Accelerating Fraser Fir Seedling Growth with Benzylaminopurine Sprays

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Abstract. Foliar application of the synthetic growth regulator BA was evaluated for increasing the duration and extent of Fraser fir [*Abies fraseri* (Pursh.) Poir.] seedling growth. Aqueous solutions of 0, 222, or 444 μM BA (0, 50, or 100 ppm) were sprayed on the shoots of Fraser fir seedlings biweekly from 18 until 38 weeks after planting. Foliar sprays of 444 μM BA increased seedling height 19%, increased shoot weight 57%, reduced root weight 22%, and increased total weight 27%. Apical meristem activity was stimulated and the long periods of dormancy typical of Fraser fir seedlings were avoided. Chemical name used: 6-benzylaminopurine (BA).

Fraser fir seedlings grow slowly in their first growth cycles. In outdoor nursery beds, the onset of dormancy following short growth flushes (Hinesley, 1982) leads to the use of 5-year-old (3 years in a seedling bed and 2 years in nursery line-out beds) transplants for the establishment of Christmas tree plantations (Hinesley, 1981). In accelerated growth programs using container-grown seedlings in greenhouses, the provision of extra light (Hinesley, 1981; Seiler and Kreh, 1986), heat (Hinesley, 1981), and fertilizer (Black, 1980; Bryan, 1988; Seiler and Kreh, 1986) can permit recurrent flushes of growth for several months before seedlings enter dormancy. Dormancy, once established, is satisfactorily broken only by chilling. Attempts to by-pass the chilling requirement by provision of warmth, nutrients, and long photoperiod result in stunting, loss of apical dominance, terminal bud abortion, lack of symmetry, and other morphological abnormalities (Hinesley, 1982).

The application of growth regulators to facilitate the growth of Fraser fir seedlings has not been evaluated. In the closely related balsam fir [*Abies balsamea* (L.) Mill.], repeated application during the growing season

of the synthetic cytokinin BA, applied at 600 ppm (2664 μM), stimulated budbreak, increased production of lateral buds, and caused late-season bud-swell and lammas growth in 5- and 6-year-old transplants. In that same study, however, BA decreased stem elongation and caused chlorosis and necrosis in current-year needles (Little, 1984).

The present experiment was conducted to determine the effects of foliar application of BA on the duration of active growth and the extent of shoot and root growth of Fraser fir seedlings. In our preliminary investigations with aqueous foliar sprays of growth regulators on Fraser fir seedlings, BA had been found to stimulate budbreak in young seedlings. However, when applied in concentrations of 555 to 4440 μM (125 to 1000 ppm), BA treatments had reduced internode and needle elongation, caused drooping leaders, and shriveled the needles of some seedlings. Therefore, we used BA at 222 and 444 μM (50 and 100 ppm) to stimulate cell division and budbreak without damaging seedlings or decreasing elongation.

Fraser fir seeds collected from Mount Rogers, Vs., (latitude 37° N, elevation to 1746 m) were moist-stratified for 2 months at $\approx 3\text{C}$ to ensure uniform germination. On 1 Sept. 1987, seeds were placed in germination trays filled with Canadian sphagnum peat (Premier Brand, New Rochelle, N. Y.) amended with dolomitic limestone at 1.5 $\text{kg}\cdot\text{m}^{-3}$ to provide an average growth medium pH of 4.3, as described by Bryan et al. (1989). Six weeks after planting, 480 seedlings were transplanted into 150-cm³ Ray Leach seedling tubes (Cone-tainer Nurseries, Canby, Ore.) containing prewatered sphagnum peat amended as described above. Seedlings were grown in a greenhouse heated to 20C and ventilated at temperatures above 22C. The greenhouse occasionally reached 40C. Supplementary lighting ($\approx 150 \mu\text{mol}\cdot\text{s}^{-1}\cdot\text{m}^{-2}$ photosynthetic photon flux at the level of the seedlings, supplied by high-pressure sodium vapor lamps) extended the

photoperiod to 16 h-day⁻¹. Liquid fertilizer (10 ml/seedling) was applied weekly at concentrations of 200 ppm N, 87 ppm P, and 166 ppm K, supplied as Peters General Purpose 20-20-20 fertilizer (Peters, Fogelsville, Pa.). Plants were kept well-watered.

Three concentrations (0, 222, and 444 μM) of BA were prepared by dissolving crystalline BA (Product No. B-6750, Sigma, St. Louis) in distilled water with 0.1% Tween 80 surfactant. While higher concentrations of BA are difficult to dissolve, 444 μM BA dissolved easily at $\approx 25\text{C}$. Preliminary investigations had shown no effect of foliar spray of 0.1% Tween 80 surfactant on Fraser fir seedling growth.

Beginning 18 weeks after seeds were planted (12 weeks after transplanting), BA was sprayed on seedlings by means of a hand-held pump sprayer every 2 weeks for 20 weeks. The growth regulator was applied to the point of runoff from buds, needles, and stems and allowed to dry on the seedlings for 24 h before subsequent watering.

Seedlings were evaluated biweekly for active growth of the terminal leader during the last 10 weeks of the experiment. Active growth was determined by the presence of new pale-green needles and the absence of a formed bud. Seedlings that developed purple needles at any time during the experiment were marked and counted. Seedlings were harvested 38 weeks after planting. At the time of harvest, seedling heights were measured ($\pm 1 \text{ mm}$) from the growth medium surface to the top of the formed bud or growing stem. Stem diameter was measured with a caliper both at the root collar and in the middle of the last flush of growth. Seedlings were cut at the root collar, and roots and shoots were oven-dried at least 3 days at 60C before being weighed.

The experiment was designed with 480 seedlings in a randomized complete block design, with five blocks. Percentages of seedlings growing actively or developing purple needles were analyzed by regression following arcsin transformation (Dixon and Massey, 1969). Size-dependent variables were transformed logarithmically before regression analysis to provide more uniformity of variance between small and large seedlings (Dixon and Massey, 1969).

The first indication of a changed pattern of growth due to BA application was the appearance of bright-purple needles in flushes of growth following BA treatment (Table 1). Anthocyanin synthesis has been shown to accompany the promotion of cell division by BA (Ozeki and Komamine, 1981, 1986), and similar temporary coloration has been observed with BA application to other conifers (Kossuth, 1978). As the needles matured, normal dark-green needles developed.

It soon became apparent that a higher percentage of seedlings treated with BA were in a state of active apical growth than untreated seedlings in five of the six biweekly evaluations (Fig. 1). Some BA-treated seedlings appeared to grow almost continuously rather than forming buds, and left no bud-scale scars on the stem between flushes. At

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Table 1. Effects of 10 biweekly foliar applications of BA on Fraser fir seedling growth. Purple-needled seedlings were counted throughout the experiment and percentages of seedlings were evaluated after arcsin transformation. Size effects were evaluated 38 weeks after planting, 20 weeks after first BA application.

BA (μM)	Purple- needled seedlings (%)	Ht (cm)	Stem diam (mm)		Dry wt (g)			Root : shoot ratio (g)
			Last flush	Root collar	Shoot	Root	Total	
0	2*	6.8*	3.39*	2.91 ^{NS}	0.659*	0.396**	1.055*	0.58*
222	74	7.4	3.67	3.03	0.872	0.448	1.319	0.50
444	91	8.1	4.49	2.91	1.033	0.307	1.340	0.32

^{NS,*,**} Effects within columns are nonsignificant at $P = 0.05$ or significant (linear or quadratic) at $P = 0.01$, respectively.

Fig. 1. Effects of foliar BA sprays ($\square$, 0; $\square$, 222; $\blacksquare$, 444 μM) on maintenance of active growth of Fraser fir seedlings. Foliar sprays began 18 weeks after seeds were planted. Nonsignificant (NS), significant linear relationship at $P = 0.01$ (*), significant quadratic relationship at $P = 0.01$ (**), or significant quadratic relationship at $P = 0.06$ (***).

age 38 weeks, after 20 weeks of treatment, 86% of the seedlings sprayed with 444 μM BA had actively growing shoots, 58% of those sprayed with 222 μM BA were actively growing, while only 31% of the control seedlings showed apical bud activity. While the 444- μM BA spray maintained a consistently high percentage (61% to 86%) of seedlings in active growth throughout the experiment, the BA effect was not always linear: the 222- μM spray was sometimes much less equally effective (Fig. 1). The increase in percentage of Fraser fir seedlings growing actively after BA spray is consistent with the stimulation by BA of lammas growth in 5- and 6-year-old balsam fir (Little, 1984).

The stimulation of apical meristem activity by BA increased the shoot size of Fraser fir seedlings in several respects (Table 1). Compared with controls, BA at 444 and 222 μM increased Fraser fir seedling height 19% and 9%, increased stem diameter in the middle of the last flush of growth 32% and 8%, and increased shoot dry weight 57% and 32%, respectively.

While treatment with BA thickened the part of the stem produced during growth regulator treatment, BA did not thicken portions of the stem produced before treatment. In seedlings treated with 444 μM BA, the mean stem diameter in the middle of the last flush of growth was 32% greater than in seedlings with 0 ppm BA, but there were no BA ef-

fects on stem diameter at the root collar, where the stem had been formed before growth regulator application (Table 1). The increase in diameter of newly developed stem results from an increase in apical meristem size and/or activity, while an increase in width of already existing stem would require an increase in cambial meristem activity (Esau, 1977). Therefore, BA sprays apparently stimulated apical meristem activity but not cambial meristem activity. In seedlings treated with 444 μM BA, stem diameter in the middle of the last flush of growth was 54% greater than at the root collar (Table 1). Microscopic inspection of typical BA-treated stem sections and of the thinner stem sections of controls revealed that much of the increased growth consisted of cortical tissue. Stem sections thickened by BA treatment had more than twice the number of cortical cells per radial transect than stem sections of controls (data not presented). The thick upper stems stimulated by BA also developed bark scales like those of 4- and 5-year-old seedlings.

In contrast to the larger shoots stimulated by 444 μM BA, roots of seedlings treated with 444 μM BA weighed 22% less than roots of controls (Table 1). The root weight : shoot weight ratio decreased with increased concentration of BA. Reduced root growth could result in poorer performance following outplanting, a potential drawback of this treatment. It should be noted that the lower

concentration of BA (222 μM) did not reduce root growth. The mean total weight of 38-week seedlings produced with the 222- and 444- μM BA sprays was 25% and 27% higher, respectively, than that of seedlings grown without BA (Table 1).

The results of this study suggest that BA sprays in low concentrations (222 or 444 μM) have the potential to speed the production of Fraser fir seedlings. The changes in growth patterns induced by BA increased whole-plant growth significantly in the 20 weeks of treatment. By stimulating apical bud growth, BA sprays effectively avoided the long periods of dormancy typical of Fraser fir seedlings.

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