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Editorial

Seedling Production and the Field Performance of Seedlings

Johanna Riikonen [1,*] and Jaana Luoranen [2]

[1] Natural Resources Institute Finland (Luke), 70200 Kuopio, Finland
[2] Natural Resources Institute Finland (Luke), 77600 Suonenjoki, Finland; jaana.luoranen@luke.fi
* Correspondence: Johanna.riikonen@luke.fi

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Abstract: The rapid establishment of seedlings in forest regeneration or afforestation sites after planting is a prerequisite for successful reforestation. The relationship between the quality of the seedling material and their growth and survival after outplanting has been recognized for decades. Despite the existence of a substantial amount of information on how to produce high-quality seedlings, there is still a need to develop practices that can be used in nurseries and at planting sites to be able to produce well-growing forest stands in ever-changing environments. This Special Issue of Forests is focused on seedling quality and how it can be manipulated in a nursery as well as how the quality of the seedlings affects their field performance after planting.

Keywords: cultural practice; field performance; nursery production; seedling quality; tree seedling

1. Use of High Quality Seedlings Is the Basis for Tree Planting Success

Seedling survival after outplanting is a complex process which can be affected by many nursery and silvicultural practices. The factors contributing to seedling quality have been comprehensively reviewed by Landis et al. [1] and Grossnickle and MacDonald [2]. Seedling quality can be assessed by measuring several morphological, physiological and performance attributes, the latter integrating the morphological and physiological attributes. However, in the end, the limiting factors on the outplanting site determine the most desirable morphological and physiological seedling attributes for improving the chances for increased growth and survival after the outplanting [3]. In this Special Issue, Grossnickle and MacDonald [4] review the historical development of the discipline of seedling quality, as well as where it is today. Because seedling quality consists of several features, such as the genetic source, morphological properties, nutritional status, stress resistance and the vitality of the seedlings, the seedling responses to different nursery practices may be variable in different tree species and under variable growth conditions [1,5]. In this Special Issue, Pinchot et al. [6] and Pinto et al. [7] consider the relationship between the initial size of the seedlings and their growth after outplanting. These studies highlight once more how the responses of the seedlings to different nursery practices are dependent on plant species and stock type.

The quality and germinability of seeds greatly influence the success of producing healthy and well-growing seedlings. Germinability and seedling health can be enhanced through different production methods [8]. In this issue, Kaliniewicz and Tylek [9] found that the quality of pedunculate oak acorns can be improved by different seed treatments prior to germination. They concluded that scarification and the elimination of infected acorns significantly increased the germination capacity of the acorns.

2. New and Existing Challenges along the Seedling Production Chain

Global change and development of technology provide new challenges and opportunities for influencing processes along the seedling production chain. According to the projections made by

Intergovernmental Panel on Climate Change [10], the global temperature will increase throughout the century. The world's forests play a key role as a carbon sink [11], and therefore, their responses to climate change may amplify or dampen atmospheric change at a regional and continental scale. During the last few years, the increased severity and frequency of summer heat waves and associated droughts have raised concerns about how climate change will interfere with forest regeneration processes. These climate extremes are projected to increase in the 21st century in many land areas [10] and they may eventually alter species compositions (as found by Vander Mijnsbrugge et al. [12] in this Special Issue), and even predispose some vulnerable species to disappearance from certain growth habitats (as found by Santos et al. [13] in this Special Issue).

Mining activity has a large impact on the surrounding landscape. It has caused significant forest losses and severe soil degradation worldwide. The post-mine areas are often reclaimed to non-forest land which results in a loss of biodiversity [14]. The reforestation of mined land would help mitigate the increase in atmospheric CO_2 concentrations and restore the potential for the land to provide forest ecosystem services and goods [15]. The restoration of forest on reclaimed post-mine land is often dependent on artificial regeneration [16]. Planted seedlings, however, are threatened by a variety of stresses, including low quality of rooting media, pre-existing competing vegetation and herbivory. In this issue, the first-year results from two experiments conducted in the reclaimed Appalachian surface mines are presented. Bell et al. [17] compared the survival and growth of native shortleaf pine to those of non-native loblolly pine (*Pinus taeda*). Hackworth et al. [18] studied herbivore damage in different tree species and how it could be reduced.

A current question in forest regeneration is how to transfer the gains from tree breeding programmes to forestry. One way to do this is to use vegetative propagation for producing somatic embryo plants. Somatic embryogenesis has been widely developed to mitigate shortages of regeneration material of a high breeding value in different conifer species ([19], and references therein). Fluctuation in the availability of genetically improved seed material of the Norway spruce has increased interest in developing the technology for the production of somatic embryos in Finland also. In this special issue, Tikkinen et al. [20] report that when state-of-the-art embryo storage and in vitro germination protocols were combined, somatic embryo plants can be grown and large-scale field testing can be initiated, although further development is still required to increase the cost-efficiency of the method.

Nursery production has traditionally focused on producing seedlings efficiently and economically. Nowadays, there is a growing interest in reducing the environmental impacts of seedling production. Sphagnum peat moss is widely used as a growth media in forest tree nurseries. However, due to its very long regeneration time, peat is no longer considered to be a renewable resource. Furthermore, peat extraction damages peatland ecosystems and reduces its capacity to act as a carbon sink ([21], and references therein). One way to reduce the C footprint of peat extraction is to develop an alternative growth media for Sphagnum peat moss. In this Special Issue, Dumroese et al. [22] evaluated different modes of biochar delivery to amend and replace Sphagnum peat moss in the production of nursery plants in containers.

In Fennoscandia, tree planting is the preferred method of stand regeneration. Most seedlings are planted manually in the regeneration sites. Economic pressure and labour shortages are pushing forest owners to manage their forests more intensively to increase wood production and profitability. Mechanized tree planting has been developed in Fennoscandia as an alternative to manual planting. It has been shown to be time efficient and to lead to high-quality regeneration when compared to manual planting [23]. However, due to its low cost-efficiency, the proportion of mechanically planted seedlings in Finland and Sweden has been only a few percentages of the total amount of plantings over the last few years [24,25]. In this issue, Ersson et al. [26] discuss the key factors that may affect the future growth of mechanized planting. They conclude that the cooperation between Sweden and Finland's forest industries and research institutes is an efficient way to enhance the mechanization level of Fennoscandian tree planting.

3. Conclusions

The papers included in this Special Issue cover a broad range of aspects, ranging from cultural practices in nurseries to the field performance of seedlings under challenging environmental conditions. Broader insights into how the existing and new information could be applied to the forest regeneration chain in the future were provided. We hope that the information in this Special Issue will be useful for the progress of science in the field of silviculture.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Landis, T.D.; Dumroese, R.K.; Haase, D.L. *The Container Tree Nursery Manual. Seedling Processing, Storage and Outplanting*; Agricultural Handbook 674; U.S. Department of Agriculture, Forest Service: Washington, DC, USA, 2010; Volume 7, 199p.
2. Grossnickle, S.C.; MacDonald, J.E. Why seedlings grow: Influence of plant attributes. *New For.* **2017**, *49*, 1–34. [CrossRef]
3. Ritchie, G.A.; Landis, T.D.; Dumroese, R.K. *Assessing Plant Quality. The Container Tree Nursery Manual. Volume 7: Seedling Processing, Storage, and Outplanting*; Agriculture Handbook 674, Chapter 2: Assessing Plant Quality; Landis, T.D., Dumroese, R.K., Haase, D.L., Eds.; USDA Forest Service: Washington, DC, USA, 2010; pp. 17–81.
4. Grossnickle, S.C.; MacDonald, J.E. Seedling Quality: History, Application, and Plant Attributes. *Forests* **2018**, *9*, 283. [CrossRef]
5. Simpson, D.G.; Ritchie, G.A. Does RGP predict field performance? A debate. *New For.* **1996**, *13*, 249–273. [CrossRef]
6. Pinchot, C.C.; Hall, T.J.; Saxton, A.M.; Schlarbaum, S.E.; Bailey, J.K. Effects of Seedling Quality and Family on Performance of Northern Red Oak Seedlings on a Xeric Upland Site. *Forests* **2018**, *9*, 351. [CrossRef]
7. Pinto, J.R.; McNassar, B.A.; Kildisheva, O.A.; Davis, A.S. Stocktype and Vegetative Competition Influences on *Pseudotsuga menziesii* and *Larix occidentalis* Seedling Establishment. *Forests* **2018**, *9*, 228. [CrossRef]
8. Himanen, K.; Nygren, M. Seed soak-sorting prior to sowing affects the size and quality of 1.5-year-old containerized *Picea abies* seedlings. *Silva Fenn.* **2015**, *49*, 1056. [CrossRef]
9. Kaliniewicz, Z.; Tylek, P. Influence of Scarification on the Germination Capacity of Acorns Harvested from Uneven-Aged Stands of Pedunculate Oak (*Quercus robur* L.). *Forests* **2018**, *9*, 100. [CrossRef]
10. IPCC. *Global Warming of 1.5 °C. An IPCC Special Report on the Impacts of Global Warming of 1.5 °C above Pre-Industrial Levels and Related Global Greenhouse Gas Emission Pathways, in the Context of Strengthening the Global Response to the Threat of Climate Change, Sustainable Development, and Efforts to Eradicate Poverty*; Masson-Delmotte, V., Zhai, P., Pörtner, H.O., Roberts, D., Skea, J., Shukla, P.R., Pirani, A., Moufouma-Okia, W., Péan, C., Pidcock, R., et al., Eds.; IPCC: Geneva, Switzerland, 2018; in press.
11. Settele, J.; Scholes, R.; Betts, R.A.; Bunn, S.; Leadley, P.; Nepstad, D.; Overpeck, J.; Taboada, M.A.; Fischlin, A.; Moreno, J.M.; et al. Terrestrial and Inland water systems. In *Climate Change 2014 Impacts, Adaptation and Vulnerability: Part A: Global and Sectoral Aspects*; Cambridge University Press: Cambridge, UK, 2015; pp. 271–360. [CrossRef]
12. Vander Mijnsbrugge, K.; Turcsán, A.; Maes, J.; Duchêne, N.; Meeus, S.; Van der Aa, B.; Steppe, K.; Steenackers, M. Taxon-Independent and Taxon-Dependent Responses to Drought in Seedlings from *Quercus robur* L., *Q. petraea* (Matt.) Liebl. and Their Morphological Intermediates. *Forests* **2017**, *8*, 407. [CrossRef]
13. Santos, M.M.; Borges, E.E.L.; Ataíde, G.M.; Souza, G.A. Germination of Seeds of *Melanoxylon brauna* Schott. under Heat Stress: Production of Reactive Oxygen Species and Antioxidant Activity. *Forests* **2017**, *8*, 405. [CrossRef]
14. Wickham, J.; Wood, P.B.; Nicholson, M.C.; Jenkins, W.; Druckenbrod, D.; Suter, G.W.; Strager, M.P.; Mazzarella, C.; Galloway, W.; Amos, J. The overlooked terrestrial impacts of mountaintop mining. *Bioscience* **2013**, *63*, 335–348. [CrossRef]
15. US Environmental Protection Agency (USEPA). *Mountaintop Mining/Valley Fills in Appalachia: Final Programmatic Environmental Impact Statement*; USEPA. Report No. EPA 9-03-R-05002; USEPA: Washington, DC, USA, 2005.

16. Zipper, C.E.; Burger, J.A.; Skousen, J.G.; Angel, P.N.; Barton, C.D.; Davis, V.; Franklin, J.A. Restoring Forests and Associated Ecosystem Services on Appalachian Coal Surface Mines. *Environ. Manag.* **2011**, *47*, 751–765. [CrossRef] [PubMed]
17. Bell, G.; Sena, K.L.; Barton, C.D.; French, M. Establishing Pine Monocultures and Mixed Pine-Hardwood Stands on Reclaimed Surface Mined Land in Eastern Kentucky: Implications for Forest Resilience in a Changing Climate. *Forests* **2017**, *8*, 375. [CrossRef]
18. Hackworth, Z.J.; Lhotka, J.M.; Cox, J.J.; Barton, C.D.; Springer, M.T. First-Year Vitality of Reforestation Plantings in Response to Herbivore Exclusion on Reclaimed Appalachian Surface-Mined Land. *Forests* **2018**, *9*, 222. [CrossRef]
19. Egertsdotter, U. Plant physiological and genetical aspects of the somatic embryogenesis process in conifers. *Scand. J. For. Res.* **2018**. [CrossRef]
20. Tikkinen, M.; Varis, S.; Aronen, T. Development of Somatic Embryo Maturation and Growing Techniques of Norway Spruce Emblings towards Large-Scale Field Testing. *Forests* **2018**, *9*, 325. [CrossRef]
21. Kern, J.; Tammeorg, P.; Shanskiy, M.; Sakrabani, R.; Knicker, H.; Kammann, C.; Tuhkanen, E.-M.; Smidt, G.; Prasad, M.; Tiilikkala, K.; et al. Synergistic use of peat and charred material in growing media—An option to reduce the pressure on peatlands? *J. Environ. Eng. Landsc. Manag.* **2017**, *25*, 160–174. [CrossRef]
22. Dumroese, R.K.; Pinto, J.R.; Heiskanen, J.; Tervahauta, A.; McBurney, K.G.; Page-Dumroese, D.S.; Englund, K. Biochar Can Be a Suitable Replacement for Sphagnum Peat in Nursery Production of *Pinus ponderosa* Seedlings. *Forests* **2018**, *9*, 232. [CrossRef]
23. Hallongren, H.; Laine, T.; Rantala, J.; Saarinen, V.-M.; Strandström, M.; Hämäläinen, J.; Poikel, A. Competitiveness of mechanized tree planting in Finland. *Scand. J. For. Res.* **2014**, *29*, 144–151. [CrossRef]
24. Ersson, B.T. Concepts for Mechanized Tree Planting in Southern Sweden. Ph.D. Thesis, SLU, Umeå, Sweden, 2014.
25. Laine, T.; Kärhä, K.; Hynönen, A. A survey of the Finnish mechanized tree-planting industry in 2013 and its success factors. *Silva Fenn.* **2016**, *50*, 1323. [CrossRef]
26. Ersson, B.T.; Laine, T.; Saksa, T. Mechanized Tree Planting in Sweden and Finland: Current State and Key Factors for Future Growth. *Forests* **2018**, *9*, 370. [CrossRef]