Effect of Uniconazole on Shoot Growth and Budset of Containerized Fraser Fir

L. Eric Hinesley¹, Stuart L. Warren¹, and Layne K. Snelling²

Department of Horticultural Science, North Carolina State University, Raleigh, NC 27695-7609

Additional index words. *Abies fraseri*, tabletop trees, growth regulator, Christmas trees, triazole

Abstract. In two experiments, uniconazole (0.25 to 16 mg·L⁻¹ a.i.) was applied as a root drench to containerized Fraser fir [*Abies fraseri* (Pursh) Poir.] at various times of the year. Leader length, stem diameter, length of laterals, and number of subterminal buds were reduced the following growing season. Treatment during the 1994 growing season reduced lateral bud formation on the leader in 1995, whereas treatment with 8 or 16 mg·L⁻¹ in Mar. 1995 (prior to budbreak) increased it. Uniconazole caused needle discoloration and abscission at concentrations ≥ 4 mg·L⁻¹. Leader growth was reduced more than branch elongation, which tended to make plants more decurrent. The utility of uniconazole in production of tabletop Fraser fir Christmas trees was unclear; reduced shoot elongation was often accompanied by fewer lateral buds and needle discoloration and/or abscission. Chemical name used: E-1-(p-Chlorophenyl)-4,4-dimethyl-2-(1,2,4-triazole-1-penten-3-ol) (uniconazole).

There is a good market for small (tabletop) Christmas trees in the United States (Crothers, 1990). Included in this category are trees ranging from potted plants 0.25 m tall to cut trees ≈ 1 m tall. Fraser fir is the principal Christmas tree species grown in North Carolina, and is gaining popularity elsewhere. It is marketed mainly as a cut tree 2 to 2.5 m tall. Fraser fir grows slowly in the first 3 to 4 years from seed, and produces one flush of growth per year in May and June. It is normally established in the field, using 4- to 5-year-old transplants 0.3 to 0.5 m tall. Height growth accelerates thereafter, reaching a maximum of 0.5 to 0.8 m annually after ≈ 4 years in the field. When a Fraser fir is pruned or shaped, the leader (primary axis) is shortened to 0.2 to 0.5 m, depending on tree age, budset, and vigor. Leader pruning is normally done with hand clippers.

Production of compact, dense, tabletop trees requires short leaders and heavy budset. Chemical treatment would be advantageous to limit leader length without reducing the number of subterminal and lateral buds, thus yielding a denser tree. A candidate for this role is uniconazole (Sumagic; Valent Co.,

Walnut Creek, Calif.), a member of a group of plant growth regulators (PGRs) known as triazoles, which can reduce height growth of several herbaceous and woody taxa (Bailey and Miller, 1989; Keever and West, 1992; Norcini and Knox, 1989; Warren, 1990; Warren et al., 1991). Little research with uniconazole has been reported with conifers, such as Fraser fir. Paclobutrazol, another triazole, has been used to shorten internodal elongation of Douglas fir [*Pseudotsuga menziesii* (Mirb.) Franco] and loblolly pine (*Pinus taeda* L.) (Wheeler, 1987). Our objective was to determine the effect of uniconazole on shoot elongation and budset of containerized Fraser fir.

Materials and Methods

Three-year-old seedlings of Fraser fir (≈ 0.2 m tall) were dug from the North Carolina Forest Service nursery at Crossnore in Sept.

1993. They were transported to Raleigh, and placed in 1-L pots containing a medium of 3 composted pine bark : 1 Canadian peat (v/v) amended with 3 kg·m⁻³ dolomitic lime and 3 kg·m⁻³ triple superphosphate (0N–20P–0K). Thereafter, plants were maintained under 50% shade lath, and received water from overhead irrigation at 1.3 cm·d⁻¹. During the month following potting, plants were fertilized twice with recommended rates of 30N–4.4P–8.3K (Miracid; Scotts Miracle-Gro Products, Port Washington, N.Y.).

Experiment 1. Aqueous solutions of uniconazole were prepared consisting of the following concentrations of active ingredient (a.i.): 0, 0.25, 0.5, 1.0, 2.0, 4.0, 8.0, or 16.0 mg·L⁻¹. In both this experiment and Expt. 2, containers were not watered within 6 h before treatment or 24 h after treatment. Each treatment was applied to 20 plants, using 30 mL per pot as a soil drench, between 0730 and 0830 HR, on 20 Apr. 1994 (near budbreak). Pots were arranged in a randomized complete-block design. Each plant received a 15-g surface application of 30N–4.4P–8.3K (Osmocote; Grace Sierra, Milpitas, Calif.) in Apr. and Sept. 1994 and 1995.

Plants were transferred to 2.8-L pots on 14–15 July 1994. The following observations were recorded for the 1995 leader on 21 Mar. 1996: length, diameter (two directions, 2 cm above 1995 branch whorl), number of subterminal buds (subtending the terminal bud), and number of lateral buds. In addition, the length of the longest lateral branch in the 1995 whorl was also measured for concentrations of 0, 1.0, 4.0, and 16 mg·L⁻¹.

Experiment 2. Using plants similar to those used in Expt. 1, uniconazole solutions (0, 2, 4, 8, and 16 mg·L⁻¹ a.i.), were applied as above on three dates: 21 June 1994 (shoots almost fully elongated, but still succulent; buds beginning to enlarge), 9 Sept. 1994 (shoots mature, active root growth), and 22 Mar. 1995 (before budbreak). Volume of solution applied to each pot was 30 mL in June 1994 and 90 mL in Sept. 1994 and Mar. 1995. Plants were repotted in 2.8-L pots on 14–15 July 1994, and shaded, watered, and fertilized as described in Expt. 1. Pots (12 per treatment) were arranged in a randomized complete-block design.

Table 1. Analyses of variance for several growth indices of Fraser fir plants treated with various concentrations of uniconazole.

Source	Leader in 1995						
	Length	Area	Subterminal buds	Lateral buds	Total buds	Lateral length ^c	Ratio ^d
<i>Experiment 1^a</i>							
Concn	**	**	(0.07)	*	---	*	---
<i>Experiment 2^a</i>							
Date (D)	**	**	**	**	**	**	**
Concn (C)	**	**	**	(0.06)	**	**	**
D $\times$ C	NS	NS	NS	*	**	NS	NS

^aLongest branch in top (1995) whorl.

^bRatio = length of 1995 leader/length of longest 1995 lateral.

^cApplication date: 20 Apr. 1994. Concentrations: 0, 0.25, 0.5, 1.0, 2.0, 4.0, and 16.0 mg·L⁻¹ a.i. Measured 21 Mar. 1996.

^dApplication dates: 21 June, 9 Sept. 1994, and 22 Mar. 1995. Concentrations: 0, 2, 4, 8, and 16 mg·L⁻¹ a.i.

ns, *, **Nonsignificant or significant at $P \leq 0.05$ or 0.01, respectively. Numbers in parentheses indicate levels of significance for $P \geq 0.05$.

Received for publication 15 Oct. 1996. Accepted for publication 14 May 1997. This research was funded by the Tennessee Valley Authority and the North Carolina Agricultural Research Service (NCARS), Raleigh. Mention of trade names is neither an endorsement by the NCARS nor criticism of similar unnamed products. We thank the North Carolina Forest Service for supplying seedlings and John Cramner (Valent Co.) for providing Sumagic. The cost of publishing this paper was defrayed in part by the payment of page charges. Under postal regulations, this paper therefore must be hereby marked advertisement solely to indicate this fact

¹Professor.

²Research Technician.

Fig. 1. Growth of containerized Fraser fir in 1995 following treatment with uniconazole (root drench) on 20 Apr. 1994 (Expt. 1). Cross-sectional area of leader (B) was measured 2 cm above 1995 branch whorl. Replication: $n = 20$ for each mean. Vertical bars = SE of mean.

Fig. 2. Growth of containerized Fraser fir in 1995 following treatment with uniconazole (root drench) on various dates in 1994 and early 1995 (Expt. 2). Cross-sectional area of leader (B) was measured 2 cm above 1995 branch whorl. In (E) and (F), data were not recorded for 8 $\text{mg}\cdot\text{L}^{-1}$. Replication: $n = 36$ (A–C, E, F); $n = 12$ (D). Vertical bars = SE of mean.

On 20 Mar. 1996, measurements were made on the 1995 leader, as in Expt. 1. Needle loss or discoloration was also noted (no formal rating system). In addition, the length of the longest lateral branch in the upper whorl (1995) was measured. Cross-sectional area of the leader was calculated using the average of the two diameter measurements in the formula for the area of a circle. A ratio “R” (length of 1995 leader divided by the length of the longest lateral in the 1995 whorl) was calculated to evaluate the relative effect of uniconazole on elongation of the leader vs. the lateral branches. Data were subjected to analysis of variance, and are presented graphically as means, with standard errors. Means were separated with Duncan’s new multiple range test or t tests.

Results and Discussion

Uniconazole reduced shoot growth and bud production of Fraser fir in both experiments. Date of application as well as concentration significantly affected all measured growth indices (Table 1). In Expt. 1, leader elongation was reduced 22% (0.25 $\text{mg}\cdot\text{L}^{-1}$) to 45% (16 $\text{mg}\cdot\text{L}^{-1}$) (Fig. 1A), and leader cross-sectional area 8% to 36% (Fig. 1B). In Expt. 2, uniconazole reduced leader elongation by 37% (2 $\text{mg}\cdot\text{L}^{-1}$) to 46% (16 $\text{mg}\cdot\text{L}^{-1}$), when averaged over treatment dates (Fig. 2A). Similarly, leader cross-sectional area was reduced 22% to 44% (Fig. 2B).

The number of subterminal buds decreased as concentration of uniconazole increased (Table 1; Figs. 1C and 2C). Control plants had almost four subterminal buds, compared to three buds for plants that received concentrations $\geq 2 \text{ mg}\cdot\text{L}^{-1}$ (Expt. 2; Fig. 2C).

Date $\times$ concentration interaction was evident in lateral bud formation (Tables 1 and 2; Expt. 2). When treated in either late June or early Sept. 1994, the number of lateral buds on the 1995 leader was reduced as much as 45% and 34%, respectively (Fig. 2D). In contrast, plants treated in Mar. 1995 with 8 and 16 $\text{mg}\cdot\text{L}^{-1}$ yielded 20% to 24% more lateral buds, respectively, during 1995. This increase in lateral buds, coupled with a 20% reduction in shoot elongation for plants treated in March (Table 2), made the plants appear denser.

Uniconazole reduced length of both leader (Figs. 1A and 2A) and laterals (Figs. 1E and 2E), but the leader was more sensitive. Leaders on plants treated 21 June 1994, 9 Sept. 1994, and 22 Mar. 1995 grew 40%, 35%, and 20% less in 1995, respectively, than did controls (Table 2). Length of lateral branches followed a similar pattern, but with smaller differences. This difference was also evident in the ratio R, which decreased from 1.17 in controls to 0.86–0.89 in plants receiving concentrations $\geq 2 \text{ mg}\cdot\text{L}^{-1}$ (Expt. 2; Fig. 2F). In conifers, elongation of the primary leader normally exceeds that of lateral branches, and branch elongation decreases basipetally (Kozłowski, 1973; Little, 1970; Waring, 1969). This pattern helps determine their characteristic arboreal shape.

For all application dates, plants that received $\geq 8 \text{ mg}\cdot\text{L}^{-1}$ had discolored (chlorotic or

Table 2. Main effects of treatment date on response in 1995 of containerized Fraser fir to root drenches of uniconazole (Expt. 2).

Date of treatment	Leader			Lateral length (cm)	Ratio ² (R)
	Length (cm)	Cross-sectional area (cm ²)	Subterminal buds (no.)		
21 June 1994	8.7 a ¹	0.16 a	2.8 a	10.2 a	0.89 a
9 Sept. 1994	9.3 a	0.18 b	3.2 b	11.0 b	0.86 a
22 Mar. 1995	11.5 b	0.20 b	3.9 c	11.8 b	0.98 b
Control	14.4 c	0.26 c	3.9 c	12.3 c	1.17 c

²Ratio = length of 1995 leader/length of longest 1995 lateral.

¹For the three treatment dates, mean separation by Duncan's new multiple range test, $P \leq 0.05$. Controls were compared with other treatments with *t* tests. Replication: shoot variables ($n = 60$); lateral length and ratio ($n = 48$); controls ($n = 36$).

dead) needles at the final evaluation. Those which received 16 mg·L⁻¹ lost most of their 1994 foliage. Discoloration was minimal on plants that received concentrations ≤ 4 mg·L⁻¹. Concentrations ≥ 8 mg·L⁻¹ also caused noticeable reductions in needle length.

In most treatments, reduced leader elongation was accompanied by fewer buds. There were two exceptions: treatment with 8 and 16 mg·L⁻¹ in Mar. 1995 increased lateral buds on the 1995 leader, compared with applications in 1994 (Fig. 2D). Apparently, the chemical diminished apical dominance early in the growing season, which allowed development of additional lateral buds. This, coupled with shorter leaders, tended to increase density. On the negative side, however, high concentra-

tions, e.g., ≥ 8 mg·L⁻¹, resulted in smaller needles, chlorosis, necrosis, or abscission. Concentrations ≤ 2 mg·L⁻¹ reduced growth, with little adverse effect on foliage.

The utility of uniconazole in production of tabletop Fraser fir Christmas trees is uncertain. The ability to chemically reduce leader length would be advantageous, allowing the apical bud cluster to be retained on a higher percentage of plants, thus yielding a more natural, tiered appearance. However, the effect on crown symmetry might be undesirable because uniconazole appears to affect the leader more than the branches. Further study could determine the duration of treatment effects, or the response to repeated treatment.

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