Nutrient dynamics of planted forests

Article *in* New Forests · September 2013

DOI: 10.1007/s11056-013-9383-7

2 authors:

Diane L. Haase
US Forest Service
59 PUBLICATIONS **853** CITATIONS
SEE PROFILE

Douglass F Jacobs
Purdue University
203 PUBLICATIONS **3,143** CITATIONS
SEE PROFILE

New Forests (2013) 44:629–633
DOI 10.1007/s11056-013-9383-7

INTRODUCTION

Nutrient dynamics of planted forests

Diane L. Haase · Douglass F. Jacobs

Published online: 10 August 2013

Introduction

Nutrition is recognized as a primary limiting factor affecting growth and vigor of seedlings and juvenile trees in plantations (Fox 2000; Smethurst 2010). Thus, nursery growers and field foresters have been providing supplemental nutrition as part of cultural practices for at least a century (Toumey 1916; Tillotson 1917; Show 1930; Haase 2010). Early nursery fertilization consisted of simple applications with water slurries of animal manure (Landis and Davey 2009). Over the decades, experimental trials led to an increased understanding of soil physical and chemical properties as well as species-specific nutritional requirements during various growth phases. As a result, guidelines and recommendations for amending soils in the nursery and the field to achieve maximal growth under specific soil conditions were established (Barnes and Bengtson 1968; Miller 1981; Landis et al. 1989; van den Driessche 1991). Additionally, the development and manufacture of inorganic chemical fertilizers and other products as well as the ability to transport materials over greater distances provided nursery growers and field foresters with more options for addressing mineral nutrient demands of young trees. Although countless research studies have led to technical articles and published texts about plant nutrition and its application to forest tree species, forestry and nursery policies, objectives, and environments are continually evolving. This necessitates corresponding changes in management practices, such as those necessary to provide optimum nutrition to seedlings and juvenile trees. Even with the large body of existing research, much more needs to be understood with regards to plant morphological and physiological responses to nutrient supplies under myriad site conditions, along with refinements to fertilizer rates, formulations, application timing, and management objectives.

D. L. Haase
USDA Forest Service, Portland, OR 97208, USA

D. F. Jacobs (✉)
Department of Forestry and Natural Resources, Hardwood Tree Improvement and Regeneration Center, Purdue University, West Lafayette, IN 47907-2061, USA
e-mail: djacobs@purdue.edu

Background and purpose of the congress

In 1997, a conference entitled "Forest Seedling Nutrition from the Nursery to the Field" was held in Corvallis, OR, USA (Haase and Rose 1997). The conference consisted of four sessions: (1) Principles of Seedling Nutrition and Fertilizer Technology, (2) Seedling Nutrition in the Nursery, (3) Monitoring Seedling Nutrition, and (4) Seedling Nutrition in the Field. Speakers represented some of the top experts in the field and more than 175 participants attended the conference.

Since the 1997 symposium many changes have occurred in the area of Forest Nutrient Dynamics, including refinements in fertilizer technology, advances in nursery stock quality, and increasing expectations for juvenile plantation productivity. For example, exponential nutrient loading was introduced as a method to induce luxury nutrient consumption during the nursery phase, leading to improved outplanting performance (Timmer 1997). Additionally, controlled-release fertilizer (CRF) is increasingly used as an alternative to soluble fertilizer in forest tree nurseries (Donald 1991; Haase et al. 2006) and at time of outplanting (Jacobs et al. 2005). Improved understanding of site-specific management needs (Fox 2000) has allowed for the development of informed fertilization prescriptions that help to maintain long-term site productivity in intensively managed plantations. Finally, an increasing emphasis on restoration plantings during the past decades has presented new challenges in the field of nursery fertilization that must be overcome in order to ensure survival and site rehabilitation (Oliet and Jacobs 2012).

Thus, we organized another event 15 years later to help communicate these advances and provide a forum to identify future research needs and priorities in this field. The symposium was organized by the USDA Forest Service, Purdue University, and the Western Forestry and Conservation Association and was held November 27–28, 2012 in Vancouver, Washington, USA. Three divisions within the International Union of Forest Research Organizations (IUFRO) supported the symposium: 1.01.03 (Temperate Forest Regeneration), 1.06.00 (Restoration of Degraded Sites), and 3.02.00 (Stand Establishment and Treatment).

The 2012 Symposium consisted of 24 speakers covering a broad range of topics divided into two sessions: (1) Nutrition in the Nursery and at Field Establishment, and (2) Juvenile Stand Nutrition. The program was aimed toward an international audience of nursery and forest practitioners, scientists, and educators and received excellent worldwide response by attracting speakers and attendees from 12 countries. This symposium emphasized the development of effective and environmentally sound technologies to optimize seedling quality and benefit reforestation and forest restoration operations. Of particular interest was the variability in nutritional requirements and fertilizer responses of forest trees across a range of site limiting factors (e.g., drought, vegetative competition, or animal browse).

Brief summary of special issue content

A total of 11 original research or review articles covering a wide range of diverse issues in forest nutrient dynamics are included in this Special Issue. Below is a brief overview of each.

Nutrition in the nursery and at field establishment (8 papers)

Simon Landhäusser (University of Alberta, Canada) described accumulation of carbon and nutrient reserves of aspen (*Populus tremuloides* Michx.) seedlings, which are characterized

by indeterminate growth, as affected by exponential fertilization and premature shoot growth termination (Schott et al. 2013). While exponential fertilization resulted in relatively poor stock quality, using paclobutarzol to induce early shoot growth termination helped to promote nutrient uptake and enhance tissue nutrient and carbon concentrations. Juan Oliet (Polytechnic University of Madrid, Spain), presented an overview of the role of nursery nutrient loading in conferring stress resistance for seedlings planted in Mediterranean semi-arid climates (Oliet et al. 2013). Nutrient loading was deemed an important tool to help improve survival in Mediterranean areas due to its promotion of root growth, frost resistance, and drought tolerance; the need for improved application regimes for exponential fertilization in this region was identified. Johanna Riikonen (Finnish Forest Research Institute) described a study to evaluate the effects of boron fertilization in the nursery and at the time of outplanting on the subsequent growth and survival of Norway spruce [*Picea abies* (L.) Karst.] seedlings planted on boron-poor sites (Riikonen et al. 2013). Application of boron in the field had longer-lasting effects on seedling boron status than did fertilization in the nursery. Joshua Sloan (Purdue University, Indiana, USA) presented results of a study examining use of polymer-coated CRF on white spruce [*Picea glauca* (Moench) Voss] and aspen tree seedlings planted for mineland reclamation in Alberta, Canada (Sloan and Jacobs 2013). Compared to traditional broadcast fertilization with immediately available fertilizer forms, CRF resulted in less vegetative competition and equal or better seedling growth at 90–95 % lower N application rates. Shucai Zeng (South China Agricultural University) presented results from a study to assess the importance of split fertilizer applications on growth and fertilizer uptake efficiency of hybrid eucalyptus, finding that this method enhanced nutrient uptake and growth versus single-time applications (Zeng et al. 2013). Jordi Cortina (University of Alicante, Spain) discussed the influence of seedling size and nutrient status on subsequent field performance in dry lands, hypothesizing that while well-fertilized, large seedlings thrive best on less stressful sites, nutrient limited small seedlings may be best adapted to the driest, harshest sites (Cortina et al. 2013). Pedro Villar-Salvador (University of Alcalá, Spain) discussed nursery fertilization strategies for oaks to improve seedling quality and field performance (Villar-Salvador et al. 2013). Nursery fertilization regimes producing large, N-rich seedlings were deemed important for improving oak plantation establishment success, especially under harsh field conditions—contradicting somewhat the results of Cortina et al. (2013) and contributing to the debate on this complex issue. Owen Burney (New Mexico State University, USA) examined the effects of seedling fertilization on foliar chemistry and corresponding changes in susceptibility to ungulate herbivory for species in boreal and temperate biomes (Burney and Jacobs 2013). While many past studies have found increased incidence of browsing on fertilized sites, these studies were somewhat confounded by use of broadcast fertilizer applications that also stimulated weed growth. Results from recent studies where fertilizer was applied directly to target crop trees (e.g., Taylor et al. 2006; Burney and Jacobs 2011) found that effects vary somewhat by species, which could be attributed to allocation of resources to secondary metabolites that deter browsing.

Juvenile stand nutrition (3 papers)

Cindy Prescott (University of British Columbia, Canada) described results of a long-term project examining cedar and hemlock plantation responses to repeated fertilization in coastal British Columbia (Prescott et al. 2013). Interestingly, the greatest volume responses to fertilization occurred on higher-quality hemlock-fir sites rather than on nutrient-poor

cedar-hemlock stands. John Turner (Forsci Pty Ltd, New South Wales, Australia) evaluated productivity and nutrition among radiata pine (*Pinus radiata* D. Don) plantations at varying sites in Australia, finding that differences in productivity among rotations were related primarily to changes in soil nutrient status and management (Turner and Lambert 2013). Craig Farnden (University of British Columbia, Canada) presented results of a study examining variations in height growth of jack pine (*Pinus banksiana* Lamb.) on reclaimed tailings following oil sands mining as related to site nutritional status (Farnden et al. 2013). A strong relationship was detected between tree height and organic matter content, representing mainly mesic peat mixed with capping materials.

Conclusions

During the past 15 years, an enhanced understanding of plant nutritional requirements and functional responses to nutrition, improved analytical methods of analysis, and advances in fertilizer technologies have promoted forest plantation establishment success and development of young stands. Knowledge of all of these factors must, however, continue to be expanded to further enhance productivity and sustainability of commercial forestry plantations. Forest restoration represents a very different context where nutrition may be key for survival on harsh sites and use of an increasingly diverse pool of species necessitates case-specific prescriptions (Oliet and Jacobs 2012). In addition to publishing selected papers in this special issue of *New Forests*, it was agreed that researchers from this discipline should meet more frequently in order to continue to debate and advance the science behind forest nutrient dynamics. Thus, we anticipate that another international symposium on this topic will be held within the next 5 years.

Acknowledgments We are very grateful to all the attendees and presenters that participated in this congress and especially to the authors of this Special Issue. The assistance of the following who served as Guest Associate Editors for this special issue is greatly appreciated: Owen Burney, Tom Fox, Rob Harrison, Barbara Hawkins, Simon Landhäusser, Juan Oliet, Cindy Prescott, and Joshua Sloan. We also thank Kas Dumroese and Juan Oliet for providing helpful review comments on this paper.

References

Barnes RL, Bengtson GW (1968) Effects of fertilization, irrigation and cover cropping on flowering and on nitrogen and soluble sugar compositions of slash pine. For Sci 14:172–180

Burney OT, Jacobs DF (2011) Ungulate herbivory of regenerating conifers in relation to foliar nutrition and terpenoid production. For Ecol Manag 262:1834–1845

Burney O, Jacobs DF (2013) Ungulate herbivory of boreal and temperate forest regeneration in relation to seedling mineral nutrition and secondary metabolites. New For. doi:10.1007/s11056-013-9381-9

Cortina J, Vilagrosa A, Trubat R (2013) The role of nutrients for improving seedling quality in drylands. New For. doi:10.1007/s11056-013-9379-3

Donald DGM (1991) Nursery fertilization of conifer planting stock. In: van den Driessche R (ed) Mineral nutrition of conifer seedlings. CRC Press, Boca Raton, pp 135–167

Farnden C, Vassov RJ, Yarmuch M, Larson BC (2013) Soil reclamation amendments affect long term growth of jack pine following oil sands mining. New For. doi:10.1007/s11056-013-9375-7

Fox TR (2000) Sustained productivity in intensively managed forest plantations. For Ecol Manag 138:187–202

Haase DL (2010) Strategies and challenges for nursery production: Perspectives on where we're going and where we've been. In: Riley LE, Pinto JR, Dumroese RK (tech cords) National proceedings: forest and conservation nursery associations-2009. Proc. RMRS-P-62. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fort Collins, CO, pp 38–44

Haase DL, Rose R (eds) (1997). Symposium proceedings: forest seedling nutrition from the nursery to the Field. Oregon State University, Nursery Technology Cooperative. 161 p, 28–29 October 1997. [available online at http://www.rngr.net/publications]
Haase DL, Rose R, Trobaugh J (2006) Field performance of three stock sizes of Douglas-fir container seedlings grown with slow-release fertilizer in the nursery growing medium. New For 31:1–24
Jacobs DF, Salifu KF, Seifert JR (2005) Growth and nutritional response of hardwood seedlings to controlled-release fertilization at outplanting. For Ecol Manag 214:28–39
Landis TD, Davey CB (2009) Determining fertilizer rates and scheduling applications in bareroot nurseries. Forest Nursery Notes. Summer 14–21. http://www.rngr.net/publications/fnn/2009-summer/2009-summer-forest-nursery-notes-publication-by-article/determining-fertilizer-rates-and-scheduling-applications-in-bareroot-nurseries
Landis TD, Tinus RW, McDonald SE, Barnett JP (1989) Seedling nutrition and irrigation, vol 4. The container tree nursery manual. Washington (DC): USDA Forest Service. Agriculture Handbook 674. 119 p
Miller HG (1981) Forest fertilization: some guiding concepts. Forestry 54:157–167
Oliet JA, Jacobs DF (2012) Restoring forests: advances in techniques and theory. New For 43:535–541
Oliet JA, Puértolas J, Planelles R, Jacobs DF (2013) Nutrient loading of forest tree seedlings to promote stress resistance and field performance: a Mediterranean perspective. New For. doi:10.1007/s11056-013-9382-8
Prescott CE, Nery V, van Niejenhuis A, Sajedi T, Marshall P (2013) Nutrition management of cedar and hemlock plantations in coastal British Columbia. New For. doi:10.1007/s11056-013-9380-x
Riikonen J, Lehto T, Rikala R (2013) Effects of boron fertilization in the nursery or after planting on the performance of Norway spruce seedlings on boron-poor sites. New For. doi:10.1007/s11056-013-9372-x
Schott KM, Pinno BD, Landhäusser SM (2013) Premature shoot growth termination allows nutrient loading of seedlings with an indeterminate growth strategy. New For. doi:10.1007/s11056-013-9373-9
Show SB (1930) Forest nursery and planting practice in the California pine region. Circular No. 92, USDA, Washington DC. 75 p
Sloan J, Jacobs DF (2013) Fertilization at planting influences seedling growth and vegetative competition on a post-mining boreal reclamation site. New For. doi:10.1007/s11056-013-9378-4
Smethurst PJ (2010) Forest fertilization: trends in knowledge and practice compared to agriculture. Plant Soil 335:83–100
Taylor TS, Loewenstein EF, Chappelka AH (2006) Effect of animal browse protection and fertilization application on the establishment of planted Nuttall oak seedlings. New For 32:229–238
Tillotson CR (1917) Nursery practice on the national forests. Agriculture Bulletin 479. USDA, Washington DC. 86p
Timmer VR (1997) Exponential nutrient loading: a new fertilization technique to improve seedling outplanting performance on competitive sites. New For 13:279–299
Toumey JW (1916) Seeding and planting: a manual for the guidance of forestry students, foresters, nurserymen, forest owners, and farmers, 1st edn. Wiley, New York 455 p
Turner J, Lambert M (2013) Analysing inter-rotational productivity and nutrition in a New South Wales radiata pine plantation. New For. doi:10.1007/s11056-013-9369-5
van den Driessche R (ed) (1991) Mineral nutrition of conifer seedlings. CRC Press, Boca Raton 274 p
Villar-Salvador P, Peñuelas JL, Nicolás-Peragón JL, Benito LF, Domínguez-Lerena S (2013) Is nitrogen fertilization in the nursery a suitable tool for enhancing the performance of Mediterranean oak plantations? New For. doi:10.1007/s11056-013-9374-8
Zeng S, Jacobs DF, Sloan JL, Xue L, Li Y, Chu S (2013) Split fertilizer application affects growth, biomass allocation, and fertilizer uptake efficiency of hybrid *Eucalyptus*. New For. doi:10.1007/s11056-013-9371-y