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Forest Ecology and Management 199 (2004) 39–50

Forest Ecology and Management

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Reclamation of roads and landings with balsam poplar cuttings

Annie DesRochers[a,*], Barb R. Thomas[b,c], Roger Butson[b]

[a]*Université du Québec en Abitibi-Témiscamingue, 551—1ère rue Est, Amos, Que., Canada J9T 2H3*
[b]*Alberta-Pacific Forest Industries Inc., Box 8000, Boyle, AB, Canada T0A 0M0*[1]
[c]*University of Alberta, 751 General Services Building, Edmonton, AB, Canada T6G 2H1*[2]

Received 5 February 2004; received in revised form 13 April 2004; accepted 13 April 2004

Abstract

Balsam poplar (*Populus balsamifera* L.) can easily be grown when planted as dormant, unrooted cuttings. The first part of this research project consisted of a greenhouse study to identify the best combination of pre-planting treatments to maximize rooting of hardwood cuttings for large-scale greenhouse propagation. Eighty-four treatment combinations were tested on 10 cm-long cuttings, including seven soaking lengths of time (0, 1, 2, 3, 4, 5 and 14 days), three dips (none, powder and liquid rooting hormone), two collection dates (fall and spring), and two cutting selections (average trees and a superior clone).

Secondly, we tested the performance of unrooted cuttings on typical forestry sites lacking natural regeneration, using 30 cm-long cuttings and full-length whips (>60 cm). Three pre-planting treatment combinations were used (soaking for 1 or 3 days, or 3 days with a dip in rooting hormone). Other factors tested were two collection dates (fall and spring), two cutting selections (average trees and a superior clone), two storage methods (stored as full whips or cut to size), and two cutting locations (basal or top 30 cm of stools).

Keywords: *Populus balsamifera*; Balsam poplar; Site reclamation; Unrooted cuttings; Rooting; Rooting hormone; NSR; Reforestation

1. Introduction

The abundance of aspen (*Populus tremuloides* Michx.) and balsam poplar (*Populus balsamifera* L.) in the mixedwood boreal forest of Northern Alberta has allowed forestry companies harvesting mainly hardwoods to prosper in this area (Karaim et al., 1990). Although the two species usually regenerate abundantly and naturally after harvesting, many small areas where natural regeneration is lacking, such as abandoned forestry roads (mostly roads used during the winter) and decking areas, need to be regenerated artificially to ensure sufficient stocking, meet the regeneration standards and maximize wood production on the land base. To date, plantation of aspen seedlings has proved challenging; quality of nursery-produced seedlings is variable and planted seedlings are often highly affected by browsing (Irwin, 1985; Timmermann and McNicol, 1988). Although the production and planting of white spruce (*Picea glauca* (Moench) Voss) seedlings are effective and widely practised in this area, they are usually slower-growing than hardwoods, are often overtopped by grass competition (Landhäusser and Lieffers, 1999) and may

* Corresponding author. Tel.: +1-819-732-8809x327; fax: +1-819-732-8805.
E-mail address: annie.desrochers@uqat.ca (A. DesRochers).
[1] Tel.: +1-780-525-8342; fax: +1-780-525-8097.
[2] Tel.: +1-780-492-8016.

0378-1127/$ – see front matter
doi:10.1016/j.foreco.2004.04.018

change the species composition of the harvested hardwood stands. In addition, it is unlikely that they will reach merchantability in sink with the surrounding hardwood stands. In contrast, balsam poplar stem cuttings have been used to rapidly reclaim degraded areas for wildlife habitat, riparian soil stabilization or soil protection purposes (Dewar and Berglund, 1983; Peterson et al., 1996). Balsam poplar stem cuttings could thus also be used in forestry settings after harvest, to operationally reforest marginal deciduous sites where natural stocking is inadequate, such as in wetter depressions, abandoned temporary roads or landing areas. Moreover, balsam poplar is relatively fast growing, cuttings from superior phenotypes can easily be propagated vegetatively, and planted trees are usually less preferred than aspen by wildlife for browsing (Sinclair and Smith, 1984; Reichardt et al., 1990).

The first part of this study aimed at identifying pre-planting treatments favoring rooting during greenhouse propagation of balsam poplar cuttings for the production of rooted planting stock. In the dry and cold climatic conditions of Northern Alberta, with less than 400 mm of annual precipitation and 80 frost-free days (Anonymous, 1982; DesRochers and Thomas, 2003), pre-rooting the cuttings in the greenhouse rather than directly planting them in the field could be a better option to maximize survival. Specifically, we tested soaking the cuttings in water for different lengths of time, the efficacy of using rooting hormones, and the effect of collecting the cutting material in the fall or spring. Although it is well know that cuttings collected later in the season, just before bud break, flush earlier after planting (Phipps and Netzer, 1981; Cunningham and Farmer, 1984; Houle and Babeux, 1993), collecting cuttings in the fall is often more convenient (less snow cover, more time to complete the task). Moreover, early bud break could be detrimental for the trees, in the case where they would leaf out before rooting (Farmer, 1966). Soaking poplar cuttings in water before planting has been shown to stimulate the development of latent root primordia (Petersen and Phipps, 1976; Hansen et al., 1993; Riemenschneider, 1997). Cuttings can also be dipped in rooting hormone (indolebutyric acid (IBA)), to increase rooting success (Nordine, 1984). Cunningham and Farmer (1984), however, found that treating balsam poplar cuttings with 100 ppm IBA did not increase rooting of cuttings collected between November and April. Perhaps the higher IBA concentrations in commercially available solutions (4000–8000 ppm) would be more effective in enhancing rooting.

Using results from the greenhouse propagation trial as a guide in selecting pre-planting treatments for the cuttings, we subsequently evaluated the performance of unrooted balsam poplar stem cuttings for direct field planting. A subset of three soaking and rooting hormone treatment combinations were used to reclaim typical forestry sites lacking natural regeneration with unrooted balsam poplar cuttings. Additionally, we compared growth and survival of full-length whips and 30 cm-long cuttings, collected in the fall or spring, as well as different methods of collecting and storing the planting material. For different poplar species, collecting cutting material from basal and mid-lower shoot locations increased the production of roots compared to cuttings from mid-upper or tip locations (Bloomberg, 1959; Smith and Wareing, 1974; Schroeder and Walker, 1991). It has also been found that although they are more costly to produce and plant, long cuttings usually survive and grow more than short cuttings (Allen and McComb, 1956; Berthelot, 1990; Rossi, 1991). Furthermore, cuttings stored in longer segments might better withstand the storage period between collection and planting.

2. Methods

2.1. Greenhouse trial

In November 2000 and February 2001, 10 cm-long dormant stem cuttings were collected from 1-year-old balsam poplar wood. These were grown in production stoolbeds, high-density beds of shoots (stools) cutback each year for cutting production. Half of the cuttings were collected from a superior selected clone (SS), in a stoolbed located at the Alberta-Pacific Forest Industries Inc. (Al-Pac) mill site (54°N, 112°W). The other half of the cuttings came from a stoolbed established from randomly selected trees (RS), at the Smoky Lake Forest Nursery (54°N, 112°W), Alberta, Canada.

All cuttings were manually prepared with hand pruners, ensuring that they all had a vegetative bud located within 1 cm of the top. Since position in the stool can affect rooting ability in *Populus* spp. (Bloomberg, 1959; Smith and Wareing, 1974; Schroeder and Walker, 1991), each cutting was collected from the same location in different stools of similar size, 30 cm above the base. The cuttings were stored in the freezer at $-3\,^{\circ}C$, in sealed plastic bags, until the experiment started in early March 2001. The experiment was designed as a $7 \times 3 \times 2 \times 2$ factorial with seven soaking lengths of time (0, 1, 2, 3, 4, 5, and 14 days), three dips (none, powder rooting hormone (Stim-Root No.3™ rooting powder at 0.8% IBA) and liquid rooting hormone (Stim-Root No.3™ liquid rooting hormone at 0.5% IBA)), two collection dates (fall: November; spring: February), and two selections (SS and RS cuttings). Each treatment combination was randomly distributed and repeated in nine different blocks to compensate for variability in greenhouse conditions, for a total of 756 cuttings ($n = 756$). The cuttings were soaked at room temperature in the greenhouse, placed vertically in cold tap water, covering three-fourth of their length. The water was replaced daily with fresh cold water until each soaking treatment was completed. Cuttings were planted, after their respective soak and dip treatments, into a commercial potting mix (Metromix™, Ajax, Ontario), consisting of equal amounts of peat moss, vermiculite, sand and perlite with a pH of 7. Styroblock™ (Beaver Plastics, Edmonton, Alberta) 415D containers (123 ml plugs: 15.2 cm depth $\times$ 3.9 cm diameter) were used. The cuttings were planted flush with the soil surface, where the tip diameter of the cuttings was measured. The cuttings were then grown in a greenhouse with natural light supplemented with artificial lighting (450 μmol photons $m^{-2}s^{-1}$ photosynthetically active radiation (PAR) at pot level), to provide a 16 h photoperiod. Day temperatures were maintained at $21\,^{\circ}C$ and night temperatures at $18\,^{\circ}C$. The cuttings were fertilized on days 14, 28 and 42 with a solution of 28N–14P–14K mixed at a concentration of 200 ppm.

Height and basal diameter of the shoots produced by the rooted cuttings were measured 8 weeks after planting, before all plants were destructively harvested. The soil media was gently washed from the roots under running water using a fine mesh sieve to avoid loss of fine roots. All plant parts including the original cutting, roots, stem and leaves were oven-dried to constant weight at $80\,^{\circ}C$, and dry mass measured to the nearest 0.001 g.

2.2. Field trial

For this part of the study, 2160 stools were collected concurrently and from the same stoolbeds as the cuttings used in the greenhouse study (described above). One-third of the stools were kept at their full-length to be planted as long whips (>60 cm in length). The remaining stools were cut into 60 cm-long sections, from which half were immediately re-cut into 2–30 cm-long cuttings (bottom 30 cm and top 30 cm) before being stored in sealed plastic bags in the freezer at $-3\,^{\circ}C$. The other half of the 60 cm-long cuttings were stored whole, and cut into bottom and top 30 cm-long cuttings only after the storage period and just prior to soaking and planting in the field. In early June 2001, the different types of cuttings were removed from storage and received one of three preplanting treatments: 1 or 3 days of soaking in water, or 3 days of soaking in water with a dip in rooting hormone (rooting hormone gel at 0.4% IBA, Wilson Laboratories Inc., Ontario) prior to planting. These treatments represented a total of 60 different combinations, which were replicated with 10 cuttings planted in three blocks on two different sites (Conklin and Heart Lake), for a total of 3600 cuttings ($n = 3600$).

Cuttings were soaked for their respective number of days and brought to the field in large Tupperware™ basins in early June 2001. The planting sites consisted of small areas lacking natural regeneration where temporary (used for less than 2 years) harvesting roads and adjoining landing areas were previously located. Five of the six experiment blocks had been site-prepared in early September 2000 with an excavator-mounder (model 320L, John Deere, Moline, Illinois), while one block at the Conklin site was left unmounded. The mounds were approximately 0.4–0.7 m in height and 0.75 m across. At the mounded sites, cuttings were planted on the highest microsite of each mound, on top of the over-turned mineral soil layer. The short cuttings were planted leaving approximately 1–2 cm of the cutting sticking out of the ground. The long cuttings were planted to the same depth, leaving >30 cm of the whip sticking out of the ground. Two cuttings were planted on each mound, one from the superior selection (SS cuttings) and one from the random selection (RS cuttings), each identified by a colored flag and spaced 0.5–0.6 m apart.

Before planting, length, and diameter at 30 cm height were measured for the long whips, while diameter at the soil surface, only, was measured for the short cuttings. After their first growing season, survival, height and basal diameter of all cuttings were measured in October 2001. Second-year measurements were taken in October 2002 for the Heart Lake site only, as the Conklin area burned during a large forest fire in early summer 2002.

The two planting sites are part of the Central Mixedwood Subregion (Hosie, 1979) or Mid Boreal Mixedwood ecoregion of Alberta (Strong and Leggat, 1992). Topography is flat to undulating terrain, with average elevations of 618 m for Conklin and 583 m for Heart Lake. The subregion is characterized by a continental boreal climate with long and cold winters (mean temperature −10.5 °C) and short cool summers (mean temperature 13.8 °C). Annual total precipitation is approximately 380 mm with the majority falling in the summer months (240 mm). The two sites had well-drained Dark Gray Luvisolic soils, except for the un-mounded block at Conklin which was moderately well drained. Typical vegetation is aspen and balsam poplar stands interspersed and/or mixed with pockets of white spruce. Most common understorey species are bluejoint grass (*Calamagrostis canadensis* Michx.), wild sarsaparilla (*Aralia nudicaulis* L.), prickly rose (*Rosa acicularis* Lindb.), fireweed (*Epilobium angustifolium* L.), bunchberry (*Cornus canadensis* L.) and dewberry (*Rubus pubescens* Raf.).

The greenhouse and field trials were analyzed with SAS (SAS Institute, version 8.02) as completely randomized blocked designs, using initial basal diameter of cuttings as a covariate in the analyses. Comparisons of means among the different levels of treatments were done using least square means (lsmeans) with the least significant difference (LSD) comparison procedure. The binary dependent variable ‘survival’ was analyzed in both studies using multiple logistic regression models (PROC Logistic). The performance of cuttings from the two selections (SS and RS cuttings) were analyzed separately because the cutting material did not come from the same nursery and therefore may have exhibited rooting and growth differences due to differing cultural practices before the cuttings were collected. A significance level of $P < 0.05$ was chosen.

3. Results

3.1. Greenhouse propagation

Over all treatments, 90% of the SS cuttings and 57% of the RS cuttings successfully rooted. Cuttings that did not root within 8 weeks were dead (rotted). Cuttings that did not receive rooting hormones survived in greater proportions than cuttings that received powder or liquid rooting hormones (Fig. 1). While survival of the SS cuttings was not affected by season of collection, those collected in the spring reached 13 and 8% greater height and basal diameter, respectively, than those collected in the fall (Fig. 2). Growth of the RS cutting material followed the same trend (Fig. 2), but differences were not statistically significant due to their greater variability in growth and to fewer live cuttings at the end of the experiment ($n = 75$ for fall-collected cuttings; $n = 135$ for spring-collected cuttings). RS cuttings survived in greater proportions when collected in the spring (spring: 72%; fall: 42%; $P < 0.001$). Soaking did not significantly increase survival of the SS cuttings (Table 1), but it increased height ($P = 0.002$) and slightly increased basal diameter ($P = 0.04$; Table 1). Soaking spring-collected SS cuttings for 1–3 days also increased root dry mass and root:shoot ratios, while it did not

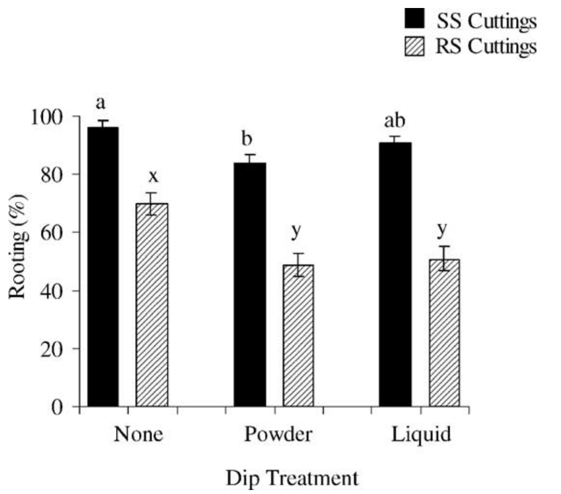

Fig. 1. Proportion of rooted cuttings for each dip treatment, 8 weeks after planting in the greenhouse. Bars (S.E.s) with the same letter are not significantly different at $P < 0.05$.

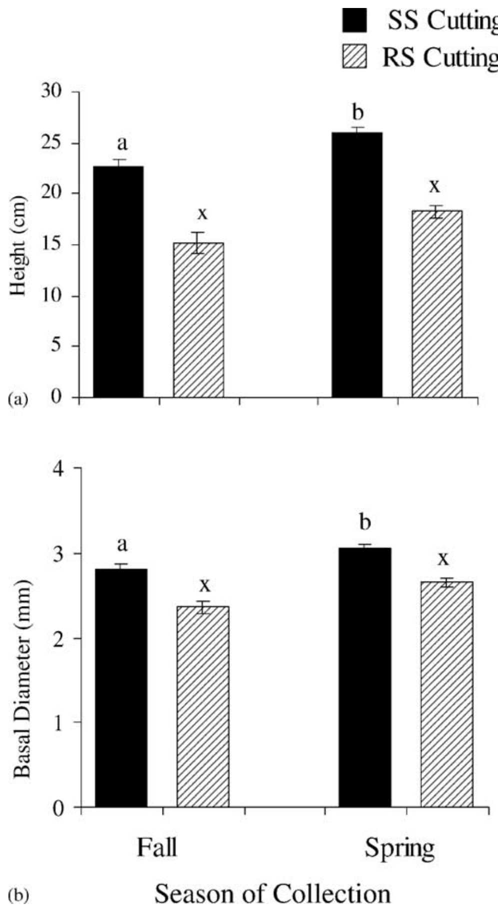

Fig. 2. Average height (a) and basal diameter (b) of the plants produced by the cuttings collected in the fall and spring, 8 weeks after planting in the greenhouse. Bars (S.E.s) with the same letter are not significantly different at $P < 0.05$.

increase root growth of cuttings collected in the fall (Fig. 3). Soaking for 1 day increased root dry mass of the RS cuttings ($P = 0.01$), but did not increase survival ($P = 0.05$), height ($P = 0.23$), basal diameter ($P = 0.65$) or root:shoot ratios ($P = 0.56$; Table 1).

3.2. Field planting

3.2.1. SS cuttings

After the first growing season, survival of the long cuttings was 88% compared to 80% for the short cuttings ($P < 0.001$). Survival was similar among the site-prepared blocks (91%), while it was only 50% for the un-mounded block at the Conklin site, resulting in a significant site $\times$ block interaction ($P < 0.001$). Mean height and basal diameter were 36.8 cm and 5.9 mm for the site-prepared blocks after one growing season, while it was significantly lower (15 and 10%, respectively) for the un-mounded block. Survival of the SS cuttings was greater with 3 days of soaking, with or without the use of rooting hormones (Fig. 4). After the second growing season, survival was even more reduced if cuttings were only soaked 1 day, especially for the long cuttings collected in the spring (7% survival; Fig. 5).

At planting, mean basal diameter of the long and short SS cuttings were 6.2 and 5.6 mm, respectively ($P < 0.001$). After the first growing season, basal diameter of the long cuttings had increased to 7.6 mm, while basal diameter of the new shoots produced by the short cuttings was 4.1 mm ($P < 0.001$). Average height of the above-ground portion of the long cuttings was 44.6 cm at planting, which slightly increased to 48.0 cm for those collected in the fall and to 45.4 cm for those collected the spring after the first growing season ($P < 0.05$). We considered that short cuttings had no height at planting, because the buds from which new shoots emerged were located close to ground level. After the first growing season, height of the new shoots produced by the short cuttings was 25.0 cm, whether they were collected in the spring or fall ($P > 0.05$). During the second growing season, height and basal diameter increased by 4.4 cm and 1.6 mm for the long cuttings and by 9.0 cm and 2.2 mm for the short cuttings, respectively. However, the trees originating from the long cuttings still had greater height ($P < 0.05$) and basal diameter ($P < 0.05$) than those from the short cuttings after two growing seasons (long cuttings: 49.4 cm in height and 9.2 mm in basal diameter; short cuttings: 34.0 cm in height and 6.3 mm in basal diameter).

There was no effect of storage or cutting location on survival and growth of the short cuttings after 2 years, except for spring-collected cuttings originating from the base of stools that were 19% shorter than those originating from the top portion of stools ($P < 0.05$).

3.2.2. RS cuttings

After the first growing season, survival of the RS cuttings was 84% at Heart Lake, and 95% at Conklin

Table 1
Mean survival, height, basal diameter, root dry mass and root:shoot ratio of the SS (superior selected) and RS (randomly selected) cuttings, for each soaking treatment after 8 weeks of growth in the greenhouse

Soaking treatment (days)	Survival (%)	Height (cm)	Basal diameter (mm)	Root dry mass (mg)	Root:shoot ratio
SS cuttings					
0	88.7 ab[a]	20.4 a	2.8 ab	55.1 a	0.057 a
1	90.6 ab	24.5 bc	3.0 bc	80.9 b	0.079 bc
2	96.3 b	25.1 bc	2.9 bc	84.2 b	0.084 bc
3	85.2 ab	25.5 bc	3.0 bc	99.2 b	0.090 c
4	90.7 ab	26.9 c	3.1 c	80.4 b	0.071 ab
5	96.3 b	25.2 bc	3.0 bc	80.4 b	0.071 ab
14	83.3 a	22.6 ab	2.7 a	54.2 a	0.061 a
RS cuttings					
0	51.7 ab	13.9 a	2.5 a	34.4 a	0.047 ab
1	44.0 a	17.9 abc	2.7 a	84.0 b	0.075 b
2	51.3 ab	17.2 abc	2.5 a	49.1 ab	0.071 b
3	63.3 bc	15.0 ab	2.5 a	48.3 ab	0.062 ab
4	62.6 bc	18.6 bc	2.5 a	43.4 a	0.049 ab
5	50.3 ab	17.7 abc	2.7 a	51.8 ab	0.057 ab
14	69.7 c	19.1 c	2.5 a	29.7 a	0.045 a

[a] Numbers with the same letter in a column are not significantly different at $P < 0.05$.

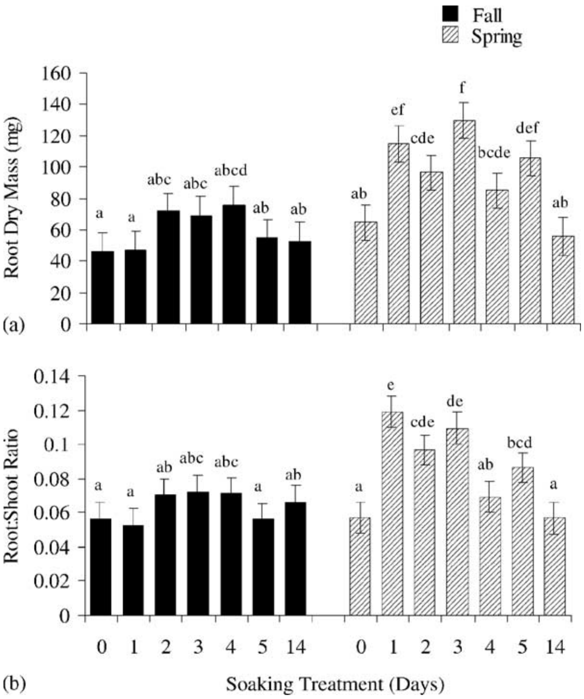

Fig. 3. Average root dry mass (a) and root:shoot ratio (b) of the plants produced by the SS cuttings for each season of collection × soaking treatment combinations, 8 weeks after planting in the greenhouse. Bars (S.E.s) with the same letter are not significantly different at $P < 0.05$.

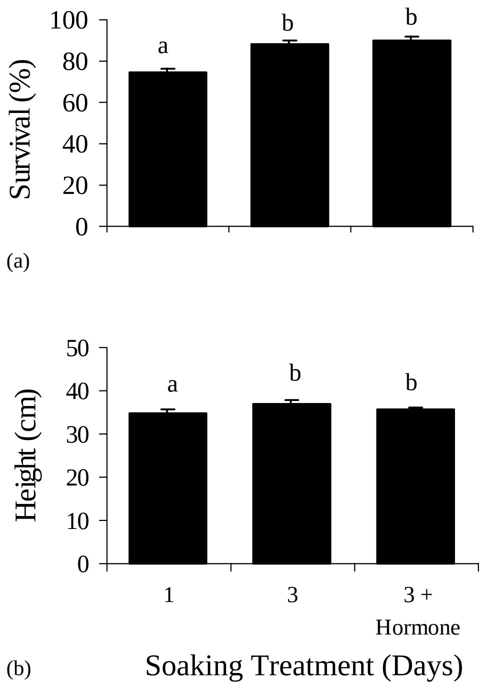

Fig. 4. Percent survival (a) and average height (b) of the plants produced by the SS cuttings after the first growing season for each soaking treatment. Bars (S.E.s) with the same letter are not significantly different at $P < 0.05$.

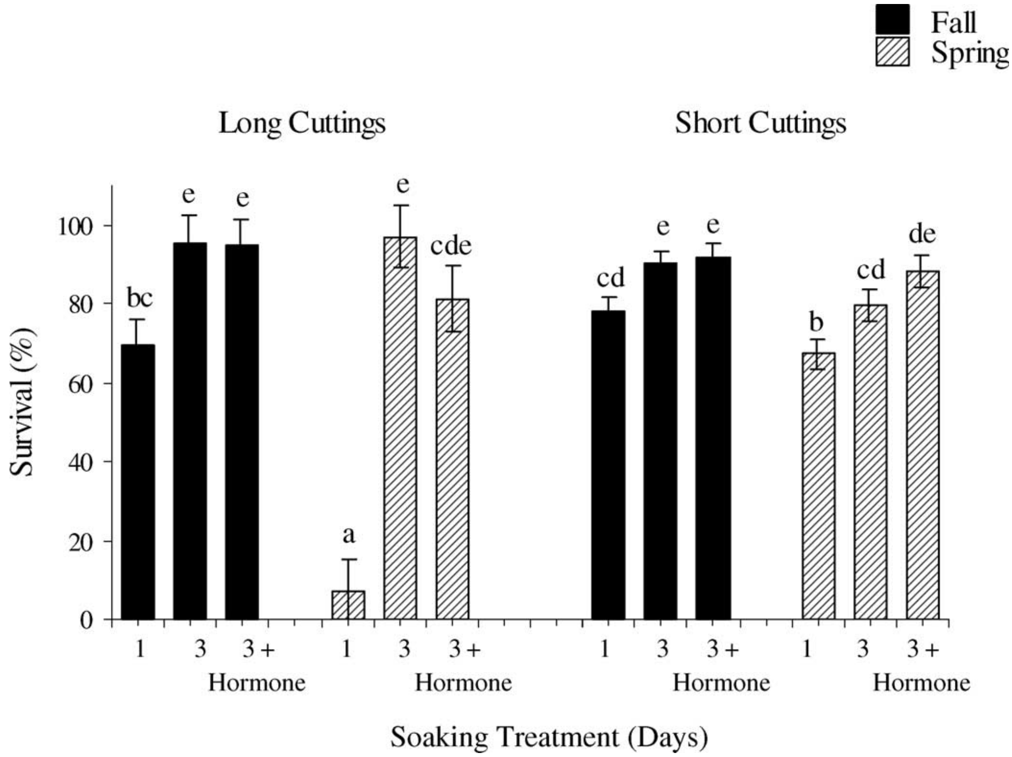

Fig. 5. Percent survival of the plants produced by the SS cuttings after the second growing season for each season of collection × soaking treatment combination. Bars (S.E.s) with the same letter are not significantly different at $P < 0.05$.

except for the un-mounded block that only had 40% survival. Survival was also reduced for the long cuttings collected in the spring if they were soaked for only 1 day, while soaking did not have an effect on survival of the short cuttings (Fig. 6a and b). After 2 years, overall survival at Heart Lake was 57.6% for the long cuttings and 67.6% for the short cuttings (Fig. 6b). However, long cuttings soaked only for 1 day had very poor survival, and overall survival increased to 72.1% after two growing seasons if these were excluded.

At planting, average height of the long cuttings was 70 cm and basal diameter was 9.0 mm, while average basal diameter of the short cuttings was 7.5 mm. The trees produced from the long cuttings had greater height and basal diameter after the first growing season when collected in the spring and soaked for 3 days, while soaking and season of collection did not significantly affect growth of the short cuttings (Figs. 7a and b and 8). Plants from spring-collected long cuttings still had greater height and basal diameter than those collected in the fall after two growing seasons (Fig. 7c and d), while the effect of soaking on growth of the long cuttings was no longer significant. On average, the short cuttings grew shoots 27.9 cm in height and 4.3 mm in basal diameter during their first growing season, increasing to 36.7 cm and 6.3 mm after the second growing season (Fig. 7).

Cutting origin (from the base or top portion of stool) did not have an effect on survival. However, cuttings originating from the top portion of stools grew 6.8% taller than cuttings from the base of stools after the first growing season ($P = 0.004$), and 9.1% taller after the second growing season ($P = 0.007$). Storage of the cuttings in 30 or 60 cm-long pieces did not have an effect on survival or growth of the cuttings in the field.

4. Discussion

Results from the greenhouse propagation trial indicated that balsam poplar cuttings should be collected in the spring and soaked for 1–3 days in water, without

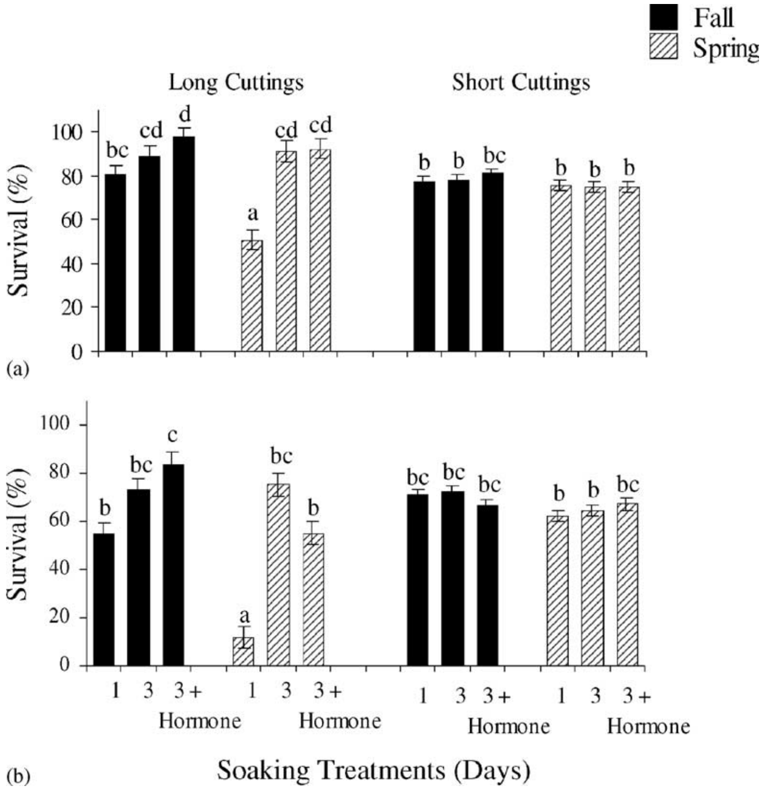

Fig. 6. Percent survival of the long and short RS cuttings after the first (a) and second (b) growing seasons, for each soaking treatment × season of collection combination. Bars (S.E.s) with the same letter are not significantly different at $P < 0.05$.

using rooting hormones, to maximize rooting and root growth of the produced plants. It has been shown that hybrid poplar (Phipps and Netzer, 1981; Fege and Phipps, 1984) and balsam poplar (Farmer, 1966) cuttings rooted and developed faster the later in the season (towards spring) they were collected. Early shoot development was beneficial in the controlled, well-watered greenhouse conditions (Figs. 2 and 3). However, when planted in the field, early shoot development may be detrimental to cutting establishment if too many leaf buds expand before roots have time to develop (Farmer, 1966). With more than 30 cm of stem length sticking out of the ground at planting and carrying many leaf buds, survival of spring-collected long cuttings was strongly reduced if they were only soaked for 1 day (Figs. 5 and 6). Cuttings collected in the spring may also have been more dehydrated than those collected in the fall, being subjected to winter winds and desiccation for a longer period of time. The longer soaking period was certainly beneficial for survival and growth of the long cuttings in the field (Figs. 4–6 and 8), presumably lessening moisture stress of the cuttings until roots developed. The effect of soaking was not as important for the short cuttings; transpiration and moisture stress were likely reduced since they were buried for most of their length at planting, allowing only one or two leaf buds to develop. Although the length of the soaking period was not critical for rooting success in the greenhouse (Table 1), the plants produced after at least 1 day of soaking had a greater root mass and root:shoot ratio, giving them an advantage for later outplanting on moisture-limited sites.

Commercial rooting hormones decreased the rooting success in the greenhouse (Fig. 1), and had essentially no effect on survival or growth of the field-planted cuttings (Figs. 4–6 and 8). The commercial formulas used for the greenhouse trial, recommended

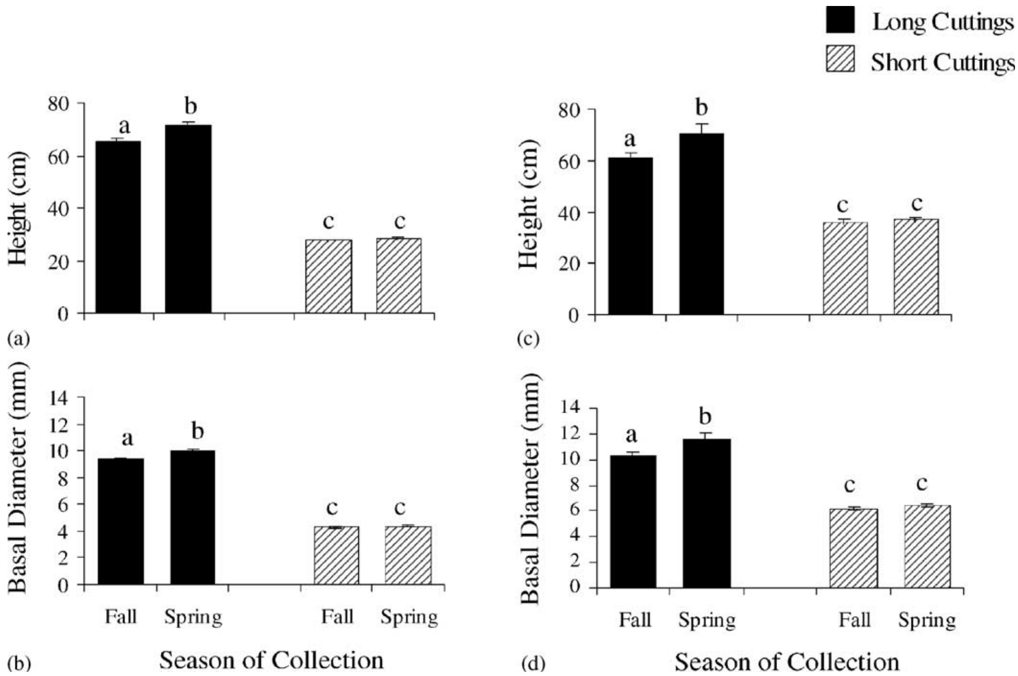

Fig. 7. Average height and basal diameter of the plants produced by the long and short RS cuttings, collected in the fall and spring after one (a and b) and two (c and d) growing seasons. Bars (S.E.s) with the same letter are not significantly different at $P < 0.05$.

for rooting hardwood cuttings, had 0.5 and 0.8% indolebutyric acid (IBA), which may be too high for balsam poplar cuttings. Balsam poplar branches already have the ability to root and do so naturally, as part of the species regeneration strategy (Dewit and Reid, 1992). Application of rooting hormone may have added too much IBA, thereby acting as a root growth inhibitor at high concentrations (Kozlowski and Pallardy, 1997).

Although the plants from the long cuttings were taller than those from the small cuttings after two growing seasons (Fig. 7), their actual amount of height growth was negligible, and even slightly decreased from their initial height at planting for the RS cuttings. A high proportion of the long cuttings suffered from tip dieback during the first growing season. This was probably caused by the very low initial root/shoot ratios at planting (no roots and >30 cm of stem sticking out of the ground). This may have affected the RS cuttings more strongly because they were initially bigger on average than the SS cuttings.

There was heavy grass competition at the unmounded block, probably causing the decrease in survival and growth of the cuttings. Grass keeps soils cold (Landhäusser and Lieffers, 1998), which in turn has been shown to decrease root development in aspen (Landhäusser et al., 2001). For the site-prepared blocks, on the other hand, the overturned layer of soil provided elevated and grass-free microsites for most of the two initial growing seasons, keeping the soil around the cuttings warmer (DesRochers and Thomas, 2003). Work by Dumant (1979) and Hansen (1986) emphasize the importance of warm soil temperatures (>10–15 °C) for successful rooting of various hybrid poplar cuttings.

We had anticipated that storing the cuttings in shorter segments may have rendered them more susceptible to deterioration or dehydration during the 3–6 months storage period, but storing the cuttings as 30 or 60 cm-long pieces had no effect on survival or growth in the field.

Cuttings originating from the top portion of the stools had similar survival than cuttings collected from the bottom portion of the stools. In some hybrid poplar varieties, the lower portion of stools have been reported to have higher rooting potential than mid

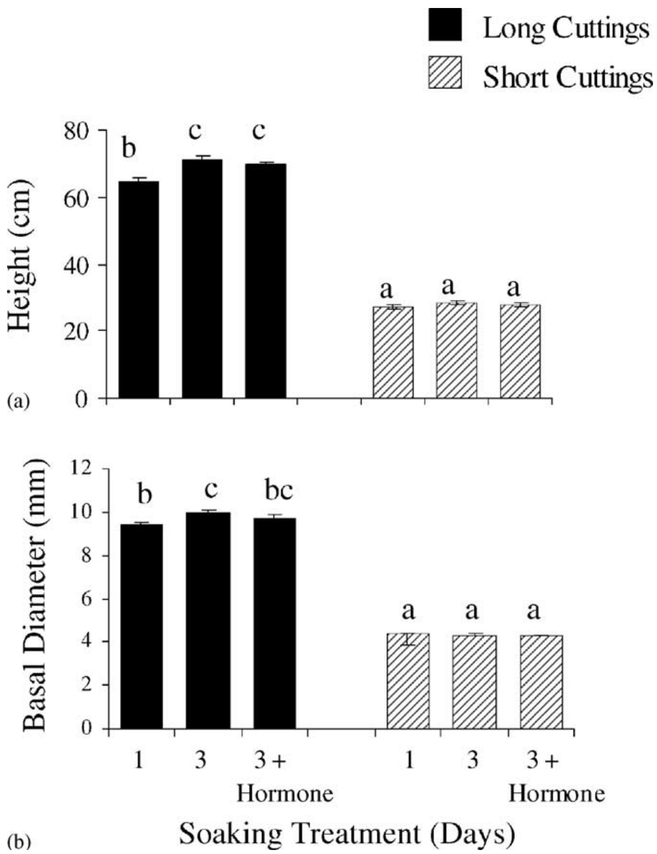

Fig. 8. Average height and basal diameter of the plants produced by the long and short RS cuttings after the first growing season, for each soaking treatment. Bars (S.E.s) with the same letter are not significantly different at $P < 0.05$.

or top portions because of the presence of more root primordia (Smith and Wareing, 1974; Schroeder and Walker, 1991). However, in this study, the top portions of stools grew taller plants than bottom portions. Work from Berthelot (1990) with different hybrid poplar varieties showed that the large buds from higher portions of the stools usually produced more vigorous plants than those from small basal buds.

4.1. Conclusions and operational recommendations

Despite the dry summer conditions of 2001 and 2002, overall survival of unrooted balsam poplar cuttings in the field was surprisingly high. Although balsam poplar is most commonly found on moist soils (Peterson and Peterson, 1992), the cuttings were able to withstand the relatively dry and warmer conditions of the mounds until roots developed. Cuttings should be soaked for 1 and 3 days in water prior to planting in the greenhouse and in the field, respectively. The effects of soaking before outplanting also emphasizes the importance of cultural practices at the nursery, which should ensure that cutting material is well hydrated in the fall when entering winter dormancy. The use of rooting hormone is not recommended since it decreased or had no effect on growth and survival of the cuttings. It is more economical and logistically easier to store, transport and plant 30 cm cuttings than whip-long (>60 cm) material. Combined with a 3-day soaking period, cuttings can be collected in the fall or in the spring for outplanting. Cuttings should be planted deeply to avoid development of too many leaf buds, which may cause desiccation before roots develop. Even though mounding was not specifically tested in this study, the cuttings planted at the unmounded block had such poor survival and growth that we strongly recommend mounding planting sites to control grass competition and increase soil temperatures around the cuttings. The greater overall performance of the SS cuttings in the greenhouse suggests a potential benefit of selecting superior material for rooting ability, drought resistance and increased growth rate. Although this study did not compare the performance of rooted versus unrooted cuttings in the field, direct field-planting of unrooted balsam poplar cuttings, avoiding the cost of greenhouse propagation altogether, may prove an operationally viable option for forestry companies in this area to regenerate pockets of territory lacking sufficient natural regeneration.

Acknowledgements

This research was funded by Alberta-Pacific Forest Industries Inc., in collaboration with Forest Resource Improvement Association of Alberta and the Natural Sciences and Engineering Research Council of Canada through an Industrial Research Fellowship to AD. We also thank the University of Alberta, L. Blackburn, D. Kamelchuk, K. Koehler-Munro and other technicians involved in greenhouse and field work.

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