Effect of Soil Temperature on Rooting and Early Establishment of Balsam Poplar Cuttings

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Low soil temperatures are the primary limiting factor when using non rooted balsam poplar (Populus balsamifera *L.) stem cuttings for reforestation of highly productive, nutrient rich, cold, wet boreal sites that have severe grass competition problems. This study investigated the effect of soil temperature on the establishment and early growth of dormant balsam poplar hardwood stem cuttings. During a 6-wk experimental period, nonrooted cuttings were subjected to 3 soil temperatures-5, 15, and 25 °C (41, 59, and 77 °F). The soil temperatures were maintained by submerging water-tight pots into temperature controlled water baths. Cuttings exposed to a soil temperature of 5 °C did not produce any roots by the end of the 6-wk experiment. At 5 °C, cuttings had 80% survival and less top growth compared to cuttings grown at soil temperatures of 15 and 25 °C. At 15 and 25 °C, survival was 100%, and all cuttings produced roots. The cuttings grown at 25 °C had the highest biomass of aboveground and belowground plant components. The strong sensitivity of root development in dormant stem cuttings of balsam poplar to low soil temperatures will have a large impact on the use o f nonrooted cuttings for reforestation on cool, wet sites.* Tree Planters' Notes 50(1): 34-37; 2003.

Valley-bottoms, floodplains, and seepage slopes are some of the most productive forest sites of the boreal forest. In late successional stages, these sites are commonly dominated by white spruce *(Picea glauca* (Moench) Voss). However, after harvesting, these sites can become too wet for successful conifer regeneration due to high water tables. Marsh reed grass *(Calamagrostis canadensis* (Michx.) Beauv.) is a fierce competitor with tree species and can dominate these sites after harvesting (Eis 1981; Landhausser and Lieffers 1998). Complete loss of conifer plantations can result. When marsh reed grass dominates a site, the accumulation of a heavy thatch can lead to delayed spring thawing of the soil and lower (by about 6 °C, 11 °F) midsummer soil temperatures (Hogg and Lieffers 1991).

At an early to mid successional stage, balsam poplar *(Populus balsamifera L.)* is commonly found on these productive, moist-to-wet (sub-hygric) soils (Zasada and Phipps 1990; Peterson and others 1996). The establishment of balsam poplar on these cool, grass-dominated sites could prove advantageous, not only by shading out marsh reed grass, but also by creating a nurse crop for white spruce.

Balsam poplar reproduces asexually very well through stem cuttings due the presence of preformed root primordia. The use of nonrooted stem cuttings in the field could provide an inexpensive and potentially effective alternative to the planting of rooted cuttings or seedlings. However, there are many factors influencing the success of root initiation and growth in cuttings. The selection and position of cuttings are important, since cuttings of last year's growth from young trees tend to root more easily than cuttings from older plants (Nordine 1984), and lower portions of the cutting tend to produce more root primordia (Bloomberg 1959; Smith and Wareing 1974). In addition, carbohydrate status, as a function of the diameter and length of the cutting, is considered very important in the success of rooting (Nanda and Anand 1970; Tschaplinski and Blake 1989; Rossi 1991). Storage (Fege and Phipps 1984), date of collection (Phipps and Netzer 1981; Fege and Phipps 1984), and the treatment before rooting-such as soaking (Hansen and Netzer 1993) and application of rooting hormones or fungicides (Nordine 1984)-are also important factors influencing rooting success of cuttings. However, since soil temperature is likely the major limiting factor in the establishment of nonrooted stem cuttings on these grass-dominated sites, the objective of this study was to investigate the rooting potential of balsam poplar stem cuttings when exposed to different soil temperatures.

Methods

In February 1999, 1-m-long whips of balsam poplar shoots collected from randomly selected clones were cut in the Slave Lake area, Alberta, Canada, wrapped in plastic, and stored in a freezer at -10 °C (14 °F). After 6 wk of storage, 90 cuttings, each 20 cm (8 in) long with similar diameters averaging 6.3 mm (0.25 in) (s = 0.63 mm, 0.025 in) and a terminal bud, were made from the most recent year's growth. The cuttings were soaked in water for 3 days at 2 °C (35.6 °F), and then 2 cuttings (subsamples) per whip were planted 10-cm-deep into a pot (15-cm diameter x 12-cm depth, 5.9 X 4.7 in) filled with sand. Cuttings were subsequently grown at 3 soil temperatures (5, 15, and 25 °C; 41, 59, and 77 °F); with 15 replicates for each soil temperature treatment.

To control soil temperature, the pots were submerged into 9 water baths (3 for each temperature) consisting of water-tight insulated polyethylene boxes (150 L, 39.6 gal). A similar design was used successfully by Landhausser and Lieffers (1994). Soil temperature treatments were maintained by regulating the water temperature with thermostats in the baths and circulating the water at 13 L/min (3.4 gal/min). Five pots were placed in each bath (15 per test temperature). To prevent water logging, the pots had false bottoms that allowed for free drainage of water into the bottom of the pot. A hose was inserted into this drainage area to suction out excess soil water. The space between the pots in the baths was covered with a white polystyrene board, and the soil surface in the pots was covered with perlite to a depth of 2 cm (0.79 in) for insulation.

The growth chamber conditions during the 6-wk period were 18 h light and 6 h dark with a day air temperature of 18 °C (64.4 °F) and night temperature of 16 °C (60.8 °F). The relative humidity was maintained at 70%. Photosynthetic flux density was 400 µmol.m-2.s ^{i} at 20 cm (8 in) above the soil surface. The light flux density at different water bath positions in the growth chamber was not different (P = 0.11). The pots were watered to field capacity when necessary, and after bud flush they were fertilized weekly with 0.1 L of a 2 g/L (0.105 qt, 0.07 oz/qt) solution of a commercial fertilizer (N:P:K 20:20:20) with chelated micronutrients. The pots were moved weekly to different water bath positions to minimize positional effects.

After 6 wk, the experiment was terminated. Survival and root development were determined on all 90 cuttings. A cutting was considered dead when no green leaves were present. Necrotic shoots with some partially green leaves were still considered alive. Height growth; leaf area; and stem, leaf, and root dry weights were determined on a random sample of 10 cuttings for each soil temperature.

The design of this experiment was completely randomized with soil temperature as the single fixed factor. After log transformation of total leaf area and dry weight of roots, all response variables met the assumption of normal distribution and homogeneity of variances. To test for treatment effects, analysis of variance with least significant difference multiple comparisons were performed with PROC GLM (SAS 1988). The significance levels were set at x=0.05.

Results

All balsam poplar cuttings broke bud within 7 d of planting. Cuttings in the 25 °C (77 °F) soil flushed about 2 d earlier than those at 5 °C (41 "F). At the end of the 6wk experiment, survival of cuttings was 100% in soil temperatures of 15 (59 "F) and 25 °C. At 5 °C the survival rate was 80%. Stem cuttings at 15 and 25 °C produced roots, while root development was completely absent at a soil temperature of 5 °C. Average root dry weight was doubled at 25 °C (0.309g) when compared with plants growing at 15 °C (0.144 g, P=0.0001) (figure 1). Total dry weight (including stem cutting) of balsam poplar cuttings grown at a soil temperature of 5 °C was 2.28 g compared to 3.17 and 5.97 g at 15 and 25 °C, respectively. The average dry weights of the new shoots at 5, 15, and 25 °C were 0.286, 1.09, and 3.84 g, respectively; about 10-fold larger than the root mass (figure 1). This resulted in generally low root:shoot ratios for cuttings exposed to the 3 soil temperatures. However, the root:shoot ratio of cuttings grown at 15 °C (r/s=0.128) was greater than that of cuttings grown at 25 °C (r/s=0.079) (P<0.05) (figure 1).

Although the terminal buds of all cuttings exposed to a soil temperature of 5 °C flushed, the shoots did not elongate and the leaves became necrotic and partially abscised. At a soil temperature of 25 °C, the cuttings had the tallest new shoots with an average of 20.1 cm (7.9 in), compared to 10.2 (4.0 in) and 2.2 cm (0.9 in) at 15 °C and 5 °C, respectively (P=0.0001). Cuttings grown at 25 °C had a greater number of leaves with 36, compared to 19 and 7 leaves per plant at 15 and 5 °C, respectively (P = 0.0001). The average leaf size was also significantly different for the 3 soil temperatures. The average area per leaf was smallest at the coldest soil: 2.7 cm^2 (0.42 in^2) at 5 °C, 6.1 cm^2 (0.95 in^2) at 15 °C, and 15.3 cm^2 (2.37 in^2)

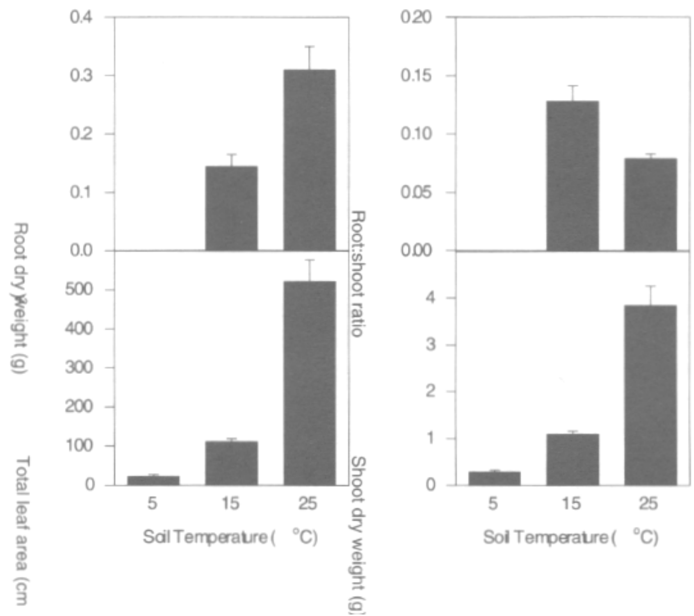

Figure *1-Aboveground and belowground responses of non rooted balsam poplar (Populus balsamifera L.) cuttings subjected to soil temperatures of 5, 15, and 25 °C (41, 59, 77 °F) (x ± s_x).*

at 25 °C (P = 0.0001). These differences in leaf size and number resulted in a total leaf area of 521 cm^2 (81 in) per plant grown at 25 °C, which was $4x_2$ higher than the total leaf area of plants at 15 °C (111 cm^2, 17.2 in^2), and 23x higher than plants grown at 5 °C (23 cm^2, 3.6 in^2, P = 0.0001) (figure 1). Similarly, leaf dry weights were 0.159, 0.756, and 2.765 g for the 3 soil temperatures of 5,15, 25 °C, respectively (P = 0.0001).

Discussion

Low soil temperature strongly affected the development of roots and shoots from balsam poplar cuttings; a soil temperature of 5 °C (41 °F) resulted in 20% mortality (no green leaves), a complete lack of root development, and poor leaf and shoot development after 6 wk. In a related study (Landhausser, unpublished data), rooted balsam poplar stem cuttings (container stock) suffered high mortality (72%) with no new root growth after 6 wk at 5 °C, while no mortality and abundant new root growth were observed at 20 °C (68 °F). Cool soil temperatures are very common early in the growing season in boreal forests (Bonan 1992), and these low soil temperatures can be maintained by an insulating mat of slowly decomposing marsh reed grass litter (Hogg and Lieffers 1991). For the western boreal forest of Alberta, Hogg, and Lieffers (1991) found that on open cut blocks (logged sites), the maximum soil temperature at a depth of 5 cm (1.97 in) in mid-August reached 19 °C (66.2 °F) without grass, while only 13 °C (55.4 °F) under the grass cover.

The lack of root development at cool soil temperatures will directly affect the feasibility of using nonrooted balsam poplar stem cuttings for reforestation purposes on sites that are already occupied by the grass. The importance of warm (20 to 30 °C, 68 to 86 °F) soil temperatures for the development of roots in cuttings is recognized (Loach 1988; Ford-Logan 1994).

The results of this study indicate that cuttings should be planted in late spring or early summer of the growing season immediately after timber harvesting to give the cuttings a headstart before grass occupies the site. In the 1st growing season after harvesting, soil temperatures will likely be the highest on these sites, creating the most favorable conditions for root development. The use of longer whips than tested here could also give balsam poplar a height advantage over early establishing grass and shrubs. Longer whips might also be more effective since they have been more successful in the development and establishment of new roots and leaf area due to higher carbohydrate reserves (Nanda and Anand 1970; Tschaplinski and Blake 1989). By inserting a larger portion of the cutting into the ground, the development of roots along a larger section of the cutting could result in more access to moisture (Rossi 1991), producing more favorable root:shoot ratios than found in the present study.

The promotion of balsam poplar as a companion in mixed wood ecosystems is desirable because it can function as a nurse crop for the shade-tolerant white spruce. Additionally, the early establishment of balsam poplar can benefit sites by suppressing the grass and other competitors due to shading. This is especially true for productive, cool, wet sites that are prone to rising water tables and severe grass and shrub competition after harvesting (Lieffers and Stadt 1994; Peterson and others 1996). Balsam poplar is well adapted to growing on wet floodplains and seepage slopes (Zasada and Phipps 1990) while white spruce cannot tolerate these wet locations with severe grass competition (Eis 1981; Grossnickle 1987).

Conclusions

The rooting of balsam poplar stem cuttings was strongly influenced by soil temperature. To successfully establish stem cuttings, soil temperatures greater than 5 °C (41 °F) are necessary to permit adequate leaf and root development. Soil temperature can be considered the major limiting factor on cool, wet sites for the planting of nonrooted cuttings in the boreal forest. These results will impact the planting time of nonrooted cuttings for reforestation purposes on these problem sites. The results of this study are limited to the effect of soil temperature on the rooting ability of nonrooted balsam poplar stem cuttings. However, other factors, such as the length of the cutting and the planting time in relation to reducing the effects of competition, need to be addressed in future studies. In addition, the selection of clones more tolerant to low soil temperatures might be considered.

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References

Bloomberg WJ. 1959. Root formation of black cottonwood cuttings in relation to region of parent shoot. Forestry Chronicle 35:13-17.

Bonan GB. 1992. Soil temperature as an ecological factor in boreal forests. In: Shugart HH, Leemans R, Bonan GB, editors. System analysis of the global boreal forest. Cambridge (MA): Cambridge Press. p 126-143.

Eis S. 1981. Effects of vegetation competition on revegetation of white spruce. Canadian Journal of Forest Research II: 1-8.

Fege AS, Phipps H. 1984. Effect of collection date and storage conditions on field performances of *Populus* hardwood cuttings. Canadian Journal of Forest Research 14: 119-123.

Ford-Logan JL. 1994. The rooting environment for cuttings from forest trees. In: Foster GS, Diner AM, editors. Proceedings of the southern regional information exchange group biennial symposium on forest genetics; 1992 July 810; Huntsville, AL. Atlanta (GA): USDA Forest Service, Southern Forest Experiment Station. General Technical Report SO-108. p 97-112.

Grossnickle SC. 1987. Influence of flooding and soil temperature on the water relations and morphological development of cold-stored black spruce and white spruce seedlings. Canadian Journal of Forest Research 17: 821-828.

Hansen EA, Netzer DA. 1993. Guidelines for establishing poplar plantations in the north-central U.S. St. Paul (MN): USDA Forest Service, North Central Forest Experiment Station. Research Note NC-363. 5 p.

Hogg EH, Lieffers VJ. 1991. The impact of *Calamagrostis canadensis* on soil thermal regimes after logging in northern Alberta. Canadian Journal of Forest Research 21: 387-394.

Landhausser SM, Lieffers VJ. 1994. Competition between *Calamagrostis canadensis* and *£pilobium angustifolium* under different soil temperature and nutrient regimes. Canadian Journal of Forest Research 24: 2244-2250.

Landhausser SM, Lieffers VJ. 1998. Growth of *Populus tremuloides* in association with *Calamagrostis canadensis.* Canadian Journal of Forest Research 28: 396-401.

Lieffers VJ, Stadt KJ. 1994. Growth of understory *Picea glauca, Calamagrosfis canadensis,* and *Epilobium angustifolium* in relation to overstory light transmission. Canadian Journal of Forest Research 24: 1193-1198.

Loach K. 1988. Controlling environmental conditions to improve adventitious rooting. In: Davies TD, Hassig BE, Sankhla N, editors. Adventitious root formation in cuttings. Advances in plant sciences series, Volume 2., Portland (OR): Dioscorides Press. p 248-273.

Nanda KK, Anand VK. 1970. Seasonal changes in auxin effects on rooting of stem cuttings of *Populus nigra* and its relationship with mobilization of starch. Physiologia Plantarum 23: 99-107.

Nordine RM. 1984. Propagation from hardwood cuttings. Plants and Gardens 40: 40-42.

Peterson EB, Peterson NM, McLennan DS. 1996. Black cottonwood and balsam poplar manager's handbook for British Columbia. FRDA Report 250.116 p.

Phipps HM, Netzer DA. 1981. The influence of collection time and storage temperature on *Populus* hardwood cutting development. Tree Planters' Notes 32: 33-36.

Rossi P. 1991. Length of cuttings in juvenile development of a hybrid poplar clone. New Forests 5: 211-218.

[SAS] SAS Institute Inc. 1988. SAS/STAT User's guide. Release 6.03. Cary (NC): SAS Institute. 1028 p.

Smith NG, Wareing PF. 1974. The distribution of latent root primordia in stems of *Populus X robusta,* and factors affecting the emergence of preformed roots. Forestry 45: 197-209.

Tschaplinski TJ, Blake TJ. 1989. Correlation between early root production, carbohydrate metabolism, and subsequent biomass production in hybrid poplar. Canadian Journal of Botany 67: 2168-2174.

Zasada JC, Phipps HM. 1990. *Populus balsamifera* L. - Balsam poplar. In: Burns RM, Honkala BH, editors. Silvics of North America. Volume 2, Hardwoods. Washington (DC): USDA Forest Service, Agriculture Handbook No. 654. p 518-529