Gamma Radiation Unpromising as an Insect Quarantine Treatment for Fraser Fir Branches

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Abstract. Dormant branches of Fraser fir [*Abies fraseri* (Pursh) Poir.] Christmas trees were subjected to single doses of gamma radiation at levels ranging from 0 to 5.0 kGy (0 to 500 kRad). Significant needle loss resulted at doses ≥ 0.10 kGy and increased with radiation intensity. Irradiation discolored foliage and accelerated drying. Irradiation does not appear to be a viable way to meet insect quarantine requirements on cut Fraser fir Christmas trees.

About 36 million live Christmas trees are sold annually in the United States (Baumann, 1992), and growth in the international market is also increasing. Live Christmas trees harbor insect pests, and disinfestation procedures will be required to meet import regulations of foreign markets.

Fraser fir is an important Christmas tree species in North America, and since it will be exported in greater quantity in the future, information is needed on quarantine treatments. Fraser fir is relatively tolerant of methyl bromide (G.A. Chastagner et al., unpublished data; U.S. Dept. of Agriculture, 1977), but information concerning its response to radiation is lacking.

Since balsam fir (*Abies balsamea* L.), a closely related species, is relatively sensitive to chronic, low-level doses of gamma radiation (Dugle, 1986), we examined postharvest quality of gamma-irradiated Fraser fir branches.

High radiation doses (Expt. 1). Ten uniform branches were collected from the middle crown of each of eight Fraser fir trees (height, ≈ 2 m; age, ≈ 12 years) at Waynesville, N.C., on 10 Nov. 1992 and stored in buckets of water. About 1 h later, branches from each tree were cut to a length of ≈ 0.5 m and tied together in pairs. One pair from each tree was placed in each of five small corrugated boxes, which were then packaged in a larger box and sent, overnight, to a commercial ⁶⁰Co food irradiation facility in Florida. The next day, each box

was randomly assigned to one of five target doses of radiation: 0, 0.5, 1.0, 2.5, and 5.0 kGy (0 to 500 kRad). Actual radiation levels, based on dosimeters (GammaChrome Laboratories, England), were 0, 0.64, 1.19, 2.54, and 4.64 kGy, and the rate of irradiation was ≈ 0.26 kGy·min⁻¹. Each box had several vent holes for gas exchange. After irradiation, boxes were returned, overnight, to Raleigh.

On 12 Nov. 1992, branches were setup in a laboratory at Raleigh. One branch from each pair and each treatment was placed in a flask of distilled water (butt end down); the other was displayed dry. Temperature and relative humidity were $18 \pm 3^\circ\text{C}$ and $40\% \pm 10\%$, respectively. Branches received fluorescent lighting (0800 to 1700 hr) on most weekdays.

After 2 weeks, needle loss was determined by lightly rubbing each shoot between the thumb and forefinger. Abscised needles were dried for 3 days at 65°C and weighed. Residual foliage on each branch was dried similarly and weighed. Needle loss was calculated as a percentage of the total foliage weight on each branch. Foliage color was evaluated with Munsell color charts (Kollmorgen Corp., 1977).

Low radiation doses (Expt. 2). Six additional branches were collected from the middle crown of the same trees on 1 Dec. 1992. They were paired and packaged as in Expt. 1. Irradiation levels of 0, 0.1, and 0.34 kGy were administered (rate = 0.01 kGy·min⁻¹) on 2 Dec. 1992. Branches were set upon 3 Dec. 1992 and observed for 2 weeks. Again, one branch of each pair was displayed wet; the other was dry. Needle loss and color was recorded after 2 weeks.

In the first experiment, most branches, whether held wet or dry, that received 4.64 kGy showed heavy needle drop less than 24 h after irradiation (data not presented), as did some that received 2.5 kGy. Dry branches subjected to 0.64 kGy lost few needles, whereas 1.2 kGy induced $\approx 35\%$ needle abscission (Fig. 1A). Most needle abscission on dry branches occurred during the first few days after treatment. Treated branches dried rapidly and became brittle, indicating death. Nonirradiated

branches displayed in water lost few needles (Fig. 1B). Needle loss of wet branches was 46% at 0.64 kGy and increased at higher dosages (Fig. 1B).

Needles on all treatments (wet and dry), except nonirradiated controls, turned a bronze-green (Munsell colors: 5Y 4/4 or 5/4; 2.5GY 5/2 or 5/4) within 2 to 3 days. After 2 weeks, nonirradiated branches were in excellent condition, needle loss was negligible, and color was dark green (Munsell colors: 7.5GY 3/4 or 4/4). However, several dry, nonirradiated branches were somewhat lighter in color (Munsell colors: 5GY 4/6 or 4/8).

In the second experiment, wet branches subjected to 0.34 kGy had 100% needle loss during the 2-week display period (Fig. 1B). Comparable dry branches lost only 5% of their needles, but foliage discolored severely. Branches subjected to 0.1 kGy, and displayed in water, lost 42% of their needles, but the remaining foliage had good color. As in Expt. 1, nonirradiated branches were in excellent condition after 2 weeks.

Our results indicate that Fraser fir is sensitive to gamma radiation, much like its close relative, balsam fir (Dugle, 1986). Branches subjected to single doses as low as 0.1 kGy averaged 40% needle loss when displayed in water (Fig. 1B). However, there was great intertree variation, e.g., within the 0.1-kGy treatment, needle loss ranged from 5% to 100% among wet branches. The cumulative

Fig. 1. Needle abscission (percent dry-weight basis) on dormant branches of Fraser fir ($n = 8$) following single doses of gamma radiation. (A) Branches displayed for 2 weeks without water or (B) with water. Expt. 1 (○); Expt. 2 (●). Vertical bars $\pm$ SE.

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lethal dose (LD_{50}) is ≈ 0.1 kGy for balsam fir subjected to low-level gamma radiation (Dugle, 1986). Although applied over a period of years, this LD_{50} is similar to the lowest radiation level in our experiments.

We cannot explain the disparity between the 0.64-kGy treatment (45% needle drop) in Expt. 1 and the 0.34-kGy treatment (100% needle drop) in Expt. 2 (Fig. 1B). The rate of irradiation was possibly a contributing factor. Evidently, 0.34 kGy caused extensive damage but was not severe enough to kill the foliage and other tissues quickly. Consequently, branches held in water remained alive long

enough for all foliage to abscise completely.

Sterilizing insect pests in cut Christmas trees would probably require 0.5 to 1.0 kGy (Tilton and Burditt, 1983), and levels needed to kill insects outright would be higher. Fraser fir appears to be intolerant of that much radiation (Fig. 1), and a single dose of gamma radiation is not a viable way to sterilize or kill insect pests on cut Fraser fir Christmas trees.

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