to obtain a dry root biomass. Shoot-root ratio was then calculated for each cutting.

Statistical Analysis

The experiment was designed as a completely randomized split-plot design. Light treatment was the whole-plot factor and species was the within-plot factor. Due to the use of one light rack per treatment, growing trays were considered replicates. The effects of grouping three growing trays within a light rack and grouping three Mini-Treepots™ per species within a light rack were treated as random effects. A mixed effects linear regression model was fit for each biomass component and photosynthesis metric with light, species, and their interaction as fixed effects. One cottonwood cutting had a negligible amount of root biomass, which was considered a measurement outlier, and thus removed from analysis. Photosynthesis analysis was restricted to cottonwood cuttings due to insufficient leaf area of black willow. Statistical significance was recognized at $\alpha = 0.05$ for all models.

Results

Across light treatments, black willow produced more biomass ($p < 0.01$ for all biomass parameters) than eastern cottonwood (figure 2). Although not statistically significant ($p = 0.07$), eastern cottonwood tended to have a higher shoot-root dry biomass ratio than black willow (figure 2). No significant light by species interactions were found for any biomass parameters. Likewise, light treatments did not significantly affect biomass components although cuttings grown in the low-intensity LED treatment tended to have the highest mean shoot-root ratio and those grown in the high-intensity LED treatment tended to have the most total biomass (figure 2). For eastern cottonwood ST-66, no significant differences were found among light treatments for maximum net photosynthesis ($p = 0.95$), 95 percent light saturation point ($p = 0.92$), light compensation point ($p = 0.94$), or photosynthetic efficiency ($p = 0.84$) (figure 3).

Discussion

Biomass Components

Given the exceptional rooting capacity of black willow (Rousseau et al. 2012), we hypothesized that black willow would produce higher total biomass with lower shoot-root ratios in the short run compared to eastern cottonwood. Our results partially support this hypothesis with greater biomass for black willow, although shoot-root did not differ significantly from that of eastern cottonwood (figure 2). Black willow higher total biomass suggested a faster growth rate of this clone and consequently greater potential as a candidate biomass species.

Light treatments did not result in differential biomass partitioning of cuttings under the light intensities tested in this study. This lack of significant differences within biomass components suggests that the contrasting light intensities achieved were less than optimal. Furthermore, the LED lights used in this study produced narrow, red and blue wavelength bands that constitute a distinct light environment as compared to the Gro-Lux wide-spectrum fluorescents, which produced a narrow blue band, a broader red band, and a substantial far-red light emission. The interaction of light quality and intensity may have diminished the statistical significance among light treatments.

Greater root biomass under the fluorescents and high-intensity LED, albeit not significantly different from low-intensity LED, suggested higher potential

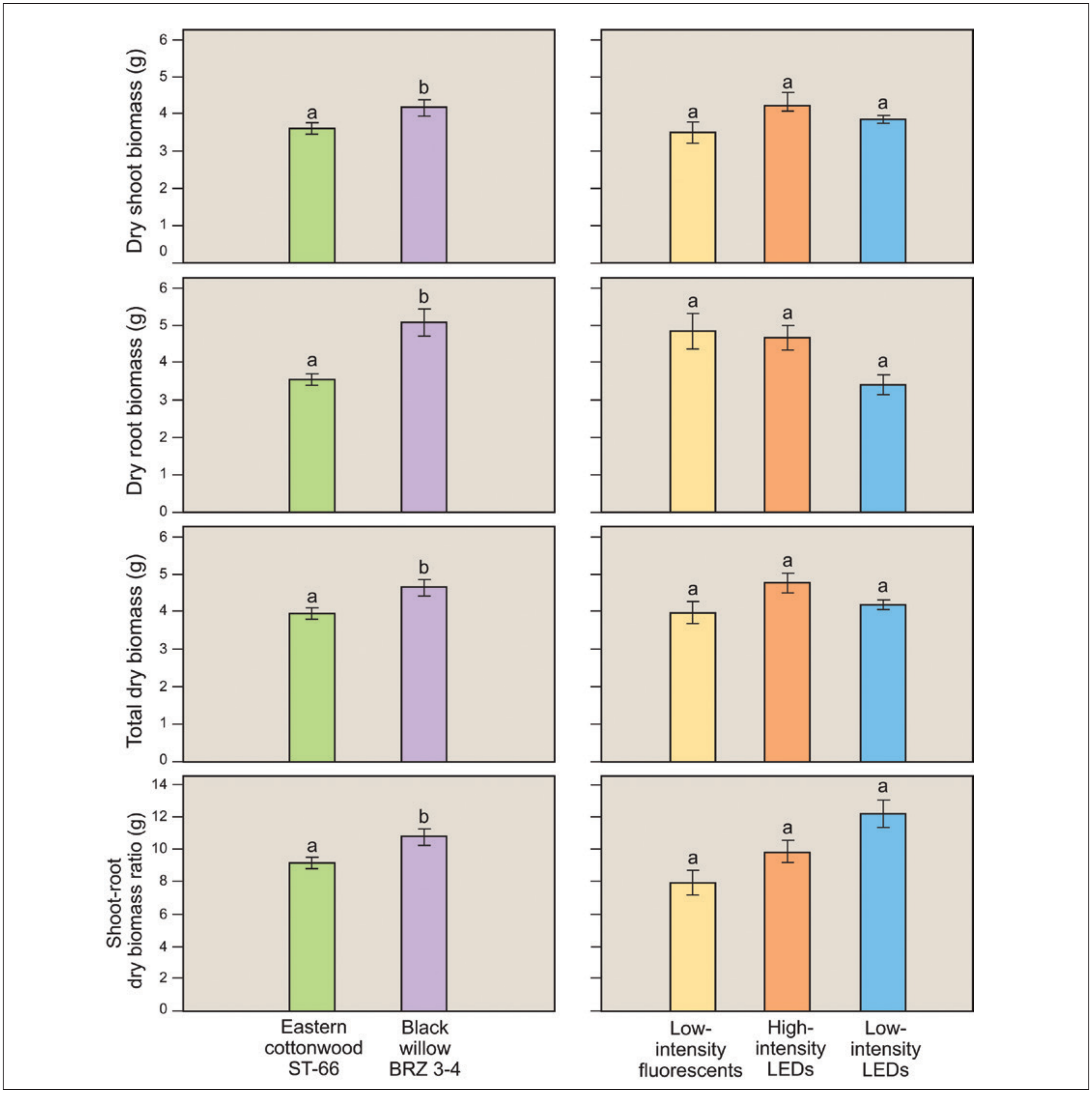


Figure 2. Mean and standard error (SE) of shoot biomass, root biomass, total biomass, and shoot-root biomass ratio for species and light treatments. Different letters denote statistical significance at $\alpha = 0.05$ within each block. LEDs = light-emitting diodes.

growth under these treatments. Cuttings grown under these treatments, however, came into direct contact with their light sources, which restricted further stem elongation. Samuoliene et al. (2010) documented increased frigo strawberry (*Fragaria x ananassa* Duch.) sprout stem elongation and shoot-root ratios when exposed to red LEDs; when a 13-percent blue light component was introduced in conjunction with the red LEDs, stem elongation decreased. Brown et al. (1995) investigated dry matter partitioning and physiology of Hungarian wax peppers (*Capsicum annum* L.) exposed to red (~660 nm) LEDs only, supplemented with blue fluorescent, or supplemented with far-red (~735 nm) LEDs at 300 µmol m^{-2} s^{-1} PAR. Peppers exposed to red LEDs only incurred reduced biomass production and fewer leaves than when blue fluorescents were added, whereas the addition of far-red LEDs resulted in taller plants and overall greater stem biomass. Additionally, the ratio of far-red:red light stimulates activity of plant phytochrome receptors, which have ecological value for shade avoidance, with a greater proportion of far-red light associated with accelerated stem elongation through the perception of shaded conditions (Schmitt et al. 2003). This is particularly prominent in shade-intolerant species, such as cottonwood and willow species.

Photosynthesis

Photosynthetic data on eastern cottonwood, although statistically not significant, provided some trends. It is surprising that the highest light intensity did not result in the highest maximum photosynthetic rates, but it is possible that even the highest light level was below that necessary to stimulate increased photosynthetic capacity. In fact, the light saturation points were all around 300 µmol m^{-2} sec^{-1}, which was higher than the "high-intensity" LED treatment (figure 3).

Cuttings in all light treatments were observed to have slight yellowing of juvenile leaves, indicating a possible nutrient deficiency (figure 4). The green veins and greenish-yellow interveinal areas indicate iron or potassium deficiencies (Hacskaylo et al. 1960). Because no fertilization was added during the study period, the cuttings relied on their stored nutrients and nutrients in the growing medium for root, shoot, and leaf growth. These available nutrient levels may have been inadequate for growth and photosynthetic capacity. While these deficiencies may have affected cuttings across light treatments, the low-intensity LEDs seemed to

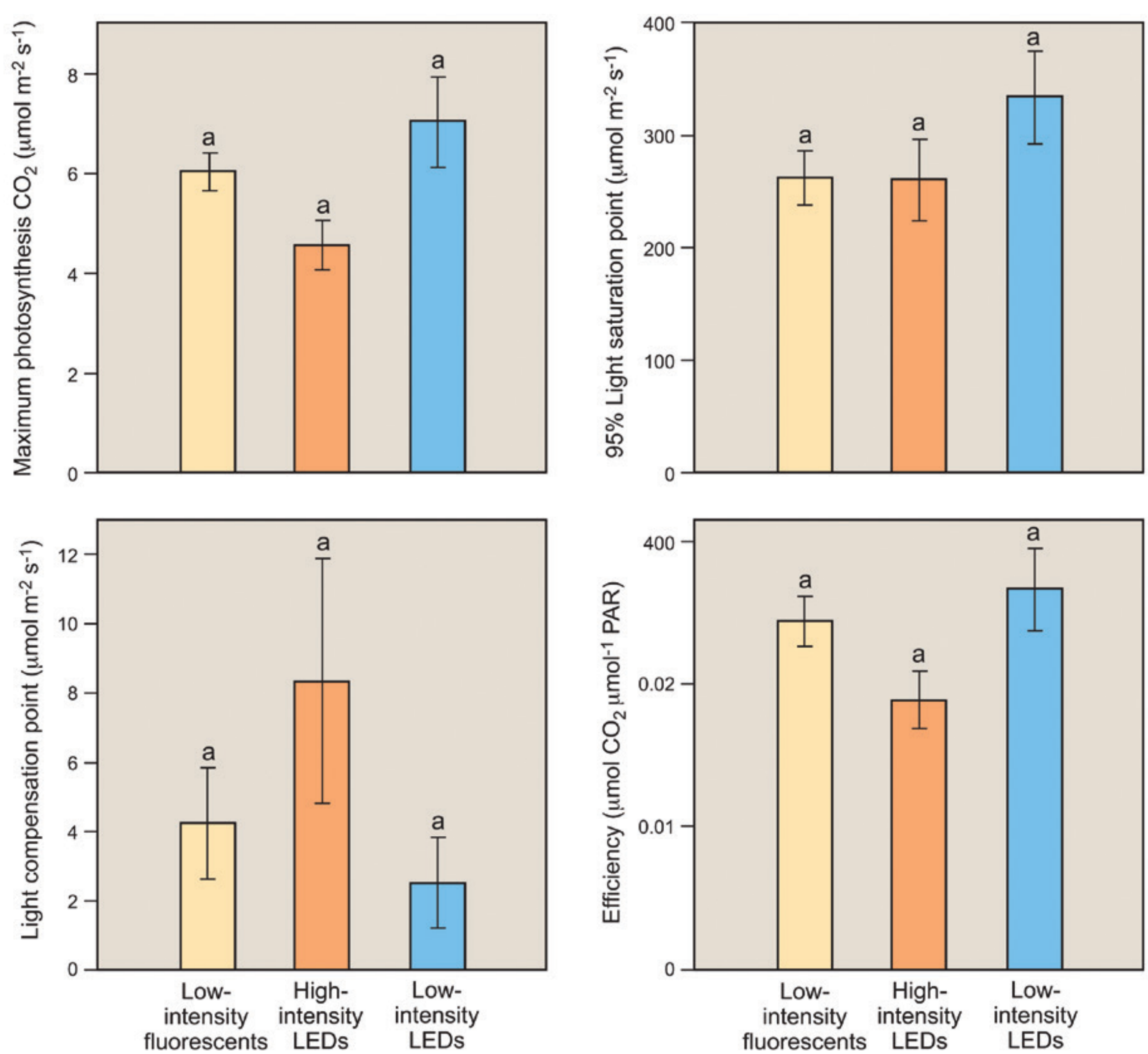


Figure 3. Mean and standard error (SE) of eastern cottonwood ST-66 maximum photosynthesis, 95 percent light saturation point, light compensation point, and photosynthetic efficiency by light treatment. Different letters denote statistical significance at $\alpha = 0.05$. LEDs = light-emitting diodes.

Figure 4. After 33 days of development within a low-intensity wide-spectrum fluorescent, low-intensity light-emitting diodes (LEDs), and high-intensity LED light racks, the majority of eastern cottonwood ST-66 (left) and black willow BRZ 3-4 (right) cuttings exhibited mild yellowing of leaves. (Photo by Alexander Hoffman, 2015)

produce the most vigorous cuttings. This is counterintuitive for a shade-intolerant plant, but may have been the result of plant growth out-stripping the nutrient supply in the higher light treatments.

The low-intensity LEDs provided high red:blue and red:far-red light ratios, which may have facilitated their marginal increase in photosynthesis performance. Blue light has been documented in regulating phototropism, photomorphogenesis, stomatal opening, and leaf photosynthesis (Whitelam and Haddiday 2007). Additionally, higher biomass production and photosynthetic capacity have been observed when a blue light component is supplied in conjunction with red light (Brown et al. 1995, Bukhov et al. 1995, Hogewoning et al. 2010, Matsuda et al. 2004, Yorio 2001). Favorable photosynthesis performance of the low-intensity LED may have also been facilitated by the cuttings' high shoot-root ratios. Investing the initial stored carbohydrates and newly produced photosynthates towards aboveground biomass may have allowed the cuttings to be more physiologically efficient.

The direct contact of shoot tips and juvenile leaves with the high-intensity LEDs probably induced negative physiological feedbacks, which diminished the potential for an accurate depiction of the red-blue light quality's effects and how applying those at a high intensity may affect cutting physiology. Similar complications were encountered with cuttings exposed to low-intensity fluorescents, whose high far-red:red light ratios could have facilitated stem elongation. Several studies have documented an advantageous physiological response to high far-red:red light ratios through enhanced stem elongation, increased biomass production, and the assimilation of more photosynthates into leaf area production for better light harvesting (Ballare et al. 1990, Gilbert et al. 1995, Ritchie 1997).

Conclusion

Artificial light sources (low-intensity fluorescents compared with low- and high-intensity LEDs) did not result in differences in biomass partitioning (shoot:root) in eastern cottonwood ST-66 or black willow BRZ 3-4 clonal cuttings. The black willow clone, however, produced greater shoot, root, and total biomass than the eastern cottonwood clone after 33 days. The specific light spectrum capabilities, especially the blue to red light ratio, and efficient energy production of LEDs warrant further research into their capabilities to influence biomass partitioning and consequently improve the competitive potential of vegetatively propagated clones on poor quality sites.

Address correspondence to—

Mohammad M. Bataineh, School of Forestry and Natural Resources, University of Arkansas at Monticello, 110 University Court, P.O. Box 3468, Monticello, AR 71656; email: bataineh@uamont.edu; phone: (870) 460-1449.

Acknowledgments

Funding for this project was provided by the Arkansas Forest Resources Center.

REFERENCES

Baker, J.B.; Broadfoot, W.M. 1979. A practical field method of site evaluation for commercially important hardwoods. General Technical Report SO-36. U.S. Department of Agriculture, Forest Service Southern Forest and Range Experiment Station, New Orleans, LA. 60 p.

Ballare, C.L.; Scopel, A.L.; Sanchez, R.A. 1990. Far-red radiation reflected from adjacent leaves: an early signal of competition in plant canopy. Science. 247(4940): 329–332.

Brown, C.S.; Schuerger, A.C.; Sager, J.C. 1995. Growth and photomorphogenesis of pepper plants under red light-emitting diodes with supplemental blue or far-red lighting. Journal of the American Society for Horticultural Science. 120(5): 808–813.

Bukhov, N.G.; Drozdova, I.S.; Bondar, V.V. 1995. Light response curves of photosynthesis in leaves of sun-type and shade-type plants grown in blue or red light. Journal of Photochemistry and Photobiology B: Biology. 30(1): 39–41.

Bula, R.J.; Morrow, R.C.; Tibbitts, T.W.; Barta, D.J.; Ignatius, R.W.; Martin, T.S. 1991. Light-emitting diodes as a radiation source for plants. Hort Science. 26(2): 203–205.

Bukhov, N.G.; Drozdova, I.S.; Bondar, V.V. 1995. Light response curves of photosynthesis in leaves of sun-type and shade-type plants grown in blue or red light. Journal of Photochemistry and Photobiology B: Biology. 30(1): 39–41.

Burgess, D.; Hendrickson, O.Q.; Roy, L. 1990. The importance of initial cutting size for improving the growth performance of *Salix alba* L. Scandinavian Journal of Forest Research. 5(4): 215–224.

Cavusoglu, A.; Ipekci-Altas, Z.; Bajrovic, K.; Gozukirmizi, N.; Zehir, A. 2011. Direct and indirect plant regeneration from various explants of eastern cottonwood clones (*Populus deltoides* Bartram ex Marsh.) with tissue culture. African Journal of Biotechnol. 10(16): 3216–3221.

Ceulemans, R.; McDonald, A.J.S.; Pereira, J.S. 1996. A comparison among eucalyptus, poplar, and willow characteristics with particular refernce to a coppice growth-modeling approach. Biomass and Bioenergy. 11(2/3): 17–22.

Desrochers, A.; Thomas, B.R. 2003. A comparison of pre-planting treatments on hardwood cuttings of four hybrid poplar clones. New Forests. 26(1): 17–32.

Desrochers, A.; Tremblay, B.R. 2009. The effect of root and shoot pruning on early growth of hybrid poplars. Forest Ecology and Management. 258(9): 2062–2067.

Dickmann, D.I.; Stuart, K.W. 1983. The culture of poplars in Eastern North America. East Lansing, MI: Michigan State University Press.. 168 p.

FAO. 1980. Poplars and willows in wood production and land use. Rome: Food and Agriculture Organization of the United Nations. 328 p.

Farmer, R.E. 1970. Variation and inhertiance of eastern cottonwood growth and wood properties under two soil mositure regimes. Silvae Genetica. 19(1): 5–8.

Gilbert, I.R.; Seavers, G.P.; Jarvis, P.G.; Smith, H. 1995. Photomorphogenesis and canopy dynamics, phytochrome-mediated proximity perception accounts for the growth dynamics of canopies of *Populus trichocarpa x P. deltoides* “Baupre.” Plant Cell and Environment. 18(5): 475–497.

Goins, G.D.; Yorio, N.C.; Sanwo, M.M.; Brown, C.S. 1997. Photomorphogenesis, photosynthesis, and seed yield of wheat plants grown under red light-emitting diodes (LEDs) with and without supplemental blue lighting. Journal of Experimental Botany. 48(312): 1407–1413.

Grossnickle, S.C. 2005. Importance of root growth in overcoming planting stress. New Forests. 30(2): 273–294.

Hacskaylo, J. 1960. Deficiency symptoms in forest trees. In: Van Baren, F.A., editor. Transactions of the 7th International Congress of Soil Science. 1962. Madison, WI. 393–405.

Heuvelink, E.; Bakker, M.J.; Hogendonk, L.; Janse, J.; Kaarsemaker, R.; Maaswinkel, R. 2006. Horticultural lighting in the Netherlands: new developments. Acta Horticulturae. 711: 25–34.

Hogewoning, S.W.; Trouwborst, G.; Maljaars, H.; Poorter, H.; Ieperen, W.V.; Harbinson, J. 2010. Blue light dose—responses of leaf photosynthesis, morphology, and chemical composition of Cucumis sativus grown under different combinations of red and blue light. Journal of Experimental Botany. 61(11): 3107–3117.

Ieperen, W.V.; Trouwborst, G. 2007. The application of LEDs as assimilation light source in greenhouse horticulture: a simulation study. Acta Horticulturae. 801: 1407–1414.

Isebrands, J.G.; Karnosky, D.F. 2001. Environmental benefits of poplar culture. In: Dickmann, D.I.; Isebrands, J.G.; Eckenwalder, J.E.; Richardson, J., editors. Poplar culture in North America. Ottawa, Ontario: National Research Council of Canada Research Press. 207–218.

Isebrands, J.G., Richardson, J., editors. 2014. Poplars and willows: trees for society and the environment. Oxfordshire, UK: CAB International and The Food and Agriculture Organization of the United Nations. 634 p.

Kuzovkina, Y.A.; Quigley, M.F. 2005. Willows beyond wetlands: uses of Salix species for environmental projects. Water, Air, and Soil Pollution. 162(1-4): 183–204.

Lobo, F.d.; de Barros, M.P.; Dalmagro, H.J.; Dalmolin, Â.C.; Pereira, W.E.; de Souza, É. C.; Rodríguez Ortíz, C.E. 2013. Fitting net photosynthetic light-response curves with Microsoft Excel—a critical look at the models. Photosynthetica. 51(3): 445–456.

Matsuda, R.; Ohashi-Kaneko, K.; Fujiwara, K.; Goto, E.; Kurata, K. 2004. Photosynthetic characteristics of rice leaves grown under red light with or without supplemental blue light. Plant and Cell Physiology, 45(12): 1870–1874.

Mohn, C.A.; Randall, W.K.; McKnight, J.S. 1970. Fourteen cottonwood clones selected for midsouth timber production. Research Paper SO-62. USDA Forest Service, New Orleans, LA. 18 p.

Morrow, R.C. 2008. LED Lighting in horticulture. HortScience. 43(7): 1947–1950.

Ritchie, G.A. 1997. Evidence for red:far-red signaling and photomorphogenic growth response in Douglas-fir (*Pseudotsuga menziesii*) seedling. Tree Physiology. 17(3): 161–168.

Robison, T.; Rosseau, R.; Zhang, J. 2006. Biomass productivity improvement for eastern cottonwood. Biomass and Bioenergy. 30(8-9): 735–739.

Rousseau, R.J.; Gardiner, E.S.; Leininger, T.D. 2012. Development of a black willow improvement program for biomass production in the Lower Mississippi River Alluvial Valley. In: Junyong, J.Y.Z.; Zhang, X.; Pan, X., editors. Sustainable Production of Fuels, Chemicals, and Fibers from Forest Biomass. ACS Symposium Series Volume 1067. American Chemical Society, Washington, DC. 27–63

Rousseau, R. 2016. Personal communication. College of Forest Resources, Mississippi State University, Starksville, MS.

Samuoliene G.; Brazaityte, A.; Urbonaviciute , A.; Sabajeviene, G.; Duchovskis, P. 2010. The effect of red and blue light component on the growth and development of frigo strawberries. Zemdirbyste. Agriculture. 97(2): 99–104.

Schaff, S.D.; Pezeshki, S.R.; Shields, F.D., Jr. 2002. Effects of pre-planting soaking on growth and survival of black willow cuttings. Restoration Ecology. 10(2): 267–274.

Schmitt, J.; Stinchcombe, J.R.; Heschel, M.S.; Huber, H. 2003. The adaptive evolution of plasticity: phytochrome-mediated shade avoidance responses. Integrative and Comparative Biology. 43(3): 459–469.

Schuler, J. L.; McCarthy, W. 2015. Development of eastern cottonwood cuttings as modified by cutting length and surface area available for rooting. New Forests. 46(4): 547–559.

Stanturf, J.; Oosten, C.; Van Netzer, D.; Coleman, M.; Portwood, C. 2001. Ecology and silviculture of poplar plantations. In: Dickmann, D.I.; Isebrands, J.G.; Eckenwalder, J.E.; Richardson, J., eds. Poplar culture in North America. Ottawa, Ontario: National Research Council of Canada Research Press. 153–206.

Tennessen, D.J.; Singsaas, E.L.; Sharkey, T.D. 1994. Light-emitting diodes as a light source for photosynthesis research. Photosynthesis Research. 39(1): 85–92.

Verwijst, T.; Lundkvist, A.; Edelfeldt, S.; Forkman, J.; Nordh, N. E. 2012. Effects of clone and cutting traits on shoot emergence and early growth of willow. Biomass and Bioenergy. 37: 257–264.

Volk, T.A.; Abrahamson, L.P.; Cameron, K.D.; Castellano, P.; Corbin, T.; Fabio, E.; Johnson, G.; Kuzovkina-Eischen, Y.; Labrecque, M.; Miller, R.; Sidders, D.; Smart, L.B.; Staver, K.; Stanosz, G.R.; Van Rees, K. 2011. Yields of willow biomass crops across a range of sites in North America. Aspects of Applied Biology. 112: 67–74.

Whitelam, G.C.; Halliday, K.J., editors. 2007. Annual Plant Reviews Volume 30: Light and Plant Development . New York: John Wiley & Sons. 344 p.

Woolfolk, W.T.; Friend, A.L. 2003. Growth response of cottonwood roots to varied NH4:NO3 ratios in enriched patches. Tree Physiology. 23(6): 427–432.

Yorio, N.C.; Goins, G.D.; Kagie, H.R.; Wheeler, R.M.; Sager, J.C. 2001. Improving spinach, radish, and lettuce growth under red light-emitting diodes (LEDs) with blue light supplementation. HortScience. 36(2): 380–383.

Zalesny, R.; Cunningham, M.; Hall, R.; Mirch, J.; Rockwood, D.; Stanturf, J.; Volk, T.A. 2011. Woody biomass from short rotation energy crops. In: Junyong, Z.; Zhang, X.; Pan, X., editors. Sustainable Production of Fuels, Chemicals, and Fibers from Forest Biomass. ACS Symposium Series Volume 1067. Washington, DC: American Chemical Society. 536 p.

Effect of Container Size and Design on Morphological Attributes of *Cercocarpus ledifolius* Nutt. (Curlleaf Mountain Mahogany) Seedlings

Christopher R. Keyes and Christine M. Brissette

Research Professor and Graduate Research Assistant, W.A. Franke College of Forestry and Conservation, University of Montana, Missoula, MT

Abstract

We conducted an experiment to evaluate the effects of four common seedling containers on the morphology and plant biomass production efficiency of *Cercocarpus ledifolius* Nutt. (curlleaf mountain mahogany) seedlings. All four types produced well-balanced shoot-root ratios. The largest container (Styro-20) produced the largest seedlings and greatest total plant biomass production per unit bedspace area, but also produced the most inconsistently sized seedlings. Among the smaller containers, cell spacing density proved more important than cell volume. The smallest container (Stubby-10) produced seedlings comparable to or greater than the Styro-10 and RL-10, with a high degree of crop consistency and efficient use of growing medium. The RL-10 produced the smallest seedlings by all measures, and plant biomass per unit volume of growing medium was lower than any of the three Copperblock™ containers. Despite its shortcomings, the versatility of the RL system may make it a worthy selection for those nurseries where seedling germination or survival has been problematic.

Introduction

Cercocarpus ledifolius Nutt. (curlleaf mountain mahogany) has high potential as a restoration species for degraded, arid upland habitats throughout the Interior West of the United States. Interest in this native dryland shrub has been spurred by the species' ability to establish and survive in harsh edaphic conditions. Additionally, it is a nitrogen-fixing, pioneer species that enhances long-term nutrient availability for itself and other species (Lepper and Fleschner 1997). Because *C. ledifolius* is a palatable shrub with high protein and digestibility ratings, it often serves as an important winter food source for ungulates (Davis and Brotherson 1991).

In the northern Rocky Mountains, *C. ledifolius* is typically prescribed for sites best characterized by dry, rocky, south-facing slopes with little to no vegetation present, and consisting primarily of exposed mineral soil, the topsoil often having eroded away. Dealy's (1975) study of the morphological development of *C. ledifolius* described a growth habit of vigorous early root development and very little shoot development; that habit likely contributes to its successful outplanting at harsh sites. Studies comparing stocktype success in hot, dry environments have generally shown that seedlings with deep, well-established root systems contribute to their survival (e.g., Lloret et al. 1999, Chirino et al. 2008). At such sites, a lower shoot-root ratio is desirable to minimize transpirational surface area while seedlings are establishing (Cregg 1994).

Yet, for growers interested in supplying *C. ledifolius* seedlings for restoration projects, knowledge about propagation practices for this species is lacking. It is generally understood that container type (cell volume, cell shape, etc.) can directly affect the morphological characteristics of nursery-grown seedlings (NeSmith and Duval 1998). This study was prompted by a need to identify the most effective container for nursery production of *C. ledifolius* seedlings for restoration of a droughty site in the Bitterroot Valley of Montana. We designed an experiment to compare morphological attributes of seedlings grown in four different containers during one growing season. The objective was to isolate the impacts of container type and volume on aspects of *C. ledifolius* seedling morphology, holding other determinants of plant growth as constant as possible. Analyses tested the following hypotheses:

1. Seedling shoot weight, root weight, shoot height, and root collar diameter will positively correlate with container cell volume.

2. No differences in the above seedling attributes will be observed for containers of equal cell volume but different shape/material.

3. Shoot-root ratio will be unaffected by container cell size or type.

Additionally, we evaluated the relative nursery production efficiency per container by comparing total seedling biomass produced per unit volume of soilless medium, and per unit area of nursery bedspace.

Methods

Treatments

In March 2014, uniformly sterilized, stratified seeds were direct-sown into four different types of sterilized containers (figure 1). Containers consisted of Copperblock™ Styrofoam containers (Beaver Plastics, Alberta, Canada) and Ray Leach Cone-tainer™ single cells in plastic trays (Stuewe & Sons, Corvallis, OR). Containers ranged in cell volumes from 125 cm^3 (Stubby-10) to 336 cm^3 (Styro-20), and in cell densities from 213/m^2 (Styro-20) to 528/m^2 (RL-10)(table 1). We used eight full units of each container type (block or tray), with container type as the experimental unit (replications) and seedlings within container type as the sampling unit.

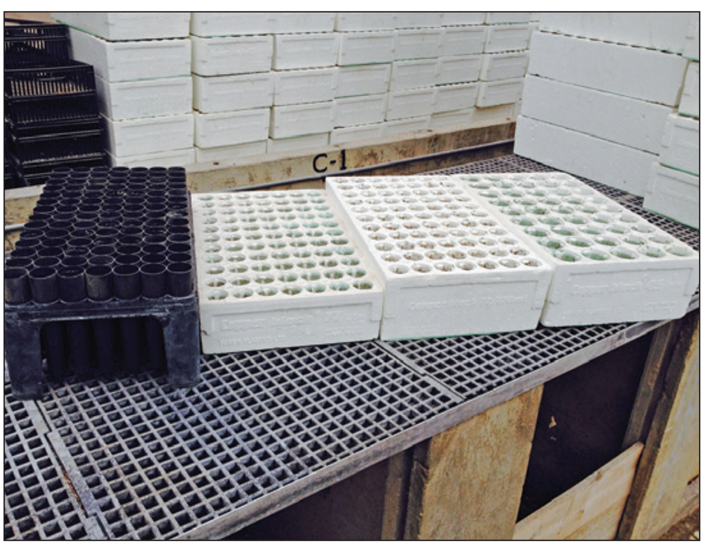


Figure 1. Four container types were compared in this study (L to R): Ray Leach Cone-tainer™ (RL-10), and Copperblock™ Styrofoam containers (Stubby-10, Styro-10, Styro-20). (Photo by Christopher Keyes, 2016)

Table 1. Attributes of the four containers evaluated in this study.

Container	Cell Depth (cm)	Cell Volume (cm^3)	Cell Density (cells/m^2)
Ray Leach Cone-tainer™ SC10; "RL-10"	21.0	164	528
Copperblock™ 415D; "Styro-10"	15.2	164	364
Copperblock™ 412A; "Stubby-10"	11.7	125	364
Copperblock™ 615A; "Styro-20"	15.2	336	213

The soilless growing medium consisted of a manually blended 1:1 mixture (by volume) of *Sphagnum* peat moss and perlite. Sowing occurred within a 5-day timeframe to ensure consistency. Following sowing, a thin layer of 5-mm granite poultry grit covered each cell. Copperblocks were sown with two seeds per cavity and were later thinned (as needed) to one seedling per cavity. Germination was excellent, and about half of the cells required thinning down to one germinant. A very small number of cells per block (less than approximately 5 percent) remained empty. Cone-tainer™ cells were sown with one seed per cavity, but with additional units sown as potential substitutes. After germination was complete, empty cells (approximately 10 to 20 percent of each tray) were removed and replaced with substitute cells to produce complete cell trays.

Seedlings were grown under conditions designed to be representative of a low-intensity native plant nursery, with cultural methods aimed at producing seedlings of uniform quality. The percent saturation block weight method (Dumroese et al. 2015) determined the watering schedule (80 percent threshold during establishment and rapid growth, 70 percent thereafter), with saturation block weights updated during the growth period. Fertilizer consisted of commercial water-soluble Miracle-Gro® 24-8-16 (Scotts Miracle-Gro Company, Marysville, OH) at 250 ppm nitrogen during the rapid growth phase, applied in conjunction with irrigation via siphon injection (Hozon™ Brass Siphon Mixer, Phytotronics, Inc., Earth City, MO). Seedlings were germinated and grown indoors at a greenhouse (University of Montana) until early June, at which point they were moved outdoors to a shade-house (Vander Meer's Wildland Conservation Nursery, LLC, Missoula, MT), where they were grown for the remainder of the experiment (October 2014). To reduce the potential for bias associated with microsite, blocks and trays were shuffled monthly during residency at each facility. The four container types were kept in groups, and those four groups were shuffled monthly; on the same occasions, the eight replications within each container-type group were shuffled as well.

Measurements

After one full growing season (March–October), eight seedlings per container were randomly selected for destructive measurement. To ensure that the sample only included seedlings that germinated promptly and received the full growing season, discrimination rules were applied to constrain potential seedling selection to those taller than 15 mm. Seedlings were selected on an X-Y axis grid based on random number generation. If the random number generation produced a cell that was empty or had a seedling less than a minimum height of 15 mm, then a new, randomly generated cell replaced it.

Response variables measured were: shoot height, shoot weight, root collar diameter (RCD), root weight, total seedling weight, and shoot-root ratio. Seedling samples were removed from their cells and growing medium was gently washed off. Shoots were cut from roots. Shoot heights were measured as length from the root collar to the top of the terminal bud. Seedling RCDs were measured with a digital caliper. Plant materials were placed in paper envelopes and oven-dried at 60°C for 48 hours, then weighed with a digital balance to determine root and shoot dry weights. Shoot-root ratios were calculated from those dry weights.

To estimate the potential production efficiency tradeoffs among containers, the sum of total seedling biomass produced was relativized to per unit volume of growing medium used (m^3), as well as per unit area of nursery bedspace (m^2) used, and those relativized values per container were compared. For those relative contrasts, we assumed filled cells for all four containers.

Experimental Design and Analyses

We used a randomized complete block design for this study with eight replications (blocks or trays) of the four container types. We used analysis of variance (ANOVA) F-tests to identify differences among container types for all response variables (α=0.05), using transformed and untransformed data as appropriate. The normality assumption was evaluated via the D'Agostino-Pearson omnibus test of skewness and kurtosis (D'Agostino et al. 1990) at α=0.05. The equal variances assumption was evaluated via the Brown-Forsythe test (a nonparametric data-means version of the Levene's test; Brown and Forsythe, 1974) at α=0.05. Untransformed RCD, and log-transformed shoot height and shoot-root ratio, met both assumptions. For the remainder (all responses related to weight), log transformations resolved normality issues, but no transformation successfully resolved variance heteroscedasticity. We used ANOVA for all responses because the samples sizes among treatments were equal, and ANOVA F-tests are robust against variance heteroscedasticity when sample sizes are equal. Where the tests indicated a significant treatment effect, two-tailed Tukey-Kramer multiple comparison tests were subsequently applied to distinguish differences among all-possible treatment pairs (α=0.05). All tests were performed using NCSS version 11 statistical software (NCSS 11 Statistical Software 2016).

Results and Discussion

As expected, the largest cells (Styro-20) produced the largest seedlings by every measure (figures 2 and 3). This result was unsurprising, since the Styro-20 cell volumes were more than double those of the other container types. Seedlings grown in the Styro-20 containers had mean shoot height 146 to 193 percent taller and mean RCD 32 to 45 percent larger than the three smaller stocktypes (figure 2). Accordingly, the Styro-20 produced seedlings with the largest mean shoot and root weights, with an average of 116 to 227 percent more total seedling weight than seedlings grown in the other three containers (figure 3).

Among the smaller containers, cell spacing density seemed to determine seedling morphologies more so than cell volume (figure 2 and 3). The Stubby-10 and the Styro-10 had the same cell density and produced seedlings with similar attributes, despite the fact that the latter's cell size was 31 percent greater in volume. In contrast, the RL-10, the most densely spaced of the four stocktypes, produced the smallest seedlings, even though its cell volume was identical to the Styro-10 and larger than the Stubby-10. Despite differences in shoot and root weights, the balance between those attributes was very similar among container types (figure 3).

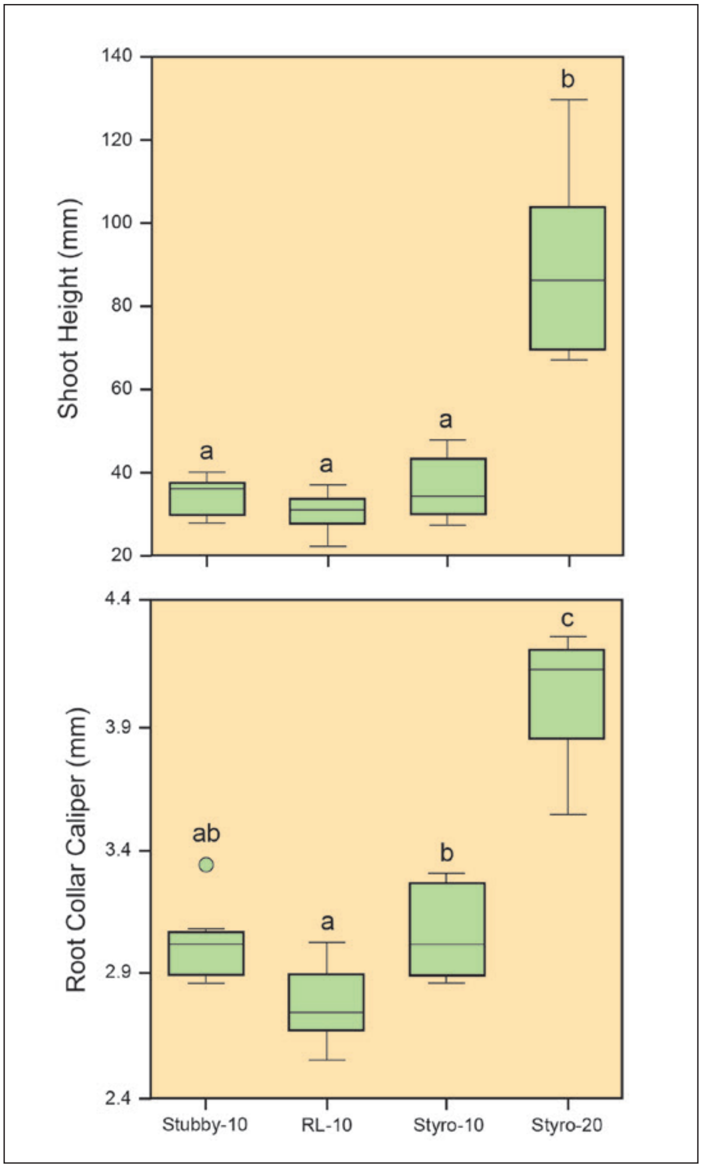


Figure 2. *Cercocarpus ledifolius* seedling shoot height and root collar diameter varied by stocktype. Letters denote statistically significant treatment differences. Bars within boxplots denote medians; box boundaries denote interquartile range (IQR); whiskers denote 1.5 times IQR.

The modest differences in root mass among the smallest three stocktypes do not adequately convey the substantial differences in root structure among containers, an observation that was revealed during the extraction of seedlings from cells (figure 4). All the Copperblock™ seedlings possessed fibrous, well-branched root systems with many fine roots that retained the root mass in a plug form with the growing medium attached. In contrast, the RL-10 seedlings possessed vertical roots with much less branching and lateral growth. When those plugs were extracted, the medium often fell away from the roots, leaving an exposed root mass. In practice, those seedlings could be vulnerable to desiccation and J-rooting during outplanting.

Although plant size is certainly important, size consistency and predictability of the seedling crop is also a matter of concern to propagators seeking to achieve a target seedling for consumers. The range of values for the Styro-20 seedlings was great for each measure, indicating a high degree of variability among the seedlings produced by that container (figure 2). In contrast, the Stubby-10, Styro-10, and RL-10 all produced smaller seedlings, but they were consistently similar.

Expressed on a volume-relativized basis, and assuming filled cells for all container types, our results indicate that the three Copperblock™ containers produce comparable amounts of biomass per unit volume of propagation medium (figure 5). The RL-10's performance was by far the worst of the four containers, at just 0.007 g of plant biomass per cm^3 of medium, a rate that was on average 37.3 percent less than the combined production rate of all three Copperblock™ containers. Because of the variability in plant morphology seen in the Styro-20 containers, its mean production (0.011 g/cm^3) was comparable to that of the Stubby-10 (0.011 g/cm^3) and the Styro-10 (0.010 g/cm^3), but its range of values was great; the highest recorded seedling biomass production rates per unit medium as well as some of the lowest production rates were measured in that container type.

Expressed on an area-relativized basis, the Styro-20 was a standout, producing a mean 775.3 g of plant biomass per square meter of bedspace, significantly greater (35.2 percent) than the smaller containers combined (figure 5). Among the three smaller containers, differences in mean production efficiency were nonsignificant. Apparently, the compact arrangement of the RL-10 cell trays compensated for their smaller seedlings and resulted in a mean production efficiency comparable to the Styro-10 and Stubby-10.

Seed use represents an additional efficiency metric, but we did not quantify the exact number of blank cells in the Copperblock™ containers nor the exact number of blank RL-10 cells that required replacement with substitutes. Thinning of duplicate germinants was required for about half of the Copperblock™ cells, so seed use efficiency was lower and thinning labor was greater for those containers compared with the trays of Ray Leach Cone-tainer™ cells. That cost, however, was likely offset by the additional growing medium and labor needed for filling, sowing, and growing the substitute seedlings needed to fill the RL-10 trays.

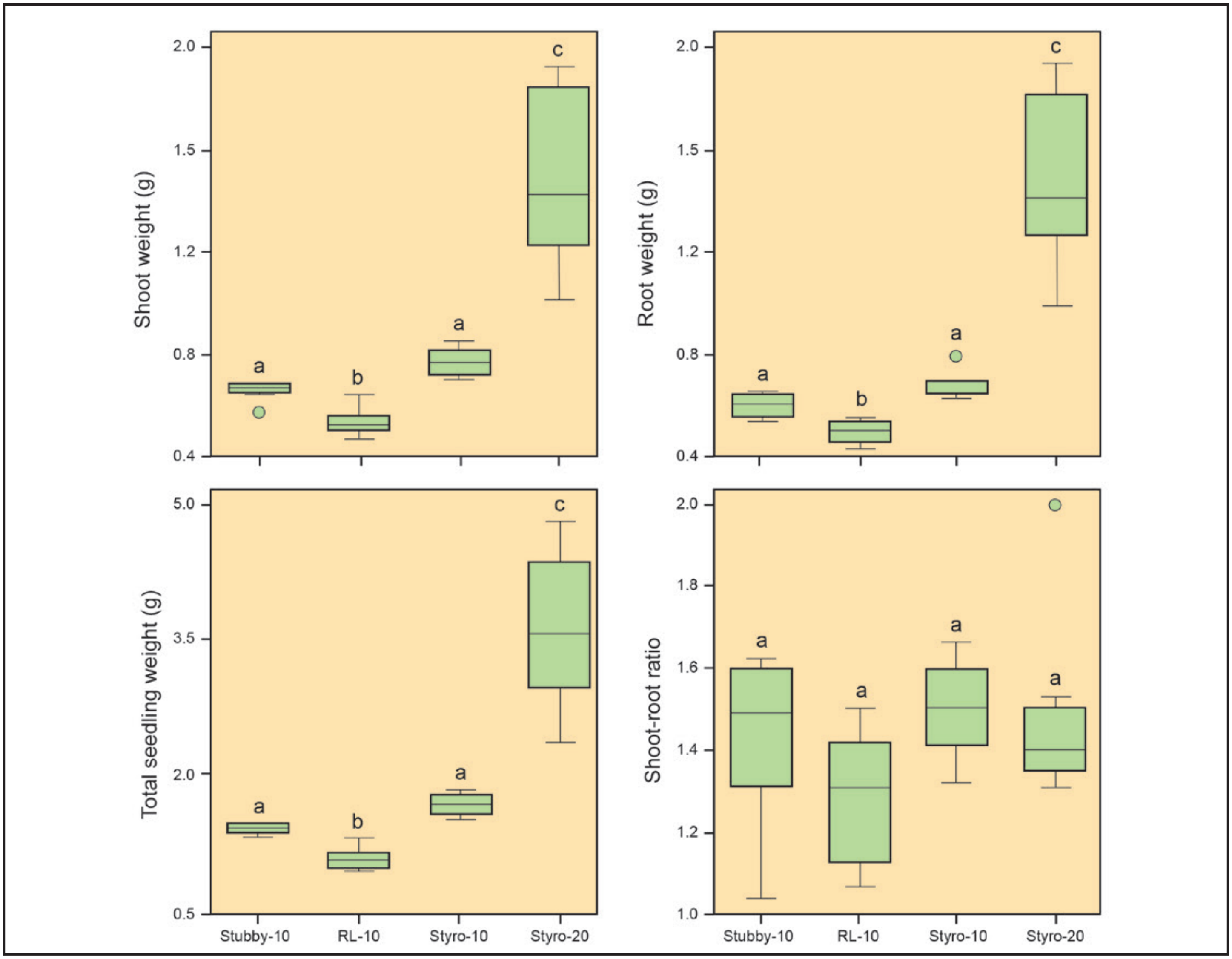


Figure 3. *Cercocarpus ledifolius* shoot weight, root weight, total seedling weight, and shoot-root ratio by stocktype. Letters denote statistically significant treatment differences. Bars within boxplots denote medians; box boundaries denote interquartile range (IQR); whiskers denote 1.5 times IQR.

Figure 4. Representative images of *Cercocarpus ledifolius* root mass structure for the RL-10 seedlings (left) and Styro-20 seedlings (right). (Photos by Christine Brissette, 2014)

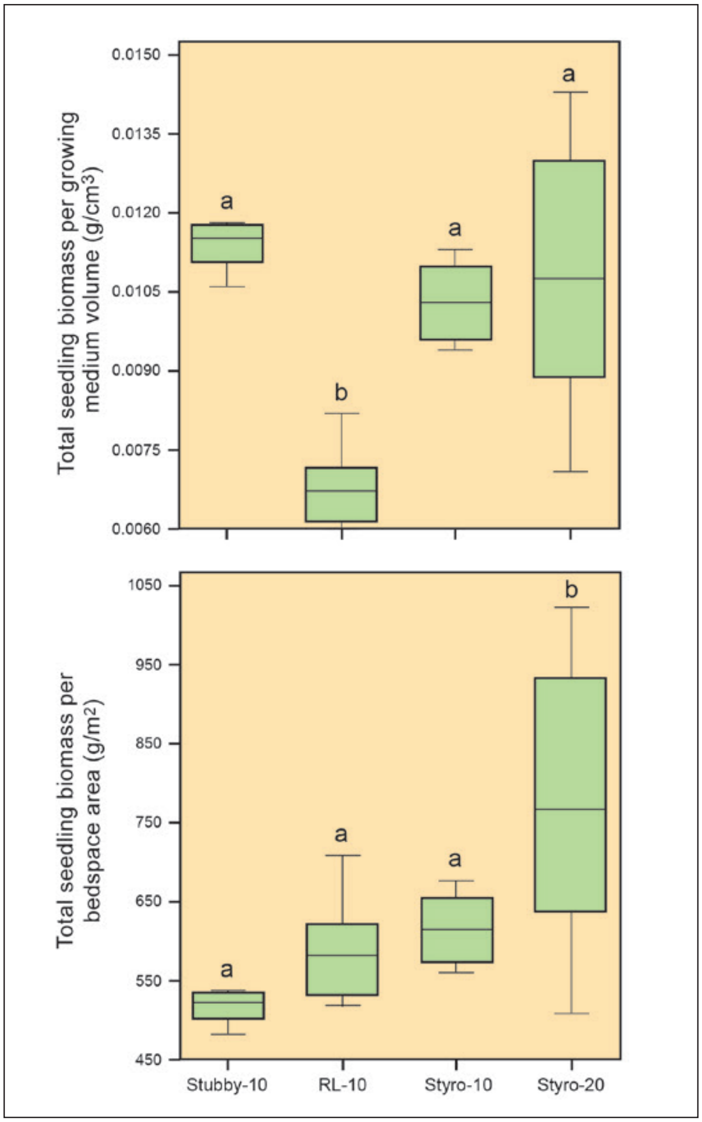


Figure 5. Nursery plant production efficiency of each container type was estimated by comparing *Cercocarpus ledifolius* total seedling biomass produced per unit volume of growing medium (g/cm^3) and per unit area of nursery bedspace (g/m^2). Letters denote statistically significant treatment differences. Bars within boxplots denote medians; box boundaries denote interquartile range (IQR); whiskers denote 1.5 times IQR.

Conclusions

Revegetation of dry, south-facing slopes is a significant challenge for restoration practitioners. *Cercocarpus ledifolius* offers promise as a pioneer species for these difficult sites, providing stability, cover, and nutrients. This experiment shows that seedling container type can significantly influence *C. ledifolius* seedling morphology and also vary in the biomass production efficiency as expressed per unit volume of growing medium and per unit bedspace area. Highlights of this study's findings are as follows:

- All cell types produced well-balanced seedlings (as judged by shoot-root ratio).
- Styro-20 produced the largest seedlings, but also produced the most variable crop with inconsistent seedling sizes.
- Despite its smaller volume, the Stubby-10 produced seedlings as large as or larger than the Styro-10 or RL-10.
- The RL-10 produced the smallest seedlings with least shoot weight and root weight; RCD and shoot height were also among the lowest.
- All Copperblocks produced similar levels of plant biomass per unit volume of growing medium; the efficiency of the RL-10 in this regard was very low relative to all three Copperblocks.
- The Styro-20 had the highest plant biomass production per unit bedspace area.

Although the RL-10 failed to outperform its competing alternatives in any regard, it did produce balanced seedlings in a consistently sized crop, and the versatility of the RL system (due to moveable cells within trays) may make it a worthy selection for those nurseries where *C. ledifolius* germination or survival has been a problem.

Monitoring the performance of outplanted seedlings from various containers such as those tested here is the next logical step in determining best practices for *C. ledifolius* production for restoration outplantings. Such an analysis could show whether our observed differences in seedling stocktypes translate to differential rates of seedling survival or early growth under field conditions.

Address correspondence to—

Christopher R. Keyes, Research Professor, W.A. College of Forestry and Conservation, University of Montana, Missoula, MT 59812; email: christopher.keyes@umontana.edu; phone: 406-243-5521.

Acknowledgments

This was a study of the Applied Forest Management Program at the University of Montana, a research and outreach unit of the Montana Forest and Conservation Experiment Station. Materials and space for the study were provided by the University of Montana's Experimental Seedling Nursery and by Vander Meer's Wildland Conservation Nursery,

LLC (Missoula, MT). This study was prompted by native plant restoration information gaps identified in collaboration with MPG Ranch, stewards of a conservation property in western Montana.

REFERENCES

Brown, M.B.; Forsythe, A.B. 1974. Robust tests for the equality of variances. Journal of the American Statistical Association. 69(346): 364–367.

Chirino, E.; Vilagrosa, A.; Hernández, E.I.; Matos, A.; Vallejo, V.R. 2008. Effects of a deep container on morpho-functional characteristics and root colonization in *Quercus suber* L. seedlings for reforestation in Mediterranean climate. Forest Ecology and Management. 256(4): 779–785.

Cregg, B.M. 1994. Carbon allocation, gas exchange, and needle morphology of *Pinus ponderosa* genotypes known to differ in growth and survival under imposed drought. Tree Physiology. 14(7-9): 883–898.

Dumroese, R.K.; Montville, M.E.; Pinto, J.R. 2015. Using container weights to determine irrigation needs: A simple method. Native Plants Journal. 16: 67–71.

D'Agostino, R.B.; Belander, A.; D'Agostino, Jr., R.B. 1990. A suggestion for using powerful and informative tests of normality. The American Statistician. 44(4): 316–321.

Davis, J.N.; Brotherson, J.D. 1991. Ecological relationships of curlleaf mountain-mahogany (*Cercocarpus ledifolius* Nutt.) communities in Utah and implications for management. The Great Basin Naturalist. 51(2): 153–166.

Dealy, J.E. 1975. Ecology of curlleaf mountain-mahogany (*Cercocarpus ledifolius* Nutt.) in eastern Oregon and adjacent areas. Corvallis, OR: Oregon State University. 162 p. PhD. dissertation.

Lepper, M.G.; Fleschner, M. 1977. Nitrogen fixation by *Cercocarpus ledifolius* (Rosaceae) in pioneer habitats. Oecologia. 27(4): 333–338.

Lloret, F.; Casanovas, C.; Peñuelas, J. 1999. Seedling survival of Mediterranean shrubland species in relation to root:shoot ratio, seed size and water and nitrogen use. Functional Ecology. 13(2): 210–216.

NCSS 11 Statistical Software. 2016. NCSS, LLC. Kaysville, UT. http://ncss.com/software/ncss. (October 2016).

NeSmith, D.S.; Duval, J.R. 1998. The effect of container size. HortTechnology. 8(4): 495–498.

Effects of Foliar Urea Fertilization on Nitrogen Concentrations of Containerized 2+0 Jack Pine Seedlings Produced in Forest Nurseries

Jean Gagnon and Josianne DeBlois

Forest Nursery Researcher, Ministère des Forêts, de la Faune et des Parcs (MFFP), Direction de la recherche forestière (DRF), Québec City, Québec, Canada; Statistician, MFFP, DRF, Québec City, Québec, Canada

Abstract

A 7-day study of urea foliar fertilization was performed during the growing season (July) of containerized 2+0 jack pine (*Pinus banksiana* Lamb.) to evaluate if an application of either urea (U) or urea with surfactant (US) can rapidly increase foliar nitrogen (N) concentration relative to no fertilization control (NF) treatments. Adding a surfactant to the urea solution significantly improved N concentration in needles, stems, and entire seedlings. At day 0 (2 hours after fertilization), foliar N concentration of US-fertilized seedlings was already significantly greater than that of seedlings in the U and NF treatments by 10 and 11 percent, respectively. After 7 days, foliar N concentration of US seedlings (2.03 percent) continued to be significantly greater than that of seedlings in the U and NF treatments (1.80 and 1.67 percent, respectively). These results show that foliar urea application, especially with addition of a surfactant, along the growing season is an effective tool to rapidly increase the foliar N concentration of jack pine seedlings.

Introduction

In 2015, 94 percent of the 133 million seedlings produced in Québec's (Canada) 19 forest nurseries were containerized seedlings and among them, 24.3 million (18 percent) were jack pine (*Pinus banksiana* Lamb.) seedlings (Arseneault 2015). In Québec nurseries, containerized conifer seedlings must not only meet morphological quality criteria (e.g., height, diameter, height/diameter), they must also have a minimum foliar nitrogen (N) concentration before delivery for outplanting: 1.6 percent for seedlings grown in cavities with volumes smaller than 200 cm^3 (12 in^3) and 1.8 percent for those produced in cavity volumes equal to or larger than 200 cm^3 (Veilleux et al. 2014). These seedlings are fertilized weekly during the season to satisfy their N, phosphorous (P), and potassium (K) requirements for growth by using the nutritional approach utilized in Québec nurseries (Langlois and Gagnon 1993). In complement to weekly NPK fertilizations in forest nurseries, foliar N fertilization of conifer seedlings grown in containers could be used during the growing season for rapidly increasing their foliar N concentration to the minimum N target. Foliar N applications can also be used to provide a quick "green-up" of seedlings before shipping to planting sites (Landis et al. 1989, Dumroese 2003).

Numerous foliar N fertilization studies have been conducted in agriculture and horticulture over the last 50 years (Handreck and Black 1984, Swietlik and Faust 1984, Alexander and Schroeder 1987, Gooding and Davies 1992, Wojcik 2004). In forest tree nurseries, however, only a few studies have been carried out with conifer seedlings grown in containers (Coker et al. 1987, Montville and Wenny 1990, Coker 1991, Montville et al. 1996, Gagnon 2011, Gagnon and DeBlois 2014). This lack of research may be explained by the small absorptive surface of conifer needles in comparison with hardwood leaves and by the waxy cuticular surface of needles, which slows nutrient absorption (Landis et al. 1989, 2010; Marschner 1995, Mengel and Kirkby 2001, Lamhamedi et al. 2003).

In order to ensure nutrient diffusion across the cuticle, a surfactant is often used with foliar fertilization because the hydropobic nature of the cuticle impedes the diffusion of hydrophylic ions (Mengel and Kirkby 2001). By reducing the surface tension of water droplets, the surfactant permits a thin layer to adhere to the needle surface, thus improving nutrient absorption (Wittwer and Teubner 1959, Wittwer et al. 1963, Landis et al. 1989, Mengel and Kirkby 2001, Wojcik 2004).

In studies of foliar N fertilization conducted in agriculture and horticulture since the 1960s (Wittwer et al. 1963, Handreck and Black 1984, Swietlik and Faust 1984, Alexander and Schroeder 1987, Gooding and Davies 1992, Mengel and Kirkby 2001, Wojcik 2004), urea [$CO(NH_2)_2$]) was much more utilized than ammonium (NH_4^+) or nitrate (NO_3^-) due to its high solubility in water and oil, low-phytotoxicity potential, and nonpolarity relative to the other two N sources. Indeed, being a neutral molecule, urea is absorbed more quickly by needles than either NH_4^+ or NO_3^- because it rapidly diffuses through the waxy cuticule. Coker et al. (1987) showed that after a foliar application of these three N sources on containerized Monterey pine (*Pinus radiata* D. Don.), urea was absorbed 3 and 10 times more rapidly than NH_4^+ and NO_3^-, respectively. Urea was used with success to rapidly increase (7 days) foliar N concentration of containerized 2+0 black spruce (*Picea mariana* [Mill.] B.S.P.) after fall budset (Gagnon and DeBlois 2014).

The objectives of this study were to evaluate: (1) the effects of one foliar application of urea during the growing season on N concentration in needles of containerized 2+0 jack pine seedlings, and (2) the impact of adding a surfactant to the urea solution on the efficiency of urea foliar fertilization.

Materials and Methods

Seedlings

Large 2+0 jack pine seedlings (seedlot: PIG-V1-PAR-2-2) grown in 25-310 containers (25 cavities with a volume of 310 cm^3 [19 in^3] each, IPL 25-310, Saint-Damien, Québec, Canada) were used for this study. Seedlings were produced at Normandin nursery, a governmental forest nursery (ministère des Forêts, de la Faune et des Parcs, MFFP du Québec) located in the Saguenay-Lac St. Jean region of Québec (48°48'48" N, 72°45'00" W), Canada. Cultural practices of containerized 1+0 and 2+0 seedlings grown in Quebec forest nurseries are summarized in Gagnon and DeBlois (2014).

Seedlings were fertilized biweekly from May 8 to October 2 according to the seedlings' weekly nutritional needs (Langlois and Gagnon 1993) determined by Plantec 2 software, a new version of PLANTEC (Girard et al. 2001). Fertilization totalled 170 mg (0.0057 oz) N (40 percent NH_4^+, 42 percent NO_3^-, and 18 percent urea), 17 mg (0.0006 oz) P, and 37 mg (0.0012 oz) K. The seedlings also received small amounts of calcium and magnesium as well as micronutrients present in commercial soluble fertilizers. No fertilizer was applied between June 22 and the foliar fertilization treatments of July 7. Irrigation was managed using IRREC irrigation software (Girard et al. 2011).

Foliar Fertilization Treatments

A completely randomized block design with three treatments of foliar urea fertilization and eight blocks was installed on July 6, 2015. A total of 432 containers (54 per block x 8 blocks) received 1 of the 3 treatments of foliar urea (46-0-0) fertilization on day 0 (July 7): (1) urea (U), (2) urea + surfactant (US), or (3) no fertilization (NF: control).

For each urea treatment, 4.1 kg (9.1 lb) of 46-0-0 was mixed in 55 L (14.6 gal) of water, producing a solution with a concentration of 74.3 g urea per L [0.6 lb per gal]. For the US treatment, the surfactant used was Sylgard 309 (Norac Concepts Inc. 2009, Guelph, Ontario, Canada). This nonionic, silicon surfactant was mixed with the urea solution at a rate of 2.5 ml per L (0.28 oz per gal). Because the addition of Sylgard 309 to urea solution leads to foam formation, Fighter-F® 12.5 antifoaming/defoaming agent (Loveland Products, Inc., Greeley, CO) was added at a rate of 15 ml (0.51 oz) to the 55-L (14.6-gal) mix of urea and surfactant.

The U and US treatments were applied at a rate of 937 L per ha (102 gal per ac) using a tractor-mounted boom sprayer (Model 695 XL, Case International Inc., Vars, Ontario, Canada) with a 1100-L (292-gal) reservoir and 2 rails of 12-nozzle irrigation (Model Teejet XR 11004, TeeJet Technologies, Spraying Systems Co., Wheaton, IL) (figure 1). This application rate resulted in application of 15 mg (0.0005 oz) N per seedling or 31 kg N per ha (28 lb per ac), corresponding to a dose of 33 mg (0.0011 oz) urea per seedling or 68 kg per ha [60 lb per ac].

At the time of fertilization (9 h), air temperature was 24 ºC (75 ºF) and relative humidity was 48 percent. No irrigation to rinse the foliage was applied either following foliar urea fertilization or during the 7-day study.

Figure 1. Foliar fertilization treatments with a urea solution were applied using tractor-mounted booms to 2+0 jack pine seedlings grown in 25-310 containers at Normandin nursery. (Photo by Jean Gagnon, 2015)

Seedling and Substrate Measurements

Immediately after application of the fertilization treatments (day 0: July 7) and at day 7 (July 14), a total of 72 seedlings per treatment and their root plugs (9 seedlings randomly selected in each of the 8 blocks) was harvested to assess seedling morphology (height, root-collar diameter, shoot, root, and total dry mass), total N concentration (Ntot) in tissues, and mineral N and urea concentrations in the substrate. Tissue and substrate analyses were performed by the laboratoire de chimie organique et inorganique (ISO/CEI 17025) de la Direction de la recherche forestière [DRF], MFFP du Québec. Additionally, foliar color and burning damage were assessed visually during the 7-day study.

Before the analysis of total N concentration (Ntot), seedling shoots of 3 treatments were washed for 15 seconds using a sink-mounted vegetable sprayer to remove urea residues from the needle surface. After washing, shoot and root tissues of all treatments were oven-dried for 48 hr at 65 °C (149 °F). Seedling tissues were placed in the oven 2 hours (day 0) or 7 days (day 7) after foliar urea fertilization. Seedling needle, stem, and root samples (n = 8 composite samples of 3 seedlings per block per treatment) were analyzed for Ntot using a LECO Nitrogen Determinator (model TruMac N, LECO Corporation, St. Joseph, MI). Substrate N was extracted by vacuum filtration (Whatman filters # 4) after saturating in water for 90 minutes. Urea was determined by liquid chromatography (HPLC Agilent-1200 chromatograph with diode array detector) using a Sugar-Pak I column from Waters. Mineral N (ammonium, nitrate + nitrite) was determined by colorimetry with a continuous flow spectrophotometer (model QuickChem 8000, Lachat Instruments, Milwaukee, WI).

Statistical Analyses

First, a linear mixed-effects model with repeated measurements was carried out to determine the effects, over time, of three foliar urea fertilization treatments using a variance-covariance matrix to account for the correlation between measurements done on the same experimental units. This matrix was chosen to minimize the likelihood value of the model while using as few parameters as possible. Thus, for N concentrations in needles, stems, shoots, and seedlings, the selected variance-covariance matrix was compound symmetry, whereas it was heterogeneous compound symmetry for N concentrations in roots.

Fertilization treatments, sampling days, and their interaction were introduced in the model as fixed-effect factors, whereas the replicates of fertilization treatments were considered as a random-effect factors. Because the interaction between the fertilization treatments and sampling days was significant for all variables, comparisons between the fertilization treatments were performed for each date.

All the statistical analyses were performed using the MIXED procedure of SAS (version 9.4, SAS Institute, Cary, NC, United States). When required, a simulation-based approach taking account of multiplicity was used to assess differences (Westfall et al. 1999). Normality of the residuals was confirmed using the Shapiro-Wilk's statistic and homogeneity of variance was validated using standard graphical methods. Differences were deemed significant when $\alpha < 0.05$.

Results

Seedling morphology (± standard error: SE) averaged among all treatments at day 7 was: height, 21.2 ± 0.8 cm (8.5 in); diameter, 3.1 ± 0.1 mm (0.1 in), shoot dry mass, 2.02 ± 0.09 g (0.07 oz); root dry mass, 0.71 ± 0.04 g (0.02 oz); and total dry mass, 2.73 ± 0.13 g (0.09 oz). The average substrate N concentration after 7 days was 0.8 ppm mineral N and 0.1 ppm urea-N.

For foliar N concentration, the interaction between fertilization treatments and days was significant (p = 0.0391). At day 0 (2 hours after fertilization) and day 7, foliar N concentration of US-fertilized jack pine seedlings was significantly greater than that of seedlings in the U and NF treatments (figure 2a). Foliar N concentration of US seedlings was 10 and 11 percent higher than U and NF seedlings after only 2 hours (day 0), respectively. After 7 days, foliar N concentration in US-fertilized seedlings continued to be significantly greater than that of seedlings in the U and NF treatments (figure 2a). Foliar N concentrations of U and US seedlings at day 7 were 8 and 22 percent, respectively, higher than that of NF seedlings (figure 2a). During the 7-day study, no burning damage from U or US treatments was observed.

The interaction between fertilization treatments and days was also significant for N concentrations in stems (p = 0.0391), roots (p = 0.0321), and whole seedlings (p = 0.0218) (figure 2). At day 0, stem (figure 2b) and

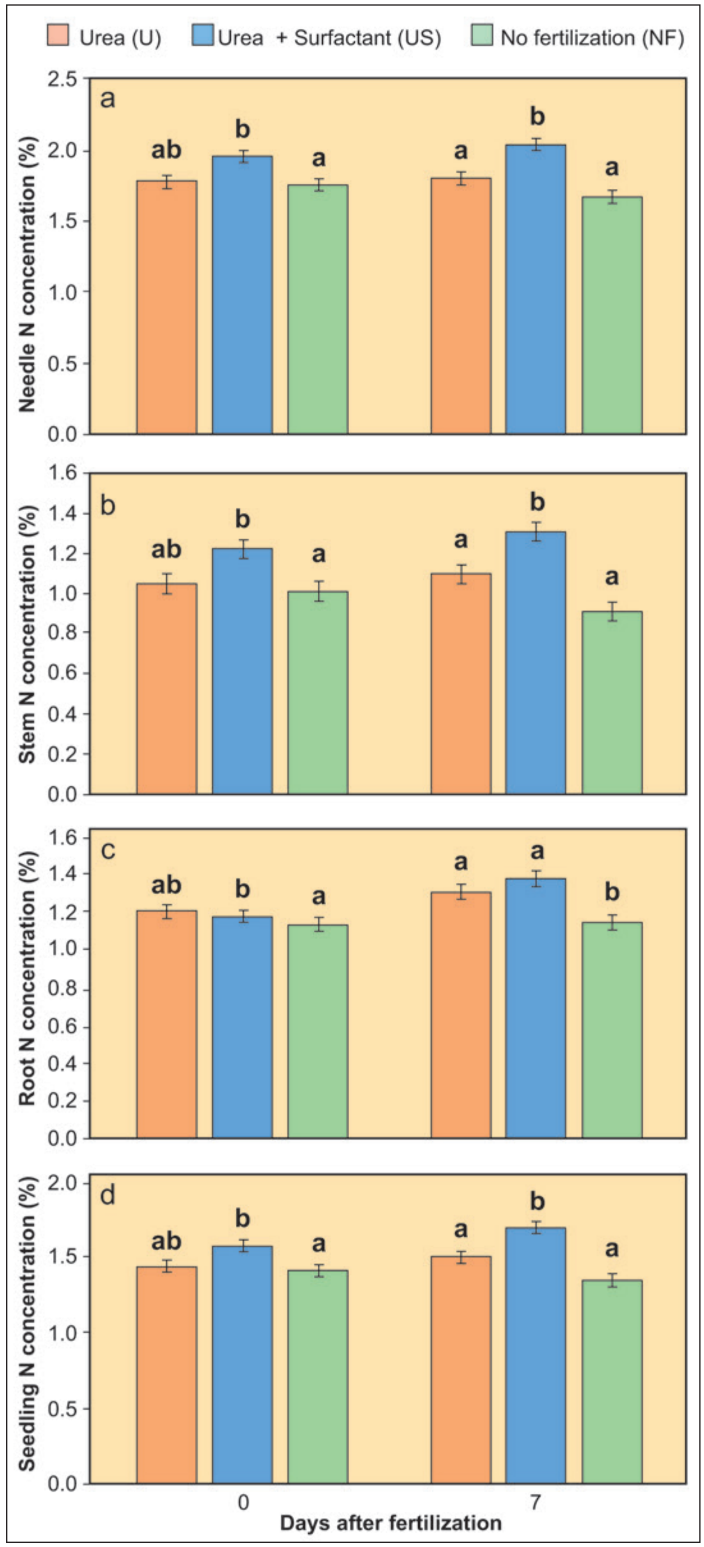


Figure 2. (a) Needle, (b) stem, (c) root, and (d) whole-seedling nitrogen concentration (percent) of 2+0 containerized jack pine seedlings 0 and 7 days after urea foliar fertilization. For each day, bars with different letters differ significantly at $\alpha \leq 0.05$ (n = 8 composites samples ± SE).

seedling (figure 2d) N concentrations of US seedlings were significantly higher compared with those in the NF treatment. After 7 days, stem and seedling N concentrations of US-treated seedlings were significantly greater than that of both U and NF treatments. At day 7, compared to NF seedlings, stem N concentration of U and US seedlings was 21 and 44 percent higher, respectively, and seedling N concentration was 12 and 26 percent higher, respectively (figures 2b and 2d). At day 0, root N concentration did not differ significantly among the 3 fertilization treatments (figure 2c). After 7 days, root N concentration of U seedlings was not significantly different than that of US seedlings, but these 2 treatments (U, US) were significantly greater than NF treatment.

Discussion

This 7-day study showed that foliar fertilization with a urea and surfactant mixture during the growing season of containerized 2+0 jack pine seedlings resulted in a significant increase in foliar, stem, and seedling N concentration under forest nursery conditions, compared with control seedlings and those fertilized without the surfactant. This rapid increase of foliar N concentration observed after only 2 hours (day 0) led also to a rapid increase of N concentration in stem and the whole seedling, indicating that the foliar N increase is a result of uptake, not by urea residues on the needle surfaces. To prevent this possibility, seedling shoots were washed before the analysis of N. Our previous 7-day study of foliar urea fertilization of black spruce seedlings showed that washing treatments significantly reduced foliar N concentration compared with those that were not washed (Gagnon and DeBlois 2014). We always recommend washing seedling shoots prior to nutrient analyses to remove fertilizer residues.

Rapid urea absorption and increased N concentration after foliar fertilization was also found in our previous experiment with containerized 2+0 black spruce seedlings (Gagnon and DeBlois 2014). Similarly, in studies with Monterey pine seedlings (Coker et al. 1987, Coker 1991) or apple (*Malus domestica* Borkh) trees (Dong et al. 2002), all or most foliar-applied ^{15}N urea was taken up within 6 hours or 2 days, respectively. A rapid increase of foliar N concentration after foliar urea fertilization has also been observed in agriculture and horticulture studies (Handreck and Black 1984, Swietlik and Faust 1984, Alexander and Schroeder 1987, Gooding and Davies 1992, Wojcik 2004).

According to Mengel and Kirkby (2001), the recommended concentration of urea solution for foliar fertilization to avoid leaf burning is 20 to 50 g per L (0.2 to 0.4 lb per gal). In the present study and a previous one with black spruce seedlings (Gagnon 2011), we did not observe any burning damage with urea solution concentrations of 74 g per L (0.6 lb per gal) and 80 g per L (0.7 lb per gal), respectively. Likewise, no foliar damage was observed on black spruce seedlings with a much higher concentration of urea solution of 146 g per L (1.2 lb per gal) (Gagnon and DeBlois 2014).

The efficiency of foliar urea fertilization is often improved by using surfactants (Swietlik and Faust 1984, Alexander and Schroeder 1987, Gooding and Davies 1992, Wojcik 2004). In our previous 7-day study with containerized 2+0 black spruce seedlings (Gagnon and DeBlois 2014), adding a surfactant (Agral 90) to the urea solution did not significantly increase foliar N concentration. In the present experiment, however, adding a surfactant (Sylgard 309) to the urea fertilizer significantly improved N concentration of containerized 2+0 jack pine seedlings.

In Québec forest nurseries, containerized conifer seedlings receive weekly NPK fertilizers during the season to satisfy their growth needs and to meet their minimum N targets. Growers try to produce seedlings that meet adequate foliar N concentrations throughout the growing season so that there is no need for a last-minute rapid increase. But, if the target is not reached due to varying circumstances (rapid growth, incorrect estimates of nutrient status/needs, rainfall causing N leaching, etc.), foliar urea fertilization in addition to the weekly NPK fertilizers would then be useful to increase foliar N concentration to the minimum target. The results of this 7-day study showed that foliar urea fertilization is a potential tool for rapidly increasing the foliar N concentration of containerized conifer seedlings to help Québec growers meet the physiological quality criteria of 1.8 percent N concentration for large conifer seedlings.

Address correspondence to—

Jean Gagnon, Ministère des Forêts, de la Faune et des Parcs, Direction de la recherche forestière, 2700, rue Einstein, Québec City, Québec, Canada G1P 3W8; e-mail: jean.gagnon@mffp.gouv.qc.ca; phone: 418–643–7994 (ext. 6566).

Acknowledgments

The authors thank Michelle Simard of Normandin nursery for her technical assistance in this study and the staff of the nursery for their collaboration in seedling measurements. They acknowledge the staff of the laboratoire de chimie organique et inorganique (ISO/CEI 17025) de la Direction de la recherche forestière (DRF) of the Ministère des Forêts, de la Faune et des Parcs (MFFP) who performed analyses of tissue and substrate. They also thank Michel Campagna (DRF) for the revision of this article. They acknowledge Maripierre Jalbert (DRF) for the final edition of the figures. The authors thank Diane Haase (editor of Tree Planters' Notes) for her suggestions and editorial comments. Financial support for this research project was provided to Jean Gagnon by the MFFP (project: 142332084).

REFERENCES

Alexander, A.; Schroeder, M. 1987. Modern trends in foliar fertilization. Journal of Plant Nutrition. 9(16): 1391–1399.

Arseneault, J. 2015. Personal communication regarding the number and species of containerized and bareroot seedlings produced in 2015 in forest tree nurseries of Québec. Forest Technician, Ministère des Forêts, de la Faune et des Parcs (MFFP), Direction générale de la production de semences et de plants forestiers (DGPSPF), Québec City, Québec, Canada.

Coker, A. 1991. [^{15}N] urea foliar application effect on allocation of overwinter reserves for *Pinus radiata* seedling growth. Canadian Journal of Forest Research. 21(7): 947–956.

Coker, A.; Court, D.; Silvester, W.B. 1987. Evaluation of foliar urea applications in the presence and absence of surfactant on the nitrogen requirements of conditioned *Pinus radiata* seedlings. New Zealand Journal of Forest Science. 17(1): 51–66.

Dong, S.; Cheng, L.; Scagel, C.F.; Fuchigami, L.H. 2002. Nitrogen absorption, translocation and distribution from urea applied in autumn to leaves of young potted apple (*Malus domestica*) trees. Tree Physiology. 22(18): 1305–1310.

Dumroese, R.K. 2003. Hardening fertilization and nutrient loading of conifer seedlings. In: Riley, L.E.; Dumroese, R.K.; Landis, T.D.; tech. coords. National proceedings, forest and conservation nursery associations—2002. Proc. RMRS-P-28: Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station: 31–36.

Gagnon, J. 2011. Évaluation de l'efficacité de la fertilisation foliaire d'urée sur la concentration foliaire en azote des plants d'épinette noire en récipients 2+0. In: Colas, F.; Lamhamedi, M.S., eds. Production de plants forestiers au Québec: la culture de l'innovation. October 4–6, 2011. Québec City, Québec, Canada: Carrefour Forêt Innovations: 97–106.

Gagnon, J.; DeBlois, J. 2014. Effects of foliar urea fertilization on nitrogen status of containerized 2+0 black spruce seedlings produced in forest nurseries. Tree Planters' Notes 57(2): 53-61.

Girard, D.; Gagnon, J.; Lamhamedi, M. 2011. IRREC: Un système informatisé de calcul des besoins en irrigation pour les plants en récipients produits dans les pépinières forestières du Québec. Mémoire de recherche forestière no 162, Sainte-Foy, Québec, Canada: Ministère des Ressources naturelles, Direction de la recherche forestière. 54 p.

Girard, D.; Gagnon, J.; Langlois, C.G. 2001. PLANTEC: un logiciel pour gérer la fertilisation des plants dans les pépinières forestières. Note de recherche forestière no 111, Sainte-Foy, Québec, Canada: Ministère des Ressources naturelles, Direction de la recherche forestière. 8 p.

Gooding, M.J.; Davies, W.P. 1992. Foliar urea fertilization of cereals: a review. Fertilizer Research. 32(2): 209–222.

Handreck, K.A.; Black, N.D. 1984. Growing media for ornamental plants and turf. Kensington, Australia: New South Wales University Press. 401 p.

Lamhamedi, M.S.; Chamberland, H.; Tremblay, F.M. 2003. Epidermal transpiration, ultrastructural characteristics and net photosynthesis of white spruce somatic seedlings in response to *in vitro* acclimatization. Physiologia Plantarum. 118(4): 554–561.

Landis, T.D.; Dumroese, R.K.; Haase, D.L. 2010. The container tree nursery manual. Vol. 7. Seedling processing, storage, and outplanting. Agriculture Handbook 674. Washington, DC: U.S. Department of Agriculture. 200 p.

Landis, T.D.; Tinus, R.W.; Barnett, J.P. 1989. The container tree nursery manual. Vol. 4. Seedling nutrition and irrigation. Agriculture Handbook 674. Washington, DC: U.S. Department of Agriculture. 119 p.

Langlois, C.G.; Gagnon, J. 1993. A global approach to mineral nutrition based on the growth needs of seedlings produced in forest tree nurseries. In: Barrow, N.J., ed. Plant nutrition: from genetic engineering to field practice. Dordrecht, The Netherlands: Kluwer Academic Publishers: 303–306.

Marschner, H. 1995. Uptake and release of mineral elements by leaves and other aerial plant. In: Marschner, H., ed. Mineral nutrition of higher plants. 2nd ed. London, Great Britain: Academic Press: 116–130.

Mengel, K.; Kirkby, E.A. 2001. Principles of plant nutrition. Dordrecht, The Netherlands: Kluwer Academic Publishers. 849 p.

Montville, M.E.; Wenny, D.L. 1990. Application of foliar fertilizer during bud initiation treatments to container-grown conifer seedlings. In: Rose, R.; Campbell, S.J.; Landis, T.D., eds. Proceedings, Western Forest Nursery Association—1990. Gen. Tech. Rep. RM-200. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station: 233–239.

Montville, M.E.; Wenny, D.L.; Dumroese, R.K. 1996. Foliar fertilization during bud initiation improves container-grown ponderosa pine seedling viability. Western Journal of Applied Forestry. 11(4): 114–119.

Swietlik, D.; Faust, M. 1984. Foliar nutrition of fruit crops. Horticultural Reviews. 6: 287–355.

Veilleux, P.; Allard, J.Y.; Bart, F. [and others]. 2014. Inventaire de qualification des plants résineux cultivés en récipients. Guide terrain. Québec City, Québec, Canada: Ministère des Ressources naturelles du Québec, Direction générale de la production de semences et de plants forestiers. 141 p.

Westfall, P.H.; Tobias, R.D.; Rom, D. [and others]. 1999. Multiple comparisons and multiple tests using the SAS® system. Cary, NC: SAS Institute, Inc. 416 p.

Wittwer, S.H.; Bukovac, M.J.; Tukey, H.B. 1963. Advances in foliar feeding of plant nutrients. In: McVickar, M.H.; Bridger, G.L.; Nelson, L.B., eds. Fertilizer technology and usage. Madison, WI: American Society of Agronomy: 429–455.

Wittwer, S.H.; Teubner, F.G. 1959. Foliar absorption of mineral nutrients. Annual Review of Plant Physiology. 10: 13–32.

Wojcik, P. 2004. Uptake of mineral nutrients from foliar fertilization. Journal of Fruit and Ornamental Plant Research. (Special edition) 12: 201–218.