Using a Bud Volume Index with the Top-Stop Nipper to Control Leader Growth of Fraser Fir Christmas Trees

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ADDITIONAL INDEX WORDS. ***Abies fraseri*, shearing, bud density, consumer preference, crown density**

SUMMARY. The Top-Stop Nipper (TSN), a four-bladed, hand-held tool developed for reducing leader growth of Christmas trees, was used as a wounding technique to reduce leader growth of Fraser fir (*Abies fraseri*). A regression model, based on an apical bud volume index (average bud diameter squared × length), was used to predict the number of nips to apply to each leader to yield a target length of 25 to 36 cm. Treatments included control trees (0 nips) and one to seven nips per leader. Nips were applied in May at budbreak. In an earlier study, increasing the number of nips decreased leader elongation when randomly applied to trees without regard to the size of the apical bud. In this study, when the number of nips increased with increasing bud volume index, leader growth was similar among all TSN treatments. Bud density (per unit length) on the 2006 leader increased with the number of nips applied to the 2005 leader. Results might be useful for growers who want to produce dense trees with minimal shearing or for growers who choose to leave a longer leader to produce a more open, "European-style" tree during a shorter rotation time.

About 20% of the Christmas trees in the United States originate in North Carolina (North Carolina Christmas Tree Assn., 2004) where Fraser fir constitutes about 96% of sales (North Carolina Department of Agriculture and Consumer Services, 2005). Fraser fir is sheared once annually, usually with knives and hand clippers, beginning at 3 to 4 ft in height, and leaders usually are shortened to 25 to 40 cm. July and August is the optimum shearing season (Brown and Heiligmann, 2002; Douglass, 1983; Hinesley and Derby, 2004a, 2004b).

The Top-Stop Nipper (TNS; Lars Geil, Ry, Denmark) has two unequally spaced (about 2 cm apart) blades on either side, each with a half circle cut out (Fig. 1A). It makes transverse cuts (Fig. 1B) through the bark of the leader, which reduces subsequent leader growth. In Europe, the TSN has reduced leader growth of nordmann fir (*Abies nordmanniana*) by 25% (Owen et al., 2004). Retaining terminal and subterminal buds maintains the mechanism of correlative inhibition among leaders and lower-order shoots (Kozlowski et al., 1973; Little, 1970), thus enabling lateral branches to develop as in a nonsheared tree. Although the TSN can reduce leader growth more than 50% in Fraser fir (Rutledge et al., 2008a), there is no method to determine the number of nips to yield a specified target leader length. The objective of this research was to determine the number of nips to apply with a TSN, based on a bud volume index, to yield a target leader length for Fraser fir Christmas trees.

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The use of trade names does not imply endorsement by the NCARS of products named nor criticism of similar ones not mentioned.

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Materials and methods

EXPT. 1 (DERIVATION OF MODEL). During 2005, measurements were conducted in three representative Fraser fir Christmas tree plantations in Avery County in western North Carolina. Elevation was 3410 to 4000 ft above sea level, average lat. 36.1°N, average longitude 81.8°W. Soil series included Porters, Unaka-Porters complex, and Edneyville-Chestnut complex (U.S. Department of Agriculture, 2005). Soils were stony or very rocky, with slopes of 15% to 30% on two sites and 30% to 50% on the third site. Climatic data during May, June, July, August, September, and October in that locale (recorded at Banner Elk, NC) during the 12 years before the experiment were as follows: mean daily high temperature (69 °F, 74 °F, 79 °F, 77 °F, 72 °F, and 64 °F), mean daily low temperature (46 °F, 54 °F, 58 °F, 56 °F, 50 °F, and 42 °F), and monthly precipitation (3.9, 4.8, 4.6, 4.2, 5.2, and 3.0 inches) (Coweeta Long Term Ecological Research, n.d.). Rainfall in Sept. 2004 (24 inches) was extremely high owing to remnants from several hurricanes. Excluding that value, the mean for September was 3.7 inches.

Nine hundred trees were used (height ≈4 to 5 ft, with no symptoms of disease or noticeable insect damage). Trees were about 5-years-old (3 years in a seedbed and 2 years in a transplant bed) when planted in the field, had been in the field 5 years, and received standard cultural practices, including one shearing annually. They were not sheared during the experiment. On each site, the experimental design was a randomized complete block with 20 blocks and 15 trees per block. One tree in

Units

To convert U.S. to SI, multiply by	U.S unit	SI unit	To convert SI to U.S., multiply by
0.3048	ft	m	3.2808
2.54	inch(es)	cm	0.3937
16.3871	inch^3	cm^3	0.0610
(°F – 32) ÷ 1.8	°F	°C	(1.8 × °C) + 32

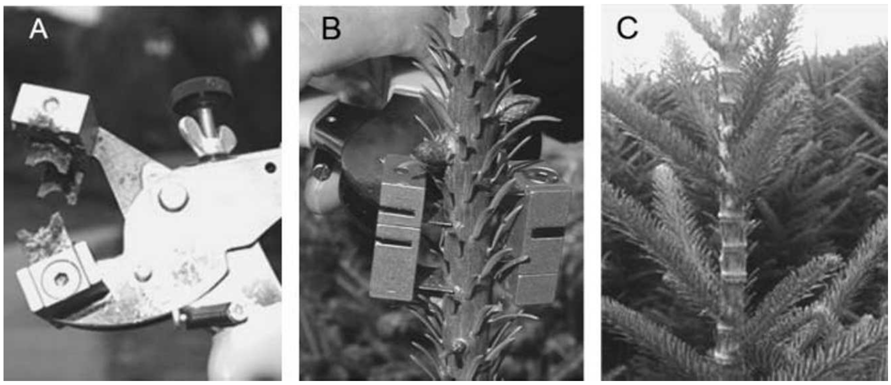

Fig. 1. (A) Jaws and cutter blades on the Top-Stop Nipper (TSN) (Lars Geil, Ry, Denmark), (B) application of cuts to the leader of Fraser fir using the TSN, and (C) scars from TSN treatments after lateral branch elongation. The TSN has two unequally spaced [about 2 cm (0.8 inch) apart] blades on either side, each with a half circle cut out (A). 1 cm = 0.3937 inch.

each block was randomly assigned to each treatment, and there were three controls.

Before treatment, two height measurements were recorded on each tree: total height through 2003 and total height through 2004. Sheared leader length for 2004 was calculated by difference. On the uppermost bud on the 2004 leader, two cross-sectional diameters at the point of maximum thickness were measured with a digital caliper. The average of the two numbers was squared and multiplied by bud length to calculate a bud volume index (BVI).

The 13 treatments included a control (zero nips) and the application of 1, 2, 3, or 4 nips at one of three stages of leader elongation: prebudbreak, 2 to 3 cm, and 6 to 9 cm (Rutledge et al., 2008a). The tool was rotated 90° before applying each additional nip. Damage to lateral buds was minimized by carefully positioning the nips (Fig. 1C). Weekly measurements were recorded for every tree at site 2 over 7 weeks, beginning 26 June 2005. Final measurements were recorded at all sites 9 weeks after treatment. Results are presented in Rutledge et al. (2008a).

An analysis of covariance was conducted to test the relationship between each covariable (BVI, leader diameter, leader length in 2004, and tree height) and final leader length in 2005. Among those variables, BVI was best correlated with final leader length. A regression model using BVI and the number of nips was used to predict the number of nips required to yield a target leader length of 25 to 36 cm. This model was used to apply nip treatments in a second experiment in 2006.

EXPT. 2 (VALIDATION OF MODEL). The 2006 experiment was conducted in the same Christmas tree plantations as in 2005. A total of 120 trees were used at each plantation. Nip treatments (Table 1), based on the model using BVI (Expt. 1), were applied to 100 trees at budbreak. Twenty trees served as controls (no nips) at each site. Apical bud diameter and length were measured for each tree using a digital caliper. BVI was calculated by squaring the diameter and multiplying it by bud length. Total tree height was recorded after the 2005 growing season along with the sheared height through 2004. Leader length (2005) was calculated by difference. In 2006, data included leader length, and the length of the highest lateral branch and the lowest lateral branch on the 2005 leader.

Treatments (1–7 nips, applied at budbreak) were determined from Eq. 1. Measurements were taken at site 2 for weeks 1, 2, 3, 4, 5, 6, and 7, beginning 26 June 2006. Final measurements for all three sites were taken at week 9. Data were analyzed using GLM, REG, and CORR procedures (SAS Institute, Cary, NC). A GLM analysis, using combined data from the three sites, was conducted to test main effects and the site × nip interaction for the dependent variables, leader length, bud count, length of upper and lower lateral branches, and bud density (buds per centimeter). The CORR procedure (SAS Institute) was used to determine the relationship between BVI and leader length, bud count, and bud density for the controls and treated trees.

Leader lengths for each treatment were compared with two hypothetical shearing systems: traditional and accelerated. These regimes refer to the leader length, which is set during mechanical shearing. With traditional shearing, the final leader length would be 20 to 36 cm, compared with 30 to 46 cm for an accelerated regime. For each system, percentages were calculated for the number of leaders that were too short, optimum, or too long relative to the ideal target length. Short leaders will yield trees of acceptable quality, whereas excessively long leaders might not. Before initiation of the experiment, trees had been annually sheared similar to the traditional system. They were not sheared during the study.

Results

EXPT. 1. Results from the first experiment are presented in Rutledge et al. (2008a). In general, leader elongation decreased with increasing nips (Fig. 2, Expt. 1, year 2005). In the

Table 1. Number of leaders that received varying numbers of nips with a Top-Stop Nipper[z] based on a bud volume index (Expt. 2, year 2006).

Nips	Bud volume index[y] (cm^3)	Site 1[x]	Site 2	Site 3
Control	—	18	20	19
1	0.005–0.007	2	3	17
2	0.008–0.011	15	5	14
3	0.013–0.016	29	9	10
4	0.017–0.022	29	18	20
5	0.023–0.028	13	10	14
6	0.029–0.036	5	14	8
7	0.037–0.051	4	38	4

[z]The Top-Stop Nipper (Lars Geil, Ry, Denmark) is a plier-like tool with two unevenly spaced blades [about 2 cm (0.8 inch) apart] on each jaw, each with a half-circle cut out.
[y]Bud volume index = (bud diameter)^2 × bud length; 1 cm^3 = 0.0610 $inch^3$.
[x]There were three Christmas tree plantations (Sites 1, 2, and 3).

analysis of covariance, leader diameter in 2004 (r = –0.29, $P \leq 0.05$) and BVI in 2004 (r = 0.47, $P \leq 0.05$) were more strongly related to leader length in 2005 compared with tree height in 2004 (r = 0.14, $P \leq 0.05$) and leader length in 2004 (r = 0.10, $P \leq 0.05$). The regression model to predict leader length was as follows:

$$\mathrm{LL} = 28.8 - 4.0\mathrm{a} + 62.8\mathrm{b} - 1204.8\mathrm{b}^2,$$
$$R^2 = 0.38 \qquad [1]$$

where LL is leader length in centimeters, a is the number of nips, and b is BVI.

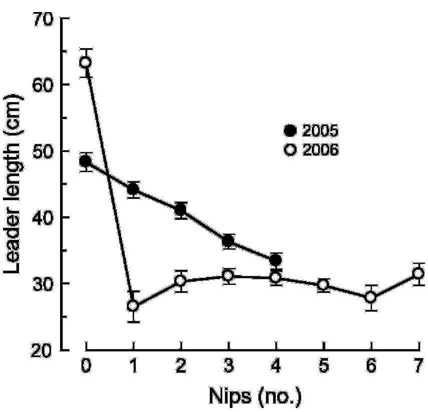

Fig. 2. Average leader length for Fraser fir Christmas trees that received one to four nips (Expt. 1, year 2005) and one to seven nips (Expt. 2, year 2006) with a Top-Stop Nipper (TSN; Lars Geil, Ry, Denmark). Means are averaged across all three sites for both experiments. Treatments in 2005 were applied randomly; in 2006, they were applied according to bud volume index. The TSN has two unequally spaced (about 2 cm apart) blades on either side, each with a half circle cut out (Fig. 1A); vertical bars = ± 1 SE, 1 cm = 0.3937 inch.

Expt. 2. Although the TSN reduced leader elongation of Fraser fir in 2005 and in 2006, the shape of the relationship was different for the 2 years (Fig. 2). In 2005, leader elongation decreased linearly with the number of nips; in 2006, leader length was similar for all TSN treatments involving one to seven nips (Table 2, Fig. 2). Leader length for nonsheared controls was much greater ($P \leq 0.01$) than in all the TSN treatments (Fig. 2). Bud density in 2006 increased with the number of nips (Table 2). Excluding controls, the site × nips interaction was negligible for all variables (Table 2). Upper lateral branch growth was significantly greater for sites 1 and 2 compared with site 3, whereas lower lateral branch growth was significantly lower for sites 1 and 2 compared with site 3 (Table 2).

Control trees displayed a strong positive correlation between BVI and final leader length (Fig. 3A). In contrast, trees that received one to seven nips, based on the model using BVI, showed no significant relationship between BVI and final leader length (Fig. 3A). There was a significant positive correlation between 2005 BVI and 2006 bud count, particularly for control trees (Fig. 3B). Nipped trees exhibited a significant positive correlation between 2005 BVI and bud density on the 2006 leader, whereas the correlation was negative for control trees (Fig. 3C). Bud density on the leader increased (Fig. 4) as the number of nips increased (Fig. 4).

For both shearing regimes (traditional and accelerated), about 50% of the leaders were within the target range (Fig. 5). The effect of TSN treatments was more apparent for leaders classified as "short" or "long"; e.g., four nips caused 45% of the leaders to be classified as too short

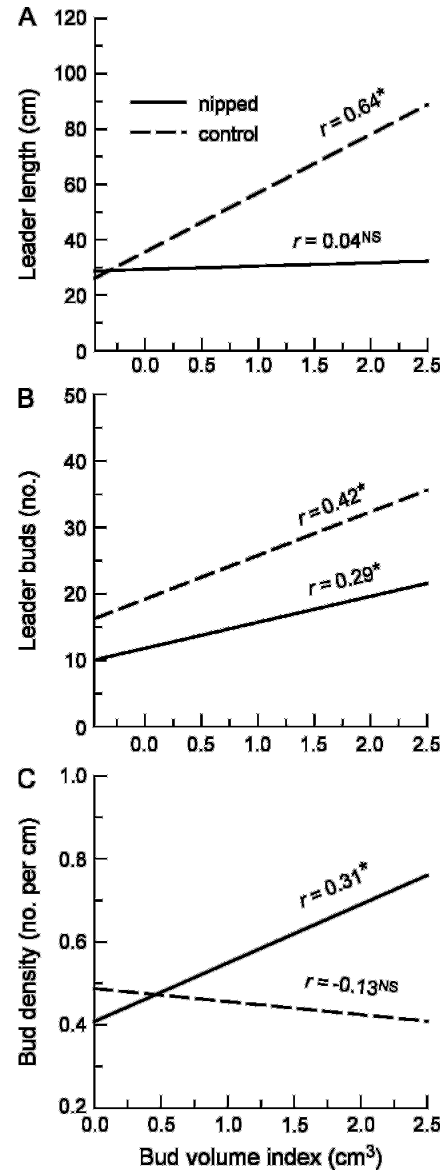

Fig. 3. Correlations and relationships between (A) leader length and bud volume index, (B) bud count and bud volume index (BVI), and (C) bud density and bud volume index for control Fraser fir Christmas trees versus those nipped with a Top-Stop Nipper (TSN; Lars Geil, Ry, Denmark). Values represent all treated trees and control trees at all three sites (Expt. 2, year 2006). Legend in A also applies to B and C. The TSN has two unequally spaced (about 2 cm apart) blades on either side, each with a half circle cut out (Fig. 1A). NS and *, Nonsignificant or significant at $P \leq 0.05$, respectively; 1 cm = 0.3937 inch, 1 bud/cm = 2.54 buds/inch, 1 cm³ = 0.0610 inch³.

Table 2. Analysis of leader length, bud count, bud density, and growth of lateral branches for Fraser fir Christmas trees treated with a Top-Stop Nipper[z] (Expt. 2, year 2006).

Source of variation[y]	df	Leader length	Bud count	Bud density	Length of laterals	
					Upper	Lower
Site	2	NS	NS	**	**	**
Nips	6	NS	**	NS	NS	NS
Site x Nips	12	NS	NS	NS	NS	NS
Error	260	—	—	—	—	—
R^2		0.05	0.13	0.12	0.18	0.24

[z]The Top-Stop Nipper (Lars Geil, Ry, Denmark) is a plier-like tool with two unevenly spaced blades [about 2 cm (0.8 inch) apart] on each jaw, each with a half-circle cut out.
[y]There were three Christmas tree plantations (sites) and seven nipping treatments. Control trees (20 per site) were not included in the analysis.
NS and **, Not significant or significant at $P \leq 0.01$, respectively.

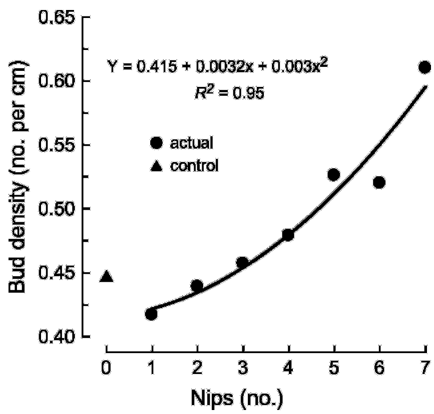

Fig. 4. Relationship of bud density to the number of nips applied with a Top-Stop Nipper (TSN; Lars Geil, Ry, Denmark) to Fraser fir Christmas trees (Expt. 2, year 2006). Values are means averaged over three sites. Nip treatments were applied at budbreak based on bud volume index. Average bud density for the control trees (no nips) is represented by a single value. The TSN has two unequally spaced [about 2 cm (0.8 inch) apart] blades on either side, each with a half circle cut out (Fig. 1A); 1 bud/cm = 2.54 buds/inch.

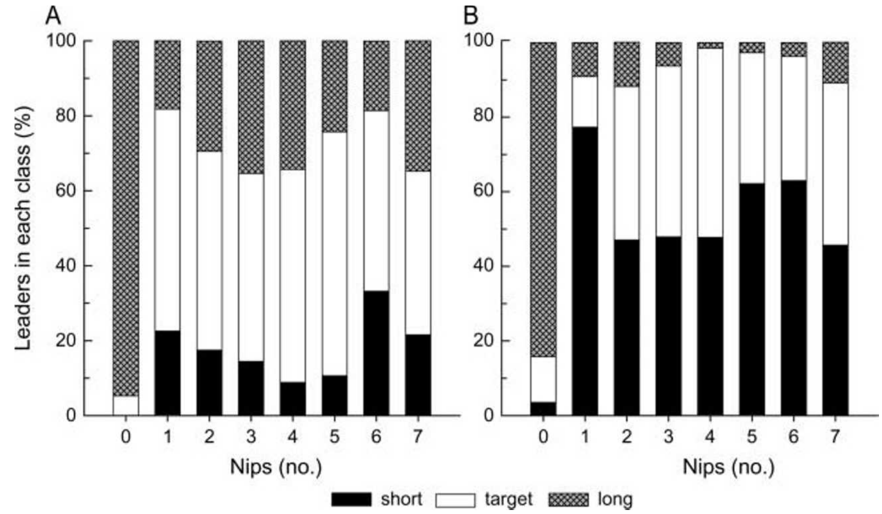

Fig. 5. Percentage of Fraser fir Christmas trees with final leader length classified as short, target, or long for seven Top-Stop Nipper (TSN; Lars Geil, Ry, Denmark) treatments and a nontreated control, averaged across three sites and two experiments (Expt. 2, year 2006). (A) Traditional shearing regime (target leader length = 20–36 cm) and (B) accelerated shearing regime (target leader length = 30–46 cm). Leaders were classified as short or long if they were less than or greater than the target length, respectively. The TSN has two unequally spaced (about 2 cm apart) blades on either side, each with a half circle cut out (Fig. 1A); 1 cm = 0.3937 inch.

for an accelerated regime compared to 10% for the traditional regime (Fig. 5).

Discussion

The TSN reduced leader growth in Fraser fir Christmas trees (Figs. 2 and 3), similar to other firs (*Abies* spp.) (Fletcher et al., 2005; Landgren and Fletcher 2006). The relationship between the number of nips and shoot elongation differed between the 2 years (Fig. 2). In 2005, one to four nips were randomly applied to trees irrespective of BVI, resulting in a negative slope for the relationship between leader length and the number of nips (Fig. 2). In 2006, the number of nips increased as BVI increased, resulting in no discernible relationship (slope $\approx$ 0) between leader length and the number of nips (Fig. 2). Thus, BVI effectively predicted the number of nips needed to produce leaders with a specified target length. Bud density on the 2006 leader also increased with BVI (Fig. 3C) as well as the number of nips (Fig. 4). Reducing leader growth while maintaining the same number of buds increases bud density, which increases crown density. This might allow growers to retain longer leaders, compared with traditional shearing, to produce taller trees or reduce rotation length.

Formation of the terminal leader is a 2-year process in firs (Powell, 1982). Bud primordia form the first year, which, in part, determines the amount of shoot elongation during the next year. Favorable environmental conditions during year 1 produce more shoot growth during year 2 (Kozlowski, 1962), perhaps explaining the similar positive correlations between bud count and BVI for treated trees as well as controls (Fig. 3B). The number of buds present on a leader should not be affected by the nipping treatments that occur after formation of primordia; therefore, the controls and nipped trees should have a similar relationship.

Americans favor dense trees, which require annual shearing, whereas Europeans prefer trees with little to no shearing, resulting in lighter crown density with layered internodal branching and more uniform whorls (Chastagner and Benson, 2000; Frampton and McKinley, 1999). Trees with the European style have gaps between the whorls to hold decorations such as candles. Owing to smaller living spaces, many Europeans also prefer slowly grown Christmas trees with narrow crowns and low to medium density (Frampton and McKinley, 1999). The TSN can yield a more open European-style tree with a layered, natural appearance, and might represent an alternative to traditional shearing. Because the TSN places only 50% to 60% of the leaders into the target range of length (Fig. 5), American Christmas tree growers probably would use it only in combination with traditional mechanical shearing or application of growth regulators (Rutledge et al., 2008b).

Although calculating BVI is too cumbersome to be useful in the field, there are several alternatives. One approach is to visually categorize terminal buds as small, medium, or large, and apply 2, 4, or 6 nips, respectively. Because bud length is strongly correlated with BVI, a second alternative would be to mount a small scale on the TSN to measure bud length, and apply nips according to bud length. The third method, commonly used in Europe, applies nips according to the length of the prior-year leader. This method, however, assumes that leaders receive no mechanical shearing after treatment with the TSN.

Literature cited

Brown, J.H. and R.B. Heiligmann. 2002. Shearing west virginia balsam and fraser fir for Christmas trees. Ohio State Univ. Ext. Bul. Spec. Circ. 188.

Chastagner, G.A. and D.M. Benson. 2000. The Christmas tree: Traditions, production, and diseases. Plant Health Progress. Plant Health Rev. DOI: 10.1094.

Coweeta Long Term Ecological Research. n.d. Monthly climate data across the southern Appalachians. 8 Apr. 2008. <http://coweeta.ecology.uga.edu/ecology/climate/climate.htm>.

Douglass, B.S. 1983. Noble fir shearing and fertilizer study. Christmas Tree Lookout 16(3):30–32, 34, 36, 38, 40.

Fletcher, R., C. Landgren, and M. Bondi. 2005. Control of *Abies* leader growth in oregon christmas trees via chemical and mechanical manipulation. 7th Intl. Christmas Tree Res. Ext. Conf. Program Abstr. p. 14–15. (Abstr.)

Frampton, J. and C.R. McKinley. 1999. Christmas trees and greenery in Denmark: Production and tree improvement. Amer. Christmas Tree J. 43(2):4–11.

Hinesley, L.E. and S.A. Derby. 2004a. Shearing date affects growth and quality of fraser fir christmas trees. HortScience 39:1020–1024.

Hinesley, L.E. and S.A. Derby. 2004b. Growth of fraser fir Christmas trees in response to annual shearing. HortScience 39:1644–1646.

Kozlowski, T.T. 1962. Tree growth. Ronald Press, New York.

Kozlowski, T.T., J.H. Torrie, and P.E. Marshall. 1973. Predictability of shoot length from bud size in *Pinus resinosa* Ait. Can. J. For. Res. 3:34–38.

Landgren, C. and R. Fletcher. 2006. From Europe to the pacific northwest. Amer. Christmas Tree J. 50(2):20–21.

Little, C.H.A. 1970. Apical dominance in long shoots of white pine (*Pinus strobus*). Can. J. Bot. 48:239–253.

North Carolina Christmas Tree Assn. 2004. Tree facts. 18 Feb. 2007. <http://www.ncchristmastrees.com/facts.htm>.

North Carolina Department of Agriculture and Consumer Services. 2005. Choose and cut guide facts for fraser fir. 28 Nov. 2005. <http://www.ncagr.com/markets/commodit/horticul/xmastree/index.htm>.

Owen, J., J. Frampton, J. Moody, and L. Geil. 2004. Top-Stop Nipper terminal growth reduction trials, p. 43. In: J. Sidebottom (ed.). Christmas tree research and extension projects: First annual summary. North Carolina Coop. Ext. Serv., Raleigh.

Powell, G.R. 1982. Shoot and bud development in balsam fir: Implications for pruning Christmas trees. For. Chron. 58: 168–172.

Rutledge, M.E., J. Frampton, L.E. Hinesley, and G. Blank. 2008a. Top-Stop Nipper reduces leader growth of fraser fir Christmas trees. HortTechnology 18: 256–260.

Rutledge, M.E., J. Frampton, L.E. Hinesley, and G. Blank. 2008b. Naphthalene acetic acid reduces leader growth of fraser fir Christmas trees. HortScience (In press).

U.S. Department of Agriculture. 2005. Soil survey of Avery County, North Carolina. 8 Apr. 2008. <http://soildatamart.nrcs.usda.gov/Manuscripts/NC011/0/Avery_NC.pdf>.