Growth of Fraser Fir Christmas Trees In Response to Annual Shearing

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Abstract. Fraser fir [*Abies fraseri* (Pursh) Poir.] Christmas trees were sheared once annually over a 4-year period using fixed schedules ranging from July to March. Shearing in July reduced potential growth of the upper crown by 38%; when done in October or March, the reduction was about 50%. Length, dry weight, and one-sided area of individual needles were smallest on nonsheared trees, and increased to maximum values on trees sheared in March. In the upper crown (top three internodes), trees sheared in July were 16% to 33% heavier than those sheared in August or later. Dry matter in the upper crown was 30% foliage and 70% woody material. Sixty-one percent of the biomass in the upper crown was branches for trees sheared in July, compared to 55% for October. In the upper crown, foliage comprised about 50% of the branch dry weight (all treatments); in 3-year-old branches, it was 54% to 58%. Among treatments, shearing in July caused the smallest reduction of potential growth and yielded the largest and heaviest branches with significantly more foliage and lateral shoots, all of which would be expected to improve crown density and commercial value. October was the least favorable time to shear.

Fraser fir (*Abies fraseri*) is a valuable Christmas tree species indigenous to isolated mountain tops in western North Carolina, eastern Tennessee, and southwestern Virginia. Christmas trees acquire their dense, conical shape as a result of annual pruning or shearing. True firs (*Abies* Mill.) are sheared once annually (Douglass, 1983; Whitfield, 1977), whereas faster growing species, e.g., virginia pine (*Pinus virginiana* L.), in warmer climates are sheared two or three times (Brown, 1979; Davis, 1972). An important issue is when to shear for best growth and quality.

The shearing season varies by species. Eastern white pine (*Pinus strobus* L.) has a narrow window of time for successful shearing (Whitfield, 1977). Virginia pine can form adequate numbers of buds on the current-year shoots when pruned throughout the summer (Brown, 1979; Davis, 1972). *Abies* can be sheared almost year-round, but middle to late summer shearing normally yields the best quality trees (Brown and Heilgmann, 2002; Douglass, 1983; Hinesley and Derby, 2004; Powell, 1982). Beyond that general observation, few specific growth effects resulting from pruning at different times have been documented, e.g., quantity and distribution of foliage; number, size, and distribution of branches; and allocation of growth to stems, branches, and foliage. Our objective was to examine the growth and distribution of dry matter in Fraser fir Christmas trees in response to annual shearing on different dates.

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Materials and Methods

The experiment was initiated in early August 1998 in a stand of Fraser fir (1 to 1.3 m tall, spacing 1.5 × 1.5 m) Christmas trees on the Upper Mountain Research Station near Laurel Springs, N.C. (lat. 36° 24' N, long. 81° 18' W). Soil was a Watauga loam (Typic hapludult, fine-loamy, mesic; elevation about 1,000 m, southwest aspect). Trees were grown with conventional cultural practices.

Five shearing schedules were used: control (nonsheared), late July, late August or early September, mid-October, and March. At the outset, trees were excluded if they were too small or off color. Acceptable trees were assigned to blocks, and treatments were randomly assigned to single-tree plots in each block. The experimental design was a randomized complete block, initially with 50 blocks (five trees per block). During the investigation some trees were omitted owing to damage from birds, insects, disease, and nutritional problems, or failure to produce a normal leader.

The first year, trees within various treatments were sheared by cutting the terminal leader to about 30 cm, and shortening the branches in the top whorl to half the length of the sheared leader. Below the top whorl the distal tip was removed from all major branches in the tree crown including the branch measured previously. Some trees with leaders shorter than 32 cm were not sheared in 1999 and eventually were excluded from the analysis. Shearing treatments were repeated according to schedule in 1999, 2000, and March 2001. No shearing occurred after the 2001 growing season to impart a more natural appearance, as in the year of harvest.

Needle measurements. On 20 Nov. 2001, needles were sampled on a dominant 2-year-old branch on each tree using methods previously described for Fraser fir (Brewer et al., 1992).

One current-year needle and one 2-year-old needle were taken from a dominant 2-year-old branch on each tree. Foliage is typically in a decussate (2-ranked) configuration with the largest needles attached to the abaxial (lower) side of the branch, mid-way between the proximal (inner) and distal (outer) ends of the internode (Brewer et al., 1992). One large needle was collected at that position in each internode. Needles were taped to labeled sheets of white paper, and stored in sealed freezer bags on ice. The next day, sheets were photocopied to preserve the images. Sheets, with needles attached, were dried at 65 °C, and needles weighed to the nearest 0.1 mg. Length and projected area were determined for each image using a Monochrome Agvion System area meter (Decagon Devices, Pullman, Wash. with DIAS II software (version 1.0, about 1989). Projected areas were multiplied by 1.145 to correct for the elliptical upper surface of needles (Brewer et al., 1992).

During winter (2000–01) two large branches (first-order laterals, 3 years old, opposite sides of the trunk) were selected at the top of the 1998 internode (25 trees/treatment), cut flush with the trunk, tagged, and placed in a nylon or burlap bag. The trunk was cut at the base of the 1999 internode, and all biomass above the cut was bagged with the two large side-branches. Material was transported to Raleigh, and stored at –1 °C.

Processing large branches. After measuring basal diameter (two directions), each of the two large branches from each tree was subdivided into shoot segments, by age (1, 2, and 3 years), and the number of segments counted. Segments were combined, by age, for each branch. After drying to constant weight at 65 °C, foliage and woody material were separated and weighed for each sample. Averages were computed for the two branches from each tree. Stem segments were processed similarly.

Processing the upper crown. For each tree, branches were removed, counted, and segregated for each of the three internodes. Leaders were counted and combined into one sample. Samples were dried at 65 °C, partitioned into wood and foliage, and weighed. Total dry weight was the sum of woody and foliar components.

Statistical analysis. Data were analyzed with general linear model (GLM) procedures (SAS Institute, Inc., 1990). Linear contrasts (1 df) were used to make certain treatment comparisons.

Results

Large branches. Shearing reduced branch growth (Table 1). Basal diameter and cross-sectional area of 3-year-old branches on nonsheared trees averaged 13% and 27% greater, respectively, than branches sheared in July. These differences were 24% and 54%, respectively, for trees sheared in August and October. Although July shearing yielded significantly larger branch diameters than August or October, average diameters for early shearing (July and August) versus later shearing (October and March) were not different (Table

Table 1. Biomass and number of shoots on 3-year-old branches of fraser fir Christmas trees sheared on various schedules.²

Shearing date ^y	No. of trees	Branch diam (mm)	Branch dry wt			Branch segments	
			Wood (g)	Foliage (g)	Total (g)	1-year-old (no.)	2-year-old (no.)
Nonsheared (control)	22	15.8	66	81	147	89	21.2
July	24	14.0	41	51	92	51	9.3
August	25	12.7	30	41	71	34	8.2
October	23	12.7	26	32	58	25	6.4
March	25	13.4	33	39	72	26	7.7
Control vs. sheared		**	**	**	**	**	**
July vs. Aug.		**	**	**	**	**	NS
August vs. October		NS	NS	*	NS	*	*
October vs. March		NS	*	NS	*	NS	NS
July and August vs. later		NS	**	**	**	**	**

²Values are means based on two branches per tree.^ySheared on these schedules the last 4 years before harvest.NS,*,**Nonsignificant or significant at $P < 0.05$ or 0.01 , respectively.Table 2. Dry weight of wood and foliage in the top three internodes of fraser fir Christmas trees sheared on various schedules.²

Shearing date ^y	No. of trees	Stem (g)	Branches			Total		
			Wood (g)	Foliage (g)	Total (g)	Wood (g)	Foliage (g)	Total (g)
Nonsheared (control)	22	480	378	392	770	850	400	1250
July	24	307	238	238	475	532	250	782
August	25	273	190	209	399	450	222	672
October	23	265	160	162	321	412	175	586
March	25	286	171	174	346	441	191	632
Control vs. sheared		**	**	**	**	**	**	**
July vs. August		NS	*	NS	*	**	NS	*
August vs. October		NS	NS	*	*	NS	*	NS
October vs. March		NS	NS	NS	NS	NS	NS	NS
July and August vs. later		NS	**	**	**	*	**	**

²Values are means based on two branches per tree.^ySheared on these schedules the last 4 years before harvest.NS,*,**Nonsignificant or significant at $P < 0.05$ or 0.01 , respectively.

1). Branches sheared in July had 37% less dry weight than nonsheared trees; the difference was 51% to 60% for August, October, and March. July shearing had 43% fewer 1-year-old shoots and 56% fewer 2-year-old shoot segments compared to nonsheared controls. However, the July shearing yielded 50% more current-year shoots than the next best shearing treatment (August) (Table 1).

Top three internodes. Shearing reduced total biomass in the upper crown (Table 2). In the top three internodes, nonsheared trees had 60% more stems, branches, foliage than the July shearing treatment; differences were even greater for later shearing dates (Table 2). Trees sheared in July were 16% to 33% heavier in the top three internodes, compared to those sheared in August, or later. Total biomass was smallest (47% of control) for October shearing.

Shearing also affected the distribution of biomass in the top three internodes (Table 2). Woody material comprised about 70% of the total dry matter (all treatments), leaving 30% in foliage. Stems were 38% to 40% of the total biomass (upper crown) in nonsheared trees as well as trees sheared in July or August. The proportion in stems increased to 45% for late shearing dates. Conversely, 62% of the dry matter in nonsheared trees was branches (wood + foliage)—similar to July shearing. Trees sheared in October contained 55% of their biomass in branches. Foliage was 50% of the branch dry weight within the top three internodes (sheared and nonsheared) (Table 2), compared to 55% to 58% in 3-year-old branches (Table 1).

Foliage. Weight, length, and one-sided

area of individual needles were smallest on nonsheared control trees, and increased to maximum values on trees sheared in October or March (Table 3). March shearing yielded individual current-year (1-year-old) needles with 86%, 50%, and 70% more dry weight, length, and one-sided area, respectively, than nonsheared trees. Needle length and projected area for trees sheared in July were similar to those of nonsheared trees, whereas dry weight was significantly greater. Dimensions of the 2-year-old needles were similar to those of current-year needles (Table 3).

Discussion

Christmas trees can be regarded as a foliage crop because crown density and quality depend

largely on the quantity and appearance of foliage, and the manner in which it is displayed on branches. Thus, it is desirable to maximize the mass and uniformity of foliage and branches within the crown since uniformly dense trees generally have the greatest value (U. S. Dept. of Agriculture, 1989). Although nonsheared leaders can exceed 0.8 m in 1 year, they are normally pruned to about 0.3 m·year⁻¹, possibly 0.5 m maximum when trees are <1.5 m tall. Growth of nonsheared trees can far exceed that of sheared trees (Tables 1 and 2), but sheared trees have greater crown density, are more uniform, and generally have greater commercial value.

Nonsheared (natural) Fraser firs tend to have long stem internodes, distinct tiers of branches, and low crown density. However, exceptional trees sometimes exhibit rapid

Table 3. Dry weight, length, and one-sided area of individual 1- and 2-year-old needles from fraser fir Christmas trees sheared on various dates.²

Shearing date ^y	1-year-old			2-year-old		
	Wt (mg)	Length (mm)	Area (cm ²)	Wt (mg)	Length (mm)	Area (cm ²)
Nonsheared (control)	8.2	18.6	0.40	8.2	19.2	0.40
July	9.6	21.4	0.48	9.7	20.3	0.45
August	12.6	26.0	0.60	12.8	24.4	0.59
October	14.8	27.7	0.68	13.7	25.2	0.61
March	15.3	28.0	0.68	14.2	25.5	0.62
Control vs. sheared	**	**	**	**	**	**
July vs. August	**	**	**	**	**	**
August vs. October	**	*	**	NS	NS	NS
October vs. March	NS	NS	NS	NS	NS	NS
July and August vs. later	**	**	**	**	**	**

²Values are means based on one needle of each age class from a 2-year-old branch on each tree.^ySheared on these schedules the last 4 years before harvest.NS,*,**Nonsignificant or significant at $P < 0.05$ or 0.01 , respectively.

growth rate and high crown density even without shearing. Sheared trees are more compact, without obvious gaps or tiered crown structure, and have greater and more uniform crown density. Although shearing is necessary to produce Christmas trees with dense crowns, it reduced potential tree growth by 37% (July) to 53% (October) (Table 2). While some reduction in growth was expected, the extent was surprising. When trees are subjected to bud and/or foliage loss, either by clipping or feeding by herbivores, tree response can vary considerably by species, nutritional status, competitive status, severity of treatment as well as timing, method, and frequency of pruning and/or defoliation (Hawkins and Henry, 1999; Margolis et al., 1988; Puettmann and Saunders, 2001). Shearing treatments used in this study represented a light pruning, i.e., in most cases, only the distal tips of branches were removed. Heavier pruning would have removed a larger portion of the shoots and buds, and likely resulted in even larger losses of potential growth.

Separation of the entire upper crown into stems, branches, and foliage provided a good measure of tree response to shearing. When subjected to pruning and defoliation, individual branches often respond as autonomous units (Långström et al., 1990; Watson and Casper, 1984); thus significant variation can occur among branches, even within the same whorl. This generalization also applies to foliage (Morgan et al., 1983).

Treatment differences were not only reflected in total biomass but also in branch counts. The fact that nonsheared trees had the maximum number of 1- and 2-year-old segments on large side-branches (Table 1) merely reflected that those branches were not sheared, and were thus longer than sheared shoots. Since bud density is highest on the distal half of the shoot (Powell, 1982), retaining that portion (no shearing) preserves the highest potential branch density, assuming no compensatory effect in the proximal part of sheared branches. Among the shearing treatments, shearing in July yielded 28% to 58% more foliage and twice as many current-year shoots on 3-year-old branches (midcrown), compared to October or March (Table 1). Thus, it appears that early shearing improved crown density.

Although shearing affected total foliage weight, the most dramatic manifestation appeared in the size of individual needles (Table 3). Trees sheared in October or March had much larger needles than nonsheared trees or trees sheared earlier. Consequently, it was possible to visually distinguish many trees in

the two latest shearing treatments. Based on total foliage weight and number of branch segments in the upper crown, i.e., greater for nonsheared and early-sheared trees (Table 1), and noting that the dimensions of individual needles (Table 3) are inversely related to total needle weight in the upper crown (Table 2), it appears that needle size varies in a manner that tends to maintain constant foliage weight and area on the tree. Evidently, needle size was not a major factor in tree quality because July and August shearing yielded the best average quality (Hinesley and Derby, 2004).

In addition to total biomass, shearing also affected allocation of growth among biomass components in the upper crown. The proportion in stems increased from 40% in July to 45% for late shearing in October and March. In the upper crown about 30% of the total dry matter was foliage. Foliage comprised 55% of the dry weight in 3-year-old branches (Table 1). An earlier study estimated that 42% of the aboveground biomass was foliage in 2.5-m trees (Hinesley and Wright, 1989).

Shoot elongation for determinant species is related to bud size (Kozłowski, 1973; Little, 1970), so leaving a small bud (late shearing) will result in less shoot elongation the following year, as confirmed by field measurements (Jeff Owen, N.C. Coop. Ext. Serv., unpublished data). Shearing in July and August allows additional bud growth during late summer and fall, resulting in bigger, more vigorous shoots the following year. In October or March buds are already developed for the current year, and have little potential for additional growth. Thus, compensatory growth likely occurs through an increase in the size of existing cells following budbreak rather than an increase in the number of cells the previous summer and fall.

Response to shearing treatments, and the subsequent effect(s) on tree quality, can vary dramatically among individual trees, particularly where there are big differences in bud density on leaders (Brown and Heiligmann, 2002). Despite considerable variation among trees within treatments, trees sheared in July and August had the best average quality; those sheared in October or March were lower quality (Hinesley and Derby, 2004). Other studies with West Virginia balsam fir (*Abies balsamea* var. *phanerolepis*) and Fraser fir have yielded similar conclusions (Brown and Heiligmann 2001). In our study, trees sheared in July and August also had the greatest biomass, excluding nonsheared trees; thus, differences in quality might be related to the smaller reduction in potential growth associated with early shearing.

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