Stock type in intensive silviculture: A (short) discussion about roots and size[1]

by Nelson Thiffault[2]

I present an overview of some main issues related to the role of stock type in the intensive silviculture of conifers. The aim of my analysis is to answer some aspects of the question of whether or not foresters involved in intensive silviculture in eastern Canada should be concerned with stock type selection. When artificially establishing a forest stand, stock type selection can interact with other treatments to influence plantation success and productivity. Of particular importance are seedling size and root system characteristics. Research has demonstrated the greater intrinsic growth potential and competitive ability of larger seedlings as compared to standard stock sizes. These results also illustrate the multiplier effect of planting large spruce (*Picea* spp.) seedlings, combined with a release treatment to reduce competing vegetation. The larger size of bareroot seedlings compared to container seedlings has often been seen as improving their competitive potential, although mortality of such stock has been higher. However, recent nursery practices are increasing the size of containerized seedlings and improving the quality of bareroot stock. The issue is now more dependent on practical reforestation considerations than on field performance. Other considerations, such as seedling genetic potential and seedling nutritional status can be raised. The production of seedling characteristics specifically for growth performance is essential to intensive plantation management, but plantation success requires both proper stock type selection and appropriate silviculture.

Key words: plantation, intensive forestry, seedling size, root systems, silviculture, boreal conifers

Je présente un survol de certains enjeux liés au choix du type de plants dans la sylviculture intensive des conifères. Par cette analyse, je désire amener des éléments de réponse à savoir si les forestiers impliqués dans la sylviculture intensive dans l'est du Canada doivent ou non se préoccuper du choix du type de plants. Lors de l'établissement d'une plantation, le type de plants peut interagir avec d'autres traitements et influencer le succès d'établissement et la productivité du peuplement. Les dimensions initiales des plants et les caractéristiques de leur système racinaire sont particulièrement importantes. La recherche a démontré que les plants de fortes dimensions d'épinettes (*Picea* spp.) ont des potentiels intrinsèques de croissance et compétitifs supérieurs à ceux des plants standards. Ces résultats illustrent également l'effet multiplicatif de l'utilisation de plants de fortes dimensions et d'un traitement de dégagement de la végétation compétitive. Les dimensions plus importantes des plants à racines nues ont fréquemment été vues comme augmentant leur potentiel compétitif comparativement aux plants en récipients, bien que l'occurrence de mortalité soit plus élevée pour ce type de plants. Cependant, les développements récents des pratiques en pépinière permettent d'augmenter les dimensions initiales des plants en récipients et d'améliorer la qualité des plants à racines nues. L'enjeu repose maintenant davantage sur les considérations pratiques du reboisement que sur les performances au champ en tant que telles. D'autres considérations, telles le potentiel génétique des plants et leur statut nutritif peuvent être soulevées. La spécification de caractéristiques liées aux performances de croissance est essentielle à l'aménagement intensif des plantations. Cependant, le succès d'une plantation requiert à la fois le choix du bon type de plants et une sylviculture appropriée.

Mots-clés : plantation, foresterie intensive, dimension des plants, système racinaire, sylviculture, conifères boréaux

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Introduction

With population growth, the steady increase in per capita consumption of wood, and increased concern about the protection of natural forests, intensive forestry will play an increasingly important role in sustaining the wood supply in the future (Cossalter and Pye-Smith 2003). In eastern Canada and elsewhere, intensive silviculture generally involves resorting to plantation forestry (Bell *et al.* 2000). Several issues are related to the use of high-yield plantations, one of which is the use of proper seedling types to optimize plantation productivity. Stock type has the potential to influence plantation success, and hence forest productivity. This is especially true during the establishment and early growth stages. In this paper, I discuss the question of whether or not foresters involved in intensive silviculture in eastern Canada should be concerned with stock type selection. Although it is based on published scientific literature, my brief analysis is not a literature review. It points out some aspects related to stock type that I believe are important for the intensive silviculture of conifers in eastern Canada.



Nelson Thiffault

The concept of "stock type" rings different bells for foresters, depending on their background and experience. In the context of this paper, the focus is from a silviculture-centred point of view. From this perspective, stock types differ with every change in the combination of species, genetic potential and cultural practices in the nursery, including seedling storage and preparation for delivery to forest sites. This approach may appear simplistic, but even subtle variations in any of the above ele-

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[2]Direction de la recherche forestière, Ministère des Ressources naturelles, de la Faune et des Parcs, 2700 Einstein, Sainte-Foy, Québec G1P 3W8, nelson.thiffault@mrnfp.gouv.qc.ca.

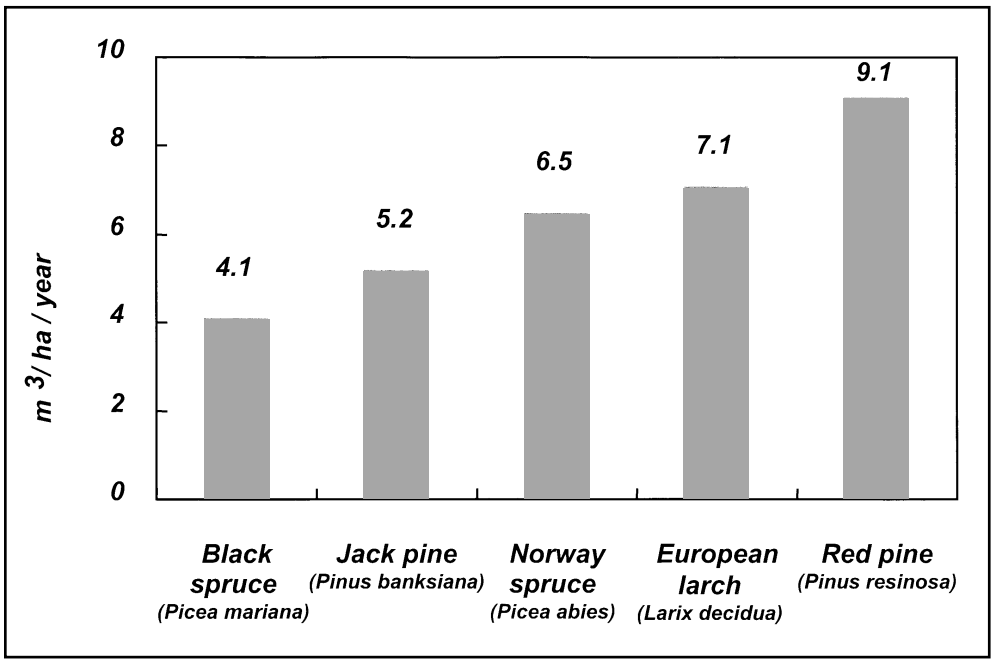


Fig. 1. Average annual productivity of the main coniferous species outplanted in Québec (Bolghari and Bertrand 1984, Prégent *et al.* 1996).

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ments have the potential to affect silviculture prescriptions, and hence, plantation success. As an example, container seedling delivery to the field, either in bundles or still in containers, influences seedling handling, irrigation and further manipulations on the forest site until planting. Each of these operations can affect seedling quality and physiological status, and thus subsequent performance and mortality (Paterson *et al.* 2001).

The choice of species is the most obvious aspect of stock type selection. Species is definitively an issue, but not only in the restrictive context of intensive silviculture. When selecting species, foresters are narrowing the potential productivity range of a plantation (Fig. 1). However, species choice is more than choosing an average productivity. An appropriate choice seeks the best compromise among site characteristics (biotic as well as abiotic elements), species autecology and production objectives (Savill *et al.* 1997). Because all these factors are specific to each reforestation context, I do not discuss them further in this paper. Instead, I focus on two other key elements of what defines stock type. First addressed is seedling size at the time of planting in terms of height and root collar diameter, and second, root system characteristics. After species, these two elements are certainly the most obvious characteristics of a given stock type and moreover, they are common to most forestry contexts.

When Size *Does* Matter

Silviculturists can now choose from an array of seedling sizes. As an example, Fig. 2 illustrates the typical seedling sizes available in Québec. Available seedling sizes vary from one place to another. However, techniques to produce such a variety of sizes exist and are operationally viable. But does size have an impact on plantation success?

Overton and Ching (1978) discussed the conceptual advantages of tall stock in a study with Douglas-fir (*Pseudotsuga menziesii* (Mirb.) conducted in the Pacific Northwest. They observed that seedlings with superior height at planting maintain a height advantage for nine years. From then on, the main objectives of using bigger seedlings have been to shorten the time required to reach a given size, and to enhance seedling competitive potential relative to the surrounding vegetation.

Several studies have investigated the effects of initial seedling size on growth and survival (e.g., Newton *et al.* 1993, Jobidon *et al.* 1998, Mason 2001, South *et al.* 2001). Fig. 3 illustrates the eight-year results of a study conducted in southeastern Québec, with severe competition from red raspberry (*Rubus idaeus* L.), pin cherry (*Prunus pensylvanica* L. f.) and mountain maple (*Acer spicatum* Lam.). In this experiment, Jobidon *et al.* (2003) observed a significant effect of initial seedling size on eight-year height and ground-level diameter (GLD) of black (*Picea mariana* (Mill.) BSP) and white spruces (*P. glauca* (Moench) Voss). Large seedlings have a higher intrinsic growth potential than do smaller seedlings, and planting large stock with competition is superior to planting small stock followed by mechanical release (Jobidon *et al.* 2003). Moreover, the response of large stock to release is greater than is that of smaller seedlings.

Whereas combining the use of large seedlings with vegetation control has multiplier effects on spruce growth (Jobidon *et al.* 2003), effects are additive for loblolly pine (*Pinus taeda* L.) (no interaction) (South *et al.* 2001). Nevertheless, growth gains remain greatest when combining intensive management and the use of large seedlings. However, as hypothesized by South and Mitchell (1999), increasing seedling size beyond a given limit does not further enhance growth (Jobidon *et al.* 2003); there is a biological limit to achieving gains.

Seedling size is a significant issue in intensive silviculture. Large seedling stock has higher growth potential than do small seedlings, and may positively interact with vegetation management practices. As defined by South and Mitchell (1999), the "optimum" seedling minimizes overall reforestation costs while achieving specific establishment objectives. With the objective of maximizing productivity, the use of stock types that provide the best growth performance should thus be favoured. Moreover, considerations of seedling size should be taken into account when defining a vegetation management strategy.

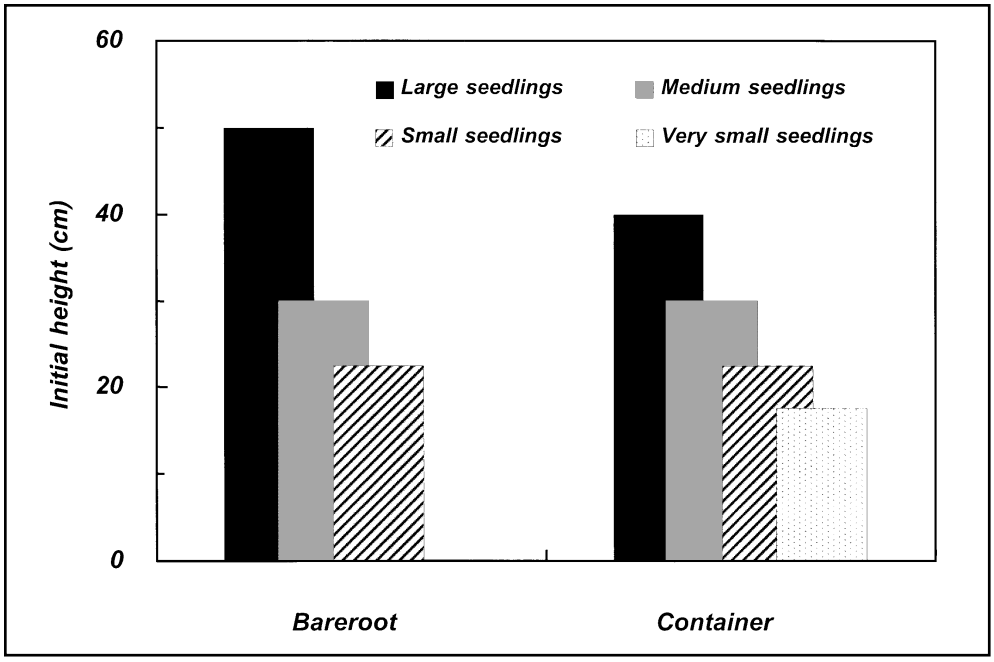


Fig. 2. Typical conifer seedling sizes available in the province of Québec.

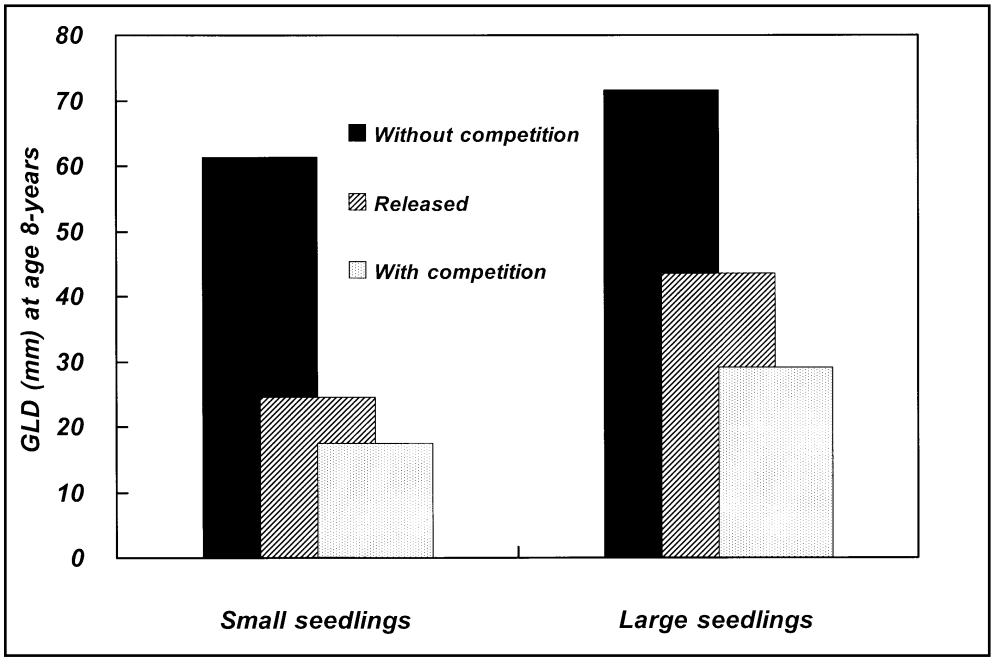


Fig. 3. Average ground-level diameter of black spruce and white spruce eight years after planting on a high-competition site in southeastern Québec. Release from competition was performed mechanically during the third growing season (Adapted from Jobidon *et al.* 2003).

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Given the possible interactions between seedling size and vegetation control, it is worth using seedling stock that will best respond to release treatments.

Roots Do Not Know What a Leaf Has In Mind – African Proverb

Seedlings can generally be classified as either container or bareroot stock. There are also in-between categories, with seedlings started as containers and then transferred into planting beds. However, my discussion is limited to the two main types.

In Canada and elsewhere, there is a trend towards a reduction in the use of bareroot seedlings for reforestation (MRNFP 2004). Eastern provinces (Ontario, Québec, New Brunswick and Newfoundland) are in keeping with this tendency, as illustrated in Table 1. Many papers have been published on the comparison of bareroot and container stock performance (see Menes *et al.* 1996). Most of them conclude that bareroot seedlings have higher competitive potential than do container-grown seedlings, mainly because of their larger size at the time of planting. The choice of bareroot seedlings over container stock is thus generally driven by the objective of using a more competitive seedling on sites where vegetation is expected to be aggressive.

It is also frequently reported that bareroot stock has higher mortality than does container stock. Mortality of bareroot seedlings can be partly explained by a greater resistance to water

Table 1. Use of bareroot seedlings for reforestation in some provinces and countries (Adapted from MRNFP 2004)

Province or country	Seedlings planted annually (conifers; in millions)	Predicted reforestation of conifers in years to come	Predicted bareroot seedling production	Main benefits associated with bareroot seedlings
Alberta	64.2	↑	↓	competitive potential
British Columbia	200.0	—	—	competitive potential
New Brunswick	55.5	↑	none	none
Newfoundland	8.5	↑	none	none
Ontario	131.0	—	↓	none
Québec	121.0	—	↓	none
Australia	1.0	—	↓	n.a.
Finland	144.9	—	↓	competitive potential
United Kingdom	40.0	n.a.	—	production costs
Norway	32.1	↓	↓	competitive potential; resistance to pests
New Zealand	5.5	n.a.	—	n.a.
Sweden	301.0	↓	↓	competitive potential; resistance to pests

Legend: ↑ = increase ; ↓ = decrease ; — = stable ; n.a. = data not available

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flow through the soil-plant-atmosphere continuum (Grossnickle and Blake 1987). Bareroot seedlings are more likely to suffer from water stress than are containerized seedlings (e.g., Becker *et al.* 1987). Water stress is the main cause of mortality in newly planted seedlings (Margolis and Brand 1990).

However, given that large container seedlings are now available and that nursery practices for bareroot stock have reached high levels of sophistication, effects of the production method (container or bareroot) on competitive potential and survival can no longer be generalized as they once were (Grossnickle 2000, Mohammed *et al.* 2001). As an example, we recently demonstrated that growth, competitive potential and survival of large container and bareroot spruce seedlings are similar on high competition sites of southeastern Québec (Thiffault *et al.* 2003). These results demonstrate that as nursery practices evolve and new stock types are produced common beliefs should be periodically verified (Grossnickle 2000).

In the context of intensive silviculture, the issue of the seedling root system is now related more to practical reforestation considerations, such as seedling availability, ease of transportation and handling, and finally, ensuring good planting quality, than on field performance per se. As illustrated in Table 2, and discussed by Mohammed *et al.* (2001), differences in seedling morphology have non-negligible effects on planting activities. Seedling transportation from the nursery to the planting site, as well as handling on the site itself, depends on stock type. Planter productivity, as influenced by the number of seedlings that can be carried and ease of planting, should also be taken into account. Available infrastructure and the reforestation context (e.g., the scale of operations) dictate most of the answers.

Stock Type Is More than Roots and Size

Stock type involves more than species, seedling size and root systems. Genetic potential is now a major characteristic of the stock type available for reforestation. Selection and reproduction of the best available material have long been used to improve productivity, but rooted cuttings and somatic embryogenesis now make clonal forestry a reality. Between stock types produced from seeds from natural stands, and clones derived from selection programs, there are huge opportunities to influence productivity (Fig. 4). Moreover, it is in intensively managed plantations, where competing vegetation is maintained at low levels, that genetically improved seedlings will best demonstrate their enhanced growth potential (McDonald *et al.* 1999).

Table 2. Perception by seedling users in Québec, of the relative advantages of container seedlings over bareroot seedlings with regard to some operational constraints (Adapted from MRNFP 2004)

Operational constraint	Container-grown
Transport from nursery to planting site	–
Delivery in the field to the planter	–
Transportation by the planter	–
Planting	+
Maintenance on the site	+
Length of planting season	+

Legend: + = advantage over bareroot; – = disadvantage over bareroot.

Seedling nutritional status is another aspect of stock type characteristics. Based on the concept of steady-state nutrition introduced by Ingestad and Lund (1986), researchers have developed new nursery fertilization techniques that provide foresters with nutrient-loaded seedlings (Timmer 1997). Seedling reserves built up in the nursery allow for more nutrient translocation to actively growing parts than do conventional seedlings (Malik and Timmer 1995). The result is that nutrient-loaded seedlings offer an enhanced competitive ability over conventionally fertilized stock (Malik and Timmer 1996).

Conclusion

Stock type selection should be considered as part of the silvicultural prescription, especially in intensive silviculture. Stock type can interact with other silvicultural treatments, such as site preparation, vegetation management and possibly others. Thus, treatment responses can be optimized if best-fitted stock types are used. Considering that intensive silviculture involves several interventions on a given site over a relatively short period of time, the possibilities for interactions are greatly increased.

Stock type is an issue in intensive silviculture, where some elements are more important than others. Foresters should indeed be concerned with stock type selection. But plantation success requires more than using the proper stock type. Appropriate silviculture is also essential.

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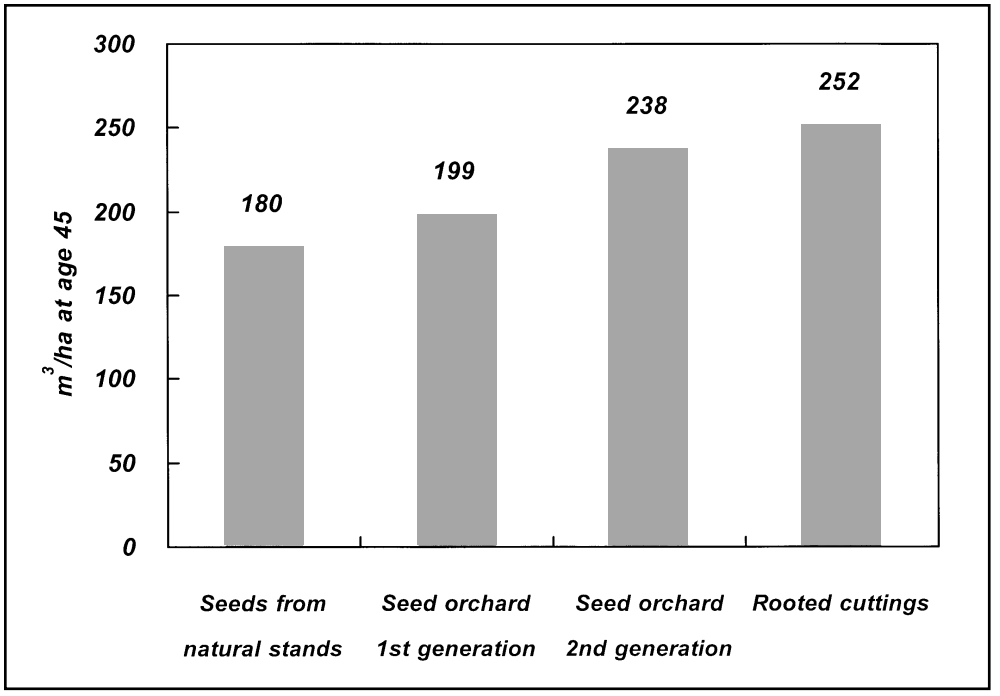


Fig. 4. Expected productivity of white spruce plantations established using seedlings from different seed sources. (Calculated from MRN 1996).

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