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New technological developments in cutting propagation to increase forest productivity in Quebec

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Abstract

Mass cutting propagation is largely used worldwide to reproduce elite material obtained from the best controlled crosses, as a means to increase forest productivity. In Quebec, the production of conifer cuttings has steadily increased since the opening of the Cutting propagation center of the Pépinière forestière de Saint-Modeste (Saint-Modeste Forest Nursery), in 1989. Several species (white spruce, black spruce, Norway spruce and hybrid larch) are now propagated using two unique and complementary systems (the "*Bouturathèques"* and double-walled enclosures) developed by the *ministère des Ressources naturelles et de la Faune du Québec.* Close collaboration between researchers of the *Direction de la recherche forestière* (Forest Research Directorate) and practicans of the *Direction générale des pépinières et des stations piscicoles* (Nurseries and Fish farms Directorate) has led to adapted culture scenarios for each species (stock plant culture, rooting conditions, and culture regimes for the production of large-size plants). This collaboration also facilitates the take-on of new challenges, such as the integration of somatic embryogenesis, the development of alternative culture scenarios and the characterization of controlled crosses. The double-walled enclosure system has now been implemented in two other public nurseries (Berthier and Grandes-Piles), for the propagation of white spruce cuttings, in a first step. In 2007, 5.15 million conifer plants will be produced via cutting propagation in Quebec.

Résumé

À l'échelle mondiale, le bouturage de masse est largement préconisé pour multiplier les individus issus des meilleurs croisements dirigés, en vue d'augmenter la productivité forestière. Au Québec, depuis les débuts du Centre de bouturage de la pépinière de Saint-Modeste (1989), la production de plants issus de boutures ne cesse d'augmenter pour diverses essences résineuses (épinettes blanche, noire et de Norvège, mélèzes hybrides). L'enracinement des boutures se fait grâce à deux systèmes uniques et complémentaires (Bouturathèques et doubles enceintes extérieures) développés par le ministère des Ressources naturelles et de la Faune du Québec. L'étroite collaboration entre des chercheurs de la Direction de la recherche forestière et des praticiens de la Direction générale des pépinières et des stations piscicoles a permis de mettre au point des scénarios de culture adaptés aux exigences de chaque espèce (culture des pieds-mères, conditions d'enracinement et repiquage pour la production de plants de fortes dimensions). Cette colaboration permet aussi d'aller au-devant des défis de l'heure, comme l'intégration de l'embryogenèse somatique, le développement de nouveaux scénarios de production et la caractérisation des croisements dirigés. Le système de doubles enceintes vient d'être introduit dans les pépinières gouvernementales de Berthier et de Grandes-Piles pour produire, dans une première phase, des plants d'épinette blanche. En 2007, l'objectif provincial est de produire 5,15 millions de plants résineux issus de boutures.

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New technological developments in cutting propagation to increase forest productivity in Quebec

Propagating elite seeds

Figure 1. Controlled polination in a white spruce seed orchard (Picture by A. Rainville, DRF).

Cutting propagation allows the vegetative reproduction of elite crosses, showing superior productivity, without the use of genetically modified trees.

The seeds obtained from these crosses provide a higher genetic gain than do those obtained from free pollination in seed orchards.

For cuttings of white spruce, black spruce and Norway spruce, stock plants originate from seeds of controlled crosses (where both the mother and father are known, Figure 1).

All hybrid larch plants in Quebec are currently produced by cuttings. Seeds for stock plants are obtained through mass pollination in sheltered seed orchards.

Characterization of controlled crosses

White spruce seedlings and stock plants exhibit a particularly high genetic variation, both at the family and clonal levels (Lamhamedi *et al.* 2000). In order to attain the production objectives for cuttings, each controlled cross is characterized both morphologically and physiologically, along each step of cutting propagation (Lamhamedi *et al.* 2005a, 2005b, 2007) : seed size and quality (Figure 2), stock plant growth and cutting yield, rooting success of cuttings, etc.

The characterization of controlled crosses will help the nurseryman to optimize the use of the best crosses, while taking genetic diversity into account. This will lead to better population management and cultural practices, which will facilitate cutting propagation and subsequent plant culture.

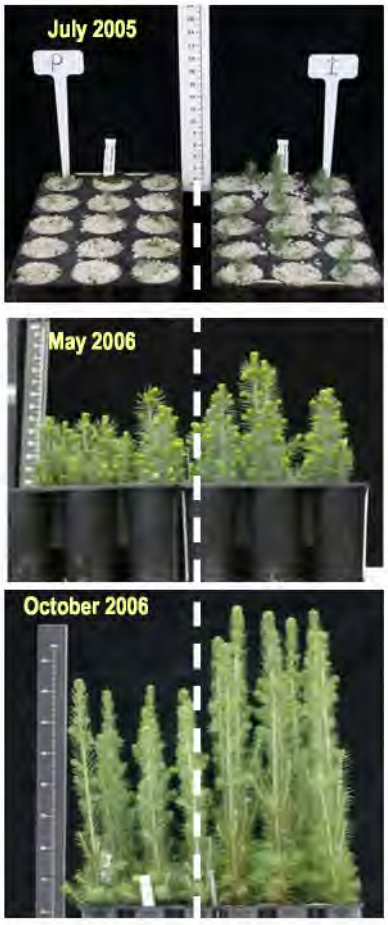

Figure 2. Growth comparison between white spruce stock plants from a same controled cross, using small (caliber 4, left) or standard (calibers 1-2-3, right) seeds. (Pictures by M.S. Lamhamedi, F. Colas, P. Lemay and N. Robert, DRF).

Cutting production in three steps

1. Cultivating the stock plants

Each species has particular needs and requires an adapted cultural scenario. Stock plant seeds are sown individually in containers, then grown on in greenhouses or tunnels. After one year, spruce stock plants are transferred outside (Figure 3a). Hybrid larch stock plants are kept under greenhouse conditions until cutting harvest.

2. Harvesting the cuttings

Softwood cuttings are collected on actively growing stock plants, during the second growth season. They consist of lateral branches, carefully selected at an optimal length (approximately 5 to 7 cm) and at a precise stage of lignification (Figure 3b).

3. Sticking the cuttings into containers

Cuttings are stuck in rooting containers filled with a moistened peat- and perlite-based substrate (Figure 3c). A misting robot keeps the foliage moist while they are conveyed towards the rooting enclosures.

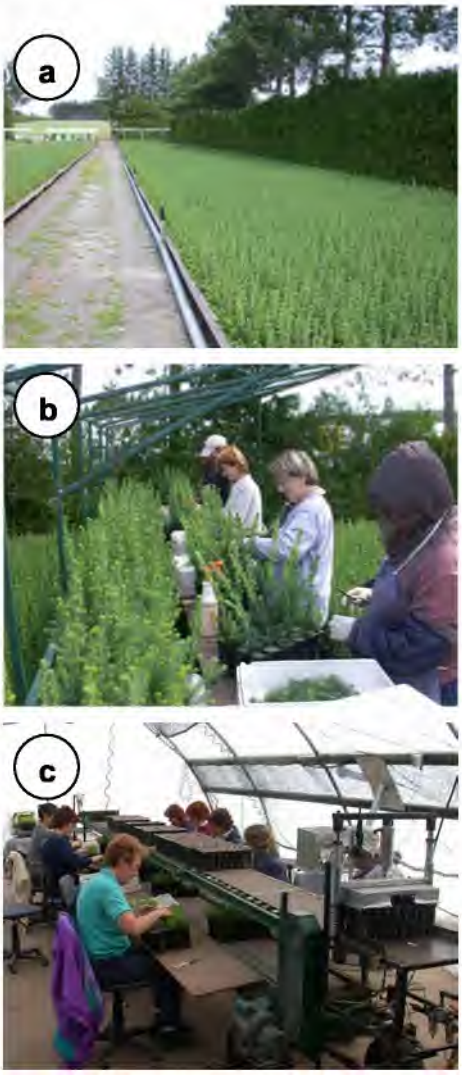

Figure 3. Production of white spruce cuttings : a) containerized stock plants during their second growth season; b) operational harvest of white spruce cuttings on stock plants; c) operational sticking of cuttings (Pictures by P. Lemay, DRF).

Two complementary rooting systems

Figure 4. General view of the two propagation systems used at the Pépinière de Saint-Modeste : a) one of the « Bouturathèques »; b) double-walled rooting enclosure. (Pictures by MRNF and P. Lemay, DRF)

The « *Bouturathèques* » (Vallée and Noreau 1990, Tousignant *et al*. 1996) and the « double walled enclosures >> (Tousignant and Rioux, 2002) are unique and complementary systems, designed and developed by the MRNF. The « *Bouturathèques* >> (Figure 4a) are used for year-round cutting propagation, mainly for black spruce. The double-walled enclosures (Figure 4b) are used for summer propagation for hybrid larch and all spruce species.

Providing optimal rooting conditions

Contrary to many ornamental species, cutting propagation of spruces and hybrid larch is complex and delicate. Rooting success requires a precisely controlled and optimized environment, in terms of light, temperature, air relative humidity and vapor pressure deficit.

The double-walled enclosures allow for optimal rooting conditions (Figure 5). Two white polyethylene covers reduce light intensity (Figure 6a), a central mist line helps raise air humidity close to saturation and reduces temperature (Figure 6b), and a misting robot keeps the needles moist (Figure 6c).

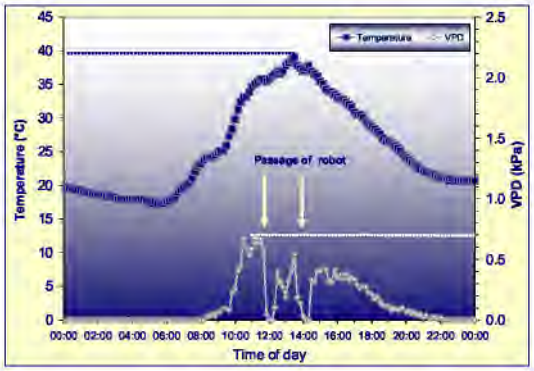

Figure 5. Example of successful environmental control within the double-walled rooting enclosures : Vapor pressure deficit (VPD) at plant level is kept below 1 kPa at al times, even on a very hot summer day.

On average, rooting success of cuttings reaches 75 % to 90 % within 12 weeks, depending on the species (Figure 7).

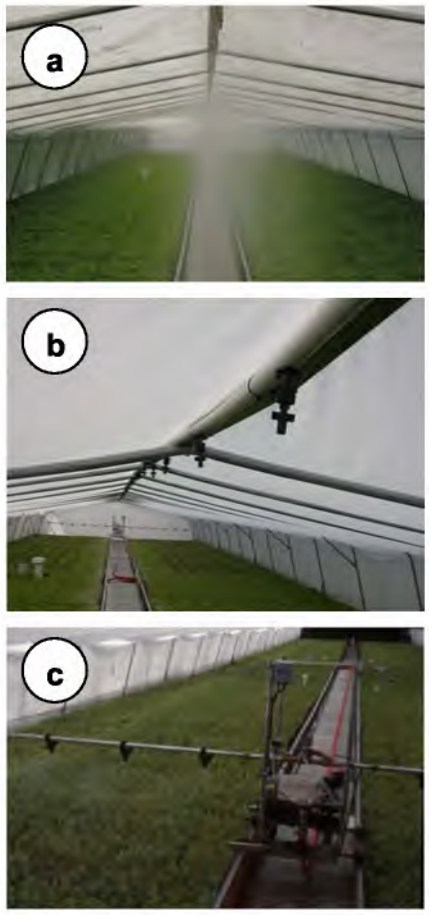

Figure 6. Components of the double-walled enclosure system : a) interior view of the enclosure, during a misting event; b) central mist line; c) misting robot applyling fine water droplets on the needles (Pictures by P. Lemay, DRF).

Figure 7. Development of adventitious roots on white spruce cuttings, after a) 8, b) 12 and c) 16 weeks of rooting in double-walled enclosures (Pictures by P. Lemay, DRF) .

High quality plants for reforestation

Rooted cuttings (Figure 8a) are transplanted, either bareroot or in larger containers (Figure 9), in order to complete their growth in the nursery. After two more growth seasons, the plants are delivered to reforestation as large-sized plants (Figure 8b).

Plants from cuttings must meet the 25 rigorous quality norms established for seedlings by the MRNF, including those for root system architecture, stem growth and nitrogen concentration.

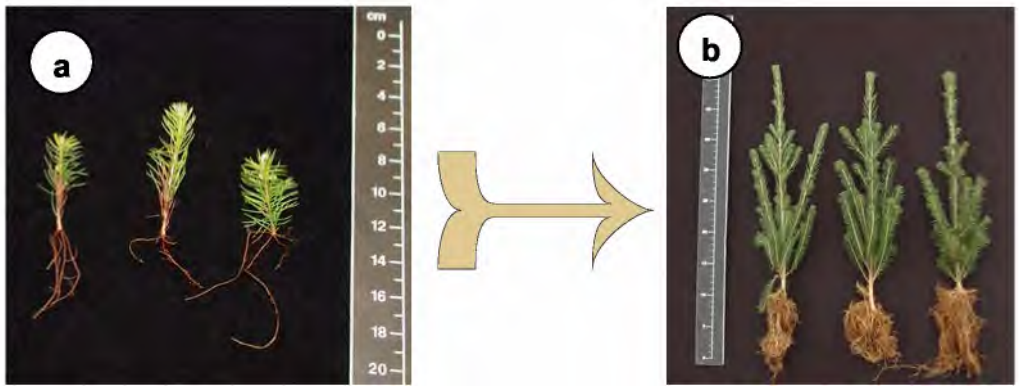

Figure 8. White spruce cuttings : a) at the time of transplant in the nursery and b) after two growth seasons in large-sized containers (25-310) (Pictures by N. Robert, DRF).

5.15 million plants from cuttings

The double-walled enclosure system perfected at the Pépinière de Saint-Modeste (Direction générale des pépinières et des stations piscicoles du MRNF) has recently been implanted in two other public nurseries, at Grandes-Piles and Berthier. In 2007, their combined production of cuttings reached 5.15 million plants (Table 1).

Table 1. Distribution of conifer cutting production in Quebec for 2007, by species and by nursery (shippable plants).

4 species		3 nurseries	
White spruce	3 100 000	Saint-Modeste	4 000 000
Black spruce	1 500 000	Grandes-Piles	600 000
Norway spruce	50 000	Berthier	550 000
Hybrid larch	500 000		
Grand Total : 5,15 million plants			

Figure 9. Aerial view of some of the cultural sectors dedicated to containerized cutting transplants (Pépinière de Saint-Modeste) (Picture by D. Tousignant, DRF).

A fruitful collaboration

This success in cutting propagation is the result of more than 15 years of research and development conducted at the operational scale, combined with continuous transfer of exertise and technolo

The collaboration between researchers and nurserymen creates a unique synergy. This dynamic facilitates the take-on of new challenges.

Future challenges

New culture scenarios

The rooting of hardwood cuttings (harvested at a dormant stage), combined with the use of multi-celled « miniplugs » (Figure 10), could lead to mechanized cutting transplantation and help to continue reducing production costs.

Figure 10. White spruce cuttings in multi-celled Jiffy® -type plugs, in trays with separation tabs (Picture by P. Lemay, DRF).

Studies on root system quality

Ongoing studies on the genetics, root quality and root system architecture of cuttings, before and after nursery transplant, will lead to more improvements of cultural regimes.

Integration of somatic embryo genesis

With the development of a highly productive multiclonal forestry program, the production of stock plants from both seeds and somatic plants are two complementary approaches which can be combined for cutting propagation, while respecting genetic diversity.

Comparative plantations

The field performance of cuttings and the long-term effects of certain cultural techniques are evaluated in plantation trials. (Figure 11).

Figure 11. Measuring tree growth after 5 years in a plantation of hybrid larch cuttings (Packington, Quebec, N47°24'38", O68°44'17") (Picture by D. Tousignant, DRF).

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