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Stem deformation in young plantations of black spruce (*Picea mariana* (Mill.) B.S.P.) and jack pine (*Pinus banksiana* Lamb.) in the boreal forest of Quebec, Canada

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Abstract

Stem deformation has often been observed in young black spruce (*Picea mariana* (Mill.) B.S.P.) and jack pine (*Pinus banksiana* Lamb.) plantations. Whenever important stem deformations are observed at the time of harvesting, timber value is negatively affected especially during the wood transformation process. The present work was undertaken to quantify and qualify the importance of stem deformation of black spruce and jack pine in the boreal forest of central Quebec at the stand and tree levels. In 30 black spruce and jack pine plantations, approximately 22% of spruce trees and 27% of pine trees exhibited stem deformation. The proportion of deformed trees was higher in the youngest plantations and decreased with the age of the plantations. Stem deformation caused the formation of compression wood which is another factor that can reduce the value of wood products. Thirty-nine black spruces and 34 jack pines were analysed at the tree level. On average, compression wood represented 14% and 20% of stem volume in 7- and 10-year old black spruce plantations, respectively. These proportions ranged from 18% in the youngest jack pine plantation to 26% in the oldest one. Stems of both species classified as normal contained a lower volume of compression wood than stems classified as deformed or very deformed. Annual percentages of compression wood and annual shoot length increased significantly with tree age ($p < 0.0001$ for both variables). Statistically significant correlations were also found between the range of displacement of the stem and the percentage of compression wood. The fewer number of trees with deformed stems in older plantations combined with high compression wood formation suggests that, over time, a deformed tree can become normal and straight in appearance.

Keywords: Plantations; Black spruce; Jack pine; Container seedling; Stem deformation; Compression wood

Résumé

La déformation de la tige a souvent été observée dans les jeunes plantations d'épinette noire (*Picea mariana* (Mill.) B.S.P.) et de pin gris (*Pinus banksiana* Lamb.). Lorsque des déformations importantes de la tige sont observées au moment de la récolte, la valeur du bois est négativement affectée spécialement au cours du processus de transformation. La présente étude a été entreprise afin de quantifier et de qualifier, au niveau du peuplement et de l'individu, l'importance de la déformation de la tige de l'épinette noire et du pin gris dans la forêt boréale du centre du Québec. Chez 30 plantations d'épinette noire et de pin gris, approximativement 22% des épinettes et 27% des pins ont présenté une déformation de la tige. La proportion des arbres avec sinuosité était plus élevée dans les jeunes plantations et diminuait avec l'âge des plantations. Les déformations de la tige induisent la formation de bois de compression qui représente un autre facteur qui peut diminuer la valeur des produits du bois. Il y a 39 épinettes noires et 34 pins gris qui ont été analysés au niveau de l'individu. En moyenne, la formation de bois de compression a atteint des proportions de 14% et 20% du volume de la tige dans des plantations d'épinette noire âgées de 7 et 10 ans respectivement. Ces proportions ont atteint 18% dans la plus jeune plantation de pin gris et 26% dans la plus vieille. Les tiges des deux espèces classées normales contenaient un plus faible volume de bois de compression que les tiges classées déformées ou très deformées. Les pourcentages annuels de bois de compression et la longueur annuelle de la pousse apicale ont augmenté significativement avec l'âge des arbres ($p < 0.0001$ pour les deux variables). Des corrélations significatives ont été

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également trouvées entre l'étendue de la déformation des tiges et le pourcentage du bois de compression. Le plus faible nombre d'arbres avec des tiges sinueuses dans les vieilles plantations, combiné avec une production élevée de bois de compression, conduit à l'hypothèse que les arbres qui présentent des sinuosités peuvent retourner à une apparence normale plus droite dans le temps.

Mots clés : Plantations; Épinette noire; Pin gris; Semis en récipients; Déformation de la tige; Bois de compression

1. Introduction

Regeneration of boreal forest stands following harvest is assured by either establishment of new plantations or by careful logging to protect young seedlings and layers. Black spruce (*Picea mariana* (Mill.) B.S.P.) relies on seedlings and layering to regenerate. In boreal forests of Quebec, harvested black spruce stands are, on average, only 80% stocked and need to be replanted to ensure relative tree density before harvesting (OIFQ, 1996; Commission Coulombe, 2004). However, natural regeneration process is not suited for all species. Advance regeneration stocking in jack pine (*Pinus banksiana* Lamb.) is only 4–7%. Because this species can only release a sufficient number of seeds from its cones that are exposed to high temperatures as in a fire (Tremblay, 1987; Ruel, 1997). In Quebec, black spruce is the main harvested species in the boreal forest. Even with 80% advance regeneration stocking, approximately 60 million black spruce seedlings, compared to 27 million jack pine seedlings, are planted annually to ensure sufficient stocking (Parent and Fortin, 2006). This type of management is an increasingly important source of biomass production for the forest industry.

Seedlings are produced either by government- or privately-owned nurseries. During the past 25 years, seedling have mostly been produced in small rigid wall containers. This method is well known to cause deformation in the root system of several tree species (Burdett et al., 1986; Gilman, 1990; Halter et al., 1993; Rune, 2003; Chapman and Colombo, 2006), including black spruce and jack pine (Sheedy, 1997).

Stem deformations are commonly observed in plantations of both tree species. We defined stem deformation as a horizontal displacement of the stem, which can occur in only one or several internodes, whereas sinuosity is defined as sinusoidal growth pattern within one internode which requires an S-shape (Campbell, 1965; Spicer et al., 2000). These deformations have been more often observed in young black spruce and especially young jack pine than in older trees (Sheedy, 1996). Similar findings have been reported in *Pinus contorta* (Dougl. Ex Loud.) (Robert and Lindgren, 2006), in *Pinus pinaster* Ait. (Rio et al., 2004) and *Pinus sylvestris* L. (Warensjö and Rune, 2004). Furthermore, in northern Europe, several scientists have observed the occurrence of stem deformation is significantly higher in planted *P. sylvestris* compared to naturally regenerated trees (Kärkkäinen and Uusvaara, 1982; Uusvaara, 1985; Agestam et al., 1998). Rio et al. (2004) did not find a relationship between stem deformation and environmental parameters such as soil, drainage, slope, climate, exposure, altitude, density and tree position. It is well known that stem deformation induces the formation of compression wood in early- or latewood as well as the whole ring-width (Cremer, 1998). These deformations cause problems in the wood transformation process and result in a loss of product quality (Timell, 1986; Johansson, 2002). Therefore, it is important to study the effect of juvenile instability, to follow the evolution of stem deformation over time and to evaluate the wood quality of these trees.

This study evaluated the occurrence of stem deformation in young, container-grown black spruce and jack pine plantations in the boreal forest of Quebec at both the plantation and the individual tree level. At the tree level, we examined pattern of stem deformation over time and its relationship with annual shoot length and the occurrence of compression wood.

Our working hypotheses were that stem deformation: (1) is more severe in jack pine than in black spruce plantations (Ministry of Natural Resources, Girard, pers. comm.); (2) will decrease with increasing age of the plantation due to an additional secondary growth each year and (3) is positively related to the annual shoot length.

2. Methodology

2.1. Study sites

Our study covered areas of managed forests in the province of Quebec, Canada. Black spruce and jack pine plantations from post-fire or harvested stands with insufficient regeneration were selected on both public and private lands within latitudes 47°N and 51°N, and longitudes 70°W and 75°W in the Saguenay—Lac Saint-Jean and Chibougamau regions. Thirty-four sites were studied. Thirty, (15 black spruce and 15 jack pine) were analysed at the stand level. The remaining four (two black spruce and two jack pine) were analyzed at the tree level.

For site level analysis, each species was classified into three groups based on duration of time since planting; 3–7, 7–12 and 13–17 years. All trees were started in containers, and grew 1–2 years in a nursery before planting. In the laboratory, we found that the ages in the 30 selected stands ranged from 6 to 18 years. In order to produce a balanced design of 30 stands with five plantations per class per species, data were pooled into three age classes as mentioned before.

For the analysis at the tree level, two additional sites were chosen for each species, with plantation ages of 7 and 10 years. With the time spent in a nursery, the tree ages were 8 and 12 years for black spruce and 9 and 12 years for jack pine.