Christmas Trees

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Introduction: Approximately 33 million natural Christmas trees were used in the U.S. in 1998. Given a conservative wholesale value of $10.00 per tree, the value of the trees alone approaches $330 million. When associated products are added to the picture, total value is well above $0.5 billion. The National Christmas Tree Association estimates the average retail price for Christmas trees in 1998 at $3.45 to $6.30 per ft. Based on a standard 6- to 7-ft tall (2 m) tree, the retail value of natural Christmas trees approaches $1.5 billion.

About 25% of the live Christmas trees consumed in the U.S. are sold on Choose-N-Cut farms. This means that 75% of the trees experience some form of storage and shipment after harvest. Storage and shipment times can be several weeks for trees shipped between countries, or less than one day for trees sold in local markets.

Natural Christmas trees quickly lose quality if handled improperly. People who grow, sell, handle or use Christmas trees should know something about tree keepability. This is true of the consumer who may use only one tree each year, as well as brokers or growers who handle thousands of trees.

Many publications have been written concerning postharvest physiology, handling and keepability of Christmas trees. Despite this, there is often ignorance of the subject, resulting wasted trees, reduced tree quality, erroneous information or dissatisfied consumers. In this article, we provide a summary of information concerning Christmas tree keepability.

Moisture Status of Cut Trees: A Christmas tree is a perishable product that contains a finite amount of water when cut. Postharvest quality and fire safety are closely tied to moisture status. When a tree is cut, it begins to dry. Rate of drying is affected by species as well as environmental conditions (vapor pressure deficit, temperature, wind) and cold hardiness.

The two most common methods for determining moisture status are 1) twig moisture content (MC) and 2) water potential (ψ, pronounced 'sigh'). The second method utilizes a pressurized chamber to extrude water from the cut end of a twig encased in a heavy-walled metal chamber. The drier the twig, the greater the pressure required to force water out of the end of the twig. Freshly harvested trees normally have a ψ = -0.2 to -0.8 Mpa (Mega Paschals). One MPa is about -10 bars = -10 atmospheres.

The temporal change in moisture has several inflection points. Initially, the tree dries quickly to an inflection point (V_1), which varies considerably by species. For example, V_1 is about -18 bars in eastern red cedar, -22 bars in eastern white pine, and -28 bars in Fraser fir. At that point, the rate of drying slows noticeably, presumably because stomata close to reduce water loss under increasing stress. Eventually, another value is reached (V_2) where the drying rate accelerates again, presumably where increasing drying stress exceeds the capacity of guard cells to limit water loss. V_2 probably corresponds to the "damage threshold," a term first used by Montano and Proebsting (1986). Further drying results in irreversible damage (needle abscission, discoloration, failure to re-hydrate when placed in water) to the tree. The damage threshold for Douglas-fir and Fraser fir is between -35 and -40 bars, respectively. compared to -30 to -32 bars for eastern white pine. Spruces typically experience very heavy needle loss when they dry to a certain MC, making it important to handle these species in a way that minimizes moisture loss after harvest, and displaying them in water before they reach that threshold.

The values of V1 and V2 varies by species. In addition, a pressure potential of -30 bars does not correspond to the same value of MC in various species. The time required to reach a particular MC also varies by species. For example, eastern red cedar and Atlantic white cedar dry very fast when displayed under room conditions, whereas Fraser fir and noble fir dry much slower. The latter species are regarded as long-lasting trees, whereas the former have a short shelf-life.

The moisture status of the tree determines its ability to rehydrate when re-cut and displayed in water. Fresh cut trees typically have a MC in excess of 100%. When a fresh tree is re-cut and displayed in water, it typically gains weight, reaching a MC 5 to 10% above the initial value. Trees without water gradually lose moisture, and can readily re-hydrate at moisture levels approaching V2. Beyond that, the degree of rehydration may decrease, or if rehydration occurs, there may be adverse changes in quality (needle abscission, discoloration). For example, eastern red cedar re-hydrates when V2 = -45 to -50 bars, but not without subsequent abscission of foliage.

The moisture status during display also varies among species. Species that endure for a long time during the display period, eg., noble fir and Fraser fir, tend to maintain a MC and ψ close to the initial value for at least 4 weeks. Species that have a short shelf-life, eg., eastern red cedar and Atlantic white cedar, maintain a high water level for about 1 week, and then begin to slowly dry even while displayed in water. This process is reflected by a decrease in ψ (more negative), a decrease in twig MC, and a reduction in water consumption.

Water Use: When supplied with water, cut Christmas trees generally consume about 1 qt (about 1 l) of water per day per inch (2.54 cm) of stem diameter. Thus, a tree with a 4-in diameter trunk would use about 4 qt (about 4 L) of water per day. The biggest mistake by consumers is using a stand with too little capacity, resulting in trees drying up between waterings. If this happens, the tree might not rehydrate when rewatered.

Water use changes during the display period, and also varies among species. Compared to other species, true firs tend to use large quantities of water over extended display periods. For example, a 6-ft (about 2 m) Fraser fir can easily use 4 qt of water per day during the first 5 to 7 days, and 2 to 3 qt (about 2 to 3 l) per day thereafter for the next 3 to 4 weeks. In contrast, water use by an eastern red cedar might decrease noticeably after a week. In general, if the tree continues to use a relatively constant amount of water, it indicates that the tree is maintaining its initial water status. On the other hand, if there is a marked reduction in water consumption, it probably indicates that the tree is beginning to dry.

Additives: Many chemicals and home concoctions have been tested in hopes of prolonging the life of cut Christmas trees. Additives are of little benefit, and sometimes produce adverse effects. Additives can undesirably increase water consumption by displayed trees. Because people often use stands that are too small, increased water consumption would increase the likelihood of a tree ‘going dry’ in the stand. Some additives can induce heavy needle loss. The best tree preservative is plain water, without additives.

Cold Hardiness: Cold hardened Christmas trees keep better after harvest, and better withstand exposure to low temperatures. Induction of cold hardiness requires photosynthesis, reduced temperatures, and shorter days. In this context, it will not occur in darkness, as in a refrigerator. When trees are harvested too early, heavy needle loss is possible, even with proper care. It is not known why cold hardened trees keep better than non-hardened trees. Foliar raffinose increases during the Fall although the absolute amount is small compared to sucrose. The increase in raffinose is mostly a response to lower temperatures. The role of raffinose is not clear although in other plants it can reduce the ice crystallization temperature in cell sap. Non-hardened trees also transpire more, and thus dry faster than hardened trees.

Tree species and seed sources also differ in their ability to tolerate exposure to cold temperatures. Coast types of Douglas-fir are genetically not as cold hardy as intermountain types. If coastal types of Douglas-fir are shipped into cold weather market areas and not protected for exposure to cold temperatures, they can exhibit severe needle loss due to cold injury. The level of damage depends on the level of cold hardiness of the trees, the rate of temperature drop and the lowest temperatures the trees are exposed to. People should be aware that tree species, the environmental conditions prior to harvest and the environmental conditions trees are exposed to during transit and on retail lots can have a bearing on postharvest quality.

Diseases and Pests: Christmas trees can be damaged by a variety of diseases and pests. Although trees and branches can be killed, most of the damage results in cosmetic needle discoloration or loss of needles prior to harvest. Little information is available concerning the direst impact of various diseases and pests on the postharvest keepability of trees. Swiss needle cast on Douglas-fir Christmas trees can accelerate moisture loss and needle loss when trees are displayed indoors.

Quarantine Issues: Live Christmas trees sometimes harbor plant pathogens, insects and arthropods. Most are only an annoyance, but some, if exported to places that have no natural enemies, could potentially cause serious problems. States and countries impose various quarantines in an effort to prevent the introduction or further spread of potentially harmful pests. For example, trees grown in areas infested with the gypsy moth, European pine shoot moth, and pine shoot beetle are frequently prevented from being shipped out of these areas unless they have been certified to be free of these pests. Many quarantine problems can be avoided by appropriate scouting, trapping, management practices and certification programs. Mechanical shakers can be used to remove old dead needles and certain types of insects. The failure to meet quarantine requirements can result in entire shipments being rejected, causing great loss and inconvenience to producers and importers.

Fumigation: In some instances trees are required to be treated prior to entry, especially in some foreign countries. Fumigation is a common method used to meet quarantine requirements for a number of horticultural products. Although methyl bromide is one of the most common materials used to fumigate horticultural products, information on the tolerance of various types of Christmas trees to methyl bromide is limited. Chastagner (1990a) fumigated several species typically grown in the Pacific Northwest with methyl bromide at rates up to 6 lb per 1000 ft^3 for 2 h at 10 ºC (50 ºF). Douglas-fir and noble fir were not damaged; Fraser fir and grand fir experienced only slight damage; Scotch pine showed moderate damage; and Shasta fir was severely damaged. Use of methyl bromide will likely diminish in the future and alternatives are needed. Increasing development of international markets will increase the demand for procedures to ensure that exported trees are pest-free.

Irradiation: Gamma radiation can be used to sterilize or kill insects in all stages of the life cycle, including larvae and pupae within the wood. Little information is available for Christmas trees, but balsam fir is sensitive to chronic, low-level doses of gamma radiation. The cumulative lethal dose (LD_{50}) is about 0.1 kGy over a period of years. Dormant branches of Fraser fir, when subjected to single doses of gamma radiation, experienced significant needle loss at 0.10 kGy. Massive needle loss occurred within 2 days for branches that receive higher doses of radiation. In addition, there was great inter-tree variation; eg., for the 0.1 kGy treatment, needle loss ranged from 5 to 100% for branches displayed for 2 weeks in water (average = 42%). Irradiation discolored foliage and accelerated drying.

If Fraser fir is representative of other Christmas tree species, irradiation does not appear to be a viable way to meet insect quarantine requirements. Sterilizing insect pests would probably require irradiation doses of 0.5 to 1.0 kGy, and levels needed to outright kill insects would be higher. These levels of radiation would result in virtually complete defoliation of Fraser fir within a few days after exposure.

Controlled Atmosphere (CA) and Modified Atmosphere (MA) Storage: Information is limited, but short-term CA or MA storage at low temperature (5 ºC; 41 ºF) appears to be of little benefit with Fraser fir. CO_2 > 5%, as well as O_2 < 3%, can lead to increased needle loss. The respiration rate at 21 ºC (70 ºF) is about 4-times that at 5 ºC (41 ºF).

Fire Safety: Fresh Christmas trees, if properly watered and maintained, are not a fire hazard, and are very difficult to ignite with a point source of flame. But, problems can arise when trees become too dry. Several factors are important in assessment of fire risk, including ignition time, peak heat release rate (PHRR), total heat released, peak smoke release rate, and total smoke released. Dry trees produce extremely high PHRR in short periods. A PHRR of 500 kW is enough for flashover to occur. Although there are limited PHRR data, very dry Douglas-fir can produce PHRR up to 3,000 kW within 1 min of exposure to an open flame.

Recent experiments (Chastagner, unpublished) tested 21 conifer species to determine the MC where branches initially begin to fail an ignition test, and the MC for consistent failure. Branches were exposed to a flame from a small alcohol lamp for 5 sec. If the sample failed to burn or self-extinguished without any additional spread when removed from the flame, it passed the test. If there was any spread of the flame after the sample was removed from the flame, it failed the test. There is considerable interspecific variation in the MC for ignition. In addition, there is often a large transition zone of MC from the point of initially failing the flammability test to the point of flash ignition. For example, Douglas-fir begins to fail the flammability test at about 68% MC, but is totally consumed only when dried to about 30% MC.

There is a close relationship between twig MC and water potential (ψ), which also varies among species. With noble fir, twig MC must reach about 37% before it begins to fail the flammability test. This corresponds to a pressure potential below -60 bars, well beyond its damage threshold. Based on this and other postharvest display data, one can estimate how long it would take for trees dry to moisture levels where they would fail the test. With proper care, winter-hardened noble fir and Fraser fir can easily be displayed in water for 6 to 8 weeks, without becoming a fire hazard.

The use of flame retardants on trees is not recommended unless it is required by law. Flame retardants can damage needles and increase moisture loss from trees. The best way to minimize any potential fire hazard associated with cut Christmas trees is to display them in water holding stands.

Colorants, Stickers and Antitranspirants: Many conifers naturally fade to a yellow-green color in the Fall. Colorants, similar to latex paint, mask this effect if applied prior to the change, which increases consumer acceptability. Needle stickers, which dry to a clear, shiny film on the surface of foliage, supposedly cause better needle retention, but this has not been confirmed by research.

Anti-transpirants form a thin film on the surface of foliage. Although it would seem that such products should greatly reduce the drying process, this is usually not the case. Under moderate to strong drying conditions, they do little to retard drying unless applied at levels sufficiently high to render trees qualitatively less acceptable to consumers, eg., sticky. However, minor differences sometimes occur. For example, drying of eastern red cedar was slowed by latex colorant, but the overall drying rate of trees was so fast that the difference was of little practical significance.

Species Comparisons: Some Christmas tree species maintain postharvest quality better than others. Based on various experiments and observations by the authors, a rating of the postharvest quality of 30 species of Christmas trees is given in Table 1 (scientific names are in Table 2). Ratings in this table should be used as a guide, given that the postharvest quality of cut Chrismas trees can be affected by pre-harvest and postharvest environmental factors, and can vary between different seed sources within a species. The postharvest period has two phases: 1) the time between cutting and placement back in water, and 2) the period after placement in water. Some trees endure well in both phases, eg., noble fir and Fraser fir. Others do poorly when displayed dry, but endure well in water, eg., white spruce and grand fir. Some species have a short shelf-life whether displayed wet or dry, eg., eastern red cedar, and are not suited for wholesale marketing or long-term display in the home. Many of the true firs have excellent quality when displayed in water, but tend to shed needles when displayed dry, eg., Nordmann fir.

Tree Handling Recommendation for Growers and Retailers. Cut Christmas trees can deteriorate under the effects of heat, wind, sunlight, and extreme changes in temperature. Thus, reducing exposure to these elements should be the goal of every grower and retailer. Below is a series of recommendations that, if followed, should insure consumers get the freshest tree possible.

1. In warm climates, harvest trees as late in the season as possible to allow for cold hardening, which will

improve keepability after harvest.

2. Bale trees soon after cutting, especially if the weather is sunny and warm. Drying can be very rapid in the first 24 h.
3. Temporarily store trees in areas that are shaded and cool. Trees can be stored either vertically (standing on the end of the trunk) or horizontally (piles or pallets). It is not clear if one method is better than the other however, under some conditions horizontal stacking can lead to increased mold problems and damage to foliage and branches. Limiting the height of storage piles and thus reducing the compaction of trees helps to minimize these problems.
4. Avoid baling wet trees under warm temperatures because it can lead to premature needle loss.
5. Ship or sell trees on a "first in, first out" basis.
6. Avoid piling baled trees on hot parking lots or against south-facing brick or concrete walls.
7. The best storage condition is low temperature of 33 ºF to 50 ºF (1 ºC to 10 ºC), high RH of 85 to 95%, and darkness.
8. Use refrigerated trucks, if possible, especially on hauls exceeding 400 miles or when moving trees into warm regions. For long distant shipment and storage in refrigerated trucks and containers, trees should be loaded and baffled to allow for air circulation on top, bottom and sides and refrigeration systems should be run on wet cycles so they do not dehydrate the trees.
9. Never allow closed vans or flatbeds to sit idle in the sun for extended periods because it quickly leads to overheating.
10. In warm marketing areas, trees should be displayed under shade, protected from the wind, and standing in water.
11. On retail lots, store trees upright or in shallow piles in a shady, cool place, out of high traffic areas. If permanent shade is unavailable, use a tarp or shade cloth suspended above the trees and down the sides with at least a 2-ft (61 cm) air-space for ventilation.
12. Minimize or eliminate walking on baled trees because it breaks limbs and leaders, and crushes foliage. Be especially careful handling frozen trees; they are very brittle.
13. Trees on display in retail lots in warm market areas can be misted or sprayed with water at night to reduce the moisture lost during daylight hours. Misting trees on the surface of storage piles may also be beneficial, but soaking trees can result in severe mold and deterioration problems.
14. Trees hauled long distances on open trucks should be smoke tarped on the front and covered with shade cloth on the top and sides to prevent windburn and damage from diesel smoke.
15. Avoid temperatures above 10 ºC (50 ºF) in closed storage.
16. In cold weather market areas, protect trees from drying winds. Do not attempt to sell trees such as coastal Douglas-fir in these types of markets, unless they can be protected from exposure to potentially damaging temperatures.

Tree Care Recommendations for Consumers: Don't buy a tree that is losing green needles, or has dry, brittle twigs or a sour, musty smell. Excessive needle loss can be detected by vigorously shaking the tree, or dropping it onto the end of the trunk several times from a height of about 1 ft (30 cm). The loss of old dead needles from the inside of the tree does not indicate that there is a problem with the tree. Mechanical shakers can remove these needles, and reduce the potential for a mess inside the home.

1. Do not buy a tree that is too large for the area where it will be displayed. Aside from paying more than necessary, up to $10 per ft (30 cm) of height, you will have to cut off a large section of the lower trunk, and possibly the lower whorl of branches. This might ruin the appearance of the lower part of the tree.
2. Note the location of large branches at the bottom of the tree. Be sure that the handle is long enough to allow display of the tree without cutting off the lower whorl of large branches. USDA grading rules specify trees should have a handle 1 to 12 in (2.5 to 3.8 cm) long per ft (30 cm) of height. However, some species are routinely sold without pruned handles, eg, Fraser fir.
3. When purchasing a tree from a choose-n-cut farm, have the producer mechanically 'shake' the tree, if

possible. This will eliminate dead, loose needles, especially in species such as Virginia pine, white pine, Scotch pine and red cedar. There is less potential mess to reach the home.

4. If the transport time from the retail lot or farm to the final destination is more than 15 min, it is best to wrap the tree in a tarp, or carry it in an enclosed camper or the back of a pick-up. Strong wind of 60 mph (100 km h^{-1}) on the highway, especially during warm weather, can damage a tree in a short time.
5. Do not leave a cut Christmas tree lying in the sun for long periods of time, especially if air temperatures are warm. Fresh trees dry rapidly in those circumstances.
6. If the tree is carried on a vehicle, tie it securely.
7. If a tree cannot be immediately displayed in water, make a fresh cut on the base of the trunk, and stand it in a bucket of water in a cool, shaded location, either indoors or outdoors. When the tree is displayed in a water holding stand, a second fresh cut is probably unnecessary, but might enhance water uptake.
8. Use a stand that fits your tree. Some stands have circular rings at the top, so the ring must be large enough so the trunk goes through the hole. Other stands are open, which allows more range in trunk size. Avoid whittling the sides of the trunk down to fit a stand. The outer layers of wood are most efficient in taking up water and should not be removed.
9. Do not use hot water in the stand; it is of no benefit.
10. Do not use chemicals in the stand to prevent evaporation. Water moves into the trunk at the lower cut end, and eventually evaporates (transpires) from the foliage. Evaporation from the surface of water in the stand is negligible, compared to the loss from transpiration.
11. Cut off a disk of wood about 0.5 to 1 in (1.25 to 2.5 cm) thick from the base of the trunk immediately before putting the tree in the stand. Make the cut perpendicular to the stem axis. Do not cut at an angle, or into a v-shape, which makes it far more difficult to hold the tree plumb in the stand, and reduces the amount of water available to the tree. Do not cut off too much trunk, resulting in a handle too short for the stand. This would lead to the situation described in (2) and (3) above.
12. If no saw is available, get the retailer to make a fresh cut on the base of the trunk before departing for home. Assuming that the trip home is relatively short, put the tree in water as soon as possible. Species like Douglas-fir and Fraser fir can go 6 to 8 h after cutting, and still take up water. Do not bruise the end of the trunk or get it dirty.
13. Do not use additives in water, including floral preservatives, molasses, sugar, bleach, soft drinks, aspirin, honey, or other concoctions. Clean water is the only requirement to maintain freshness.
14. Keep displayed trees away from point sources of heat (fireplaces, heaters, heat vents, direct sunlight). Lowering the room temperature will slow drying, resulting in less water consumption.
15. Use a stand with an adequate water holding capacity for the tree. Using stands that are too small is a very common mistake. Fresh trees use about 1 qt (about 1 L) of water per day per in (about 2.5 cm) of trunk diameter. The stand should hold enough water to last 24 h. If the stand goes dry and is subsequently refilled, water uptake may stop or be severely limited, leading to premature drying. Contraptions are available that maintain constant water level in the stand, working on the principle of a commode float.
16. Drilling a hole in the base of the trunk does not affect water uptake.
17. The use of "I-V" type devices to supply water directly to holes drilled in the tree is not as effective as displaying the tree in a more traditional type of stand.
18. Do not apply film-forming anti-transpirants. The products supposedly block the evaporation of water from the surface of foliage, but in reality have little benefit.
19. Do not use water holding gels in the stand. They reduce the amount of water available to trees.
20. Use only UL approved lights and electrical cords and devices on trees. Check electrical cords and lights for damage prior to placement on the tree.
21. Disconnect all electrical devices prior to removing them from the tree.
22. Monitor the tree for dryness. If the tree is dry, remove it from the house.
23. Never burn a tree in a fire place or wood stove.

Literature Cited and General Reference Material:

Anon. 1984. An analysis of the feasibility of requiring chemical fire retardants for all of California's Christmas trees. Office of California State Fire Marshal, 9 pp.

Anon. 1999. European gypsy moth quarantine area increased. Amer. Christmas Tree J. 43(4):67.

Ahrens, J.F. and G.R. Stephens. 1975. Effect of harvest date or dry storage on moisture content and flammability of white spruce. Amer. Christmas Tree J. 19(4):13-16.

Ahrens, J.F. and G.R. Stephens. 1975. The effects of additives on freshness and flammability of Christmas trees. Conn. Agr. Expt. Sta. Bul. No. 760, 12 pp.

Blankenship, S.M. and L.E. Hinesley. 1990. Tolerance of controlled atmosphere storage of cut Fraser fir and its respiration rate in air. HortScience 25:941-943.

Chastagner, G.A. 1984. Moisture levels in Douglas-fir Christmas trees on retail lots in Washington and California. Pacific Northwest Christmas Tree Assoc., Northwest Lookout 17(3):10-14.

Chastagner, G.A. 1985. Research on Christmas tree keepability. Amer. Christmas Tree J. 29(4):31-35.

Chastagner, G.A. 1986. Effect of postharvest moisture stress on the keeping qualities of Douglas-fir Christmas trees. HortScience 21:485-486.

Chastagner, G.A. 1987. Tree keepability on the retail lot. Pacific Northwest Christmas Tree Assoc., Northwest Lookout, 27(1):16-19.

Chastagner, G.A. 1987. Trees of the future: Tree keepability research needs. Amer. Christmas Tree J. 31(2):30-34.

Chastagner, G.A. 1989. Maximizing your sales by keeping cut trees fresh. California Christmas Tree Assoc. The Bulletin. 35:12-19.

Chastagner, G.A. 1990a. Insect contaminants - a problem that is limiting the market for Pacific Northwest trees. Pacific Northwest Christmas Tree Assoc., Northwest Lookout 23(3):72-74.

Chastagner, G.A. 1990b. Keeping cut trees fresh. Pacific Northwest Christmas Tree Assoc., Northwest Lookout 23(3):32-34, 37-40, 42-44.

Chastagner, G. A. 1991a. Retailers - The key to providing consumers with high quality Christmas trees. Amer. Christmas Tree Assoc., Milwaukee, WI (1 h video).

Chastagner, G.A. 1991b. How were these superior trees developed? Pacific Northwest Christmas Tree Assoc., Northwest Lookout 24(2):36.

Chastagner, G.A. and R.S. Byther. 1984a. Postharvest moisture stress and the keeping qualities of Douglas-fir Christmas trees. Pacific Northwest Christmas Tree Assoc., Northwest Lookout. 17(3):29-34.

Chastagner, G.A. and R.S. Byther. 1984b. Impact of Swiss needle cast on postharvest hydration and needle retention of Douglas-fir Christmas trees. Plant Dis. 68: 192-195.

Chastagner, G.A., R.S. Byther, J.D. MacDonald, and E. Michaels.1984. Impact of Swiss needle cast on postharvest hydration and needle retention of Douglas-fir Christmas trees. Plant Dis. 68:192-195.

Chastagner, G.A. and K. Riley. 1990. Effect of water additives on the postharvest quality of Douglas-fir Christmas trees. California Christmas Tree Assoc. The Bulletin 141(Oct):6-11.

Chastagner, G.A. and K. Riley. 1991. Effect of foliar sprays of antitranspirants on the postharvest quality of Douglas-fir Christmas trees. California Christmas Tree Assoc. The Bulletin 143:36-40.

Chastagner, G.A., K. Riley, and J. Brown. 2003. Identification of Canaan fir trees with superior needle retention. 6th Intl. Christmas Tree Res. Ext. Conf. Sponsored by the NCSU Kanuga Conf. Cntr., Hendersonville NC. (In Press)

Davis, T.S. and T.A. Fretz. 1972. The anti-transpirant effect on harvested Christmas trees. Amer. Christmas Tree J. 16(1):3-5.

Deion, H.J. 1964. Observations of inflammability on natural Christmas trees. Amer. Christmas Tree J. 8(1):16-18, 54-56.

Deion, H.J., Jr. 1964. Effect of a chemical fire retardant on natural Christmas trees. Amer. Christmas Tree J. 18(2):23, 24, 60.
Dugle, J.R. 1986. Growth and morphology in balsam fir: Effects of gamma radiation. Can. J. Bot. 64:1484-1492.
Griffiths, M. 1994. Index of garden plants: the new Royal Horticultural Society dictionary. Timber Press, Portland OR.

Hinesley, L.E. 1984. Measuring freshness of cut Fraser fir Christmas trees. HortScience 19:860-862.
Hinesley, L.E., D.M. Pharr, L.K. Snelling, and S.K. Funderburk. 1992. Foliar raffinose and sucrose in four conifer species: relation to seasonal temperature. J. Amer. Soc. Hort. Sci. 117: 852-855.
Hinesley, L.E. 1988. Water relations of cut eastern redcedar Christmas trees. HortScience 23:589-591.
Hinesley, L.E. 1990. Latex colorant slows drying of redcedar Christmas trees. HortScience 25:673-674.
Hinesley, L.E. and S.M. Blankenship. 1991. Attributes of water additives affect postharvest needle retention of Fraser fir. HortScience 26: 569-570.
Hinesley, L.E. and L.K. Snelling. 1991. Vapor pressure deficit, temperature and light affect postharvest drying of Fraser fir and eastern white pine. HortScience 26:402-405.
Hinesley, L.E. and S.M. Blankenship. 1991. Effect of water additives on Fraser fir needle retention. HortTechnology 1:90-91.
Hinesley, L.E., L.K. Snelling, and S. Goodman. 1992. Rehydration of Fraser fir Christmas trees: effect of time since cutting. HortScience 27:930.
Hinesley, L.E. and L.K. Snelling. 1993. "Crop-Life" does not slow postharvest drying of Fraser fir and eastern redcedar. HortScience 28:1054.
Hinesley, L.E. and L.K. Snelling. 1993. Gamma radiation unpromising as insect quarantine treatment for Fraser fir branches. HortScience 28:1109-1110.
Hinesley, L.E. and L.K. Snelling. 1994. Postharvest drying of Leyland cypress, eastern red cedar, and Fraser fir Christmas trees. HortScience 30:1427-1428.
Hinesley, L.E. and L.K. Snelling. 1997. Postharvest drying and rehydration of Leyland cypress, Atlantic white cedar, Virginia pine, Arizona cypress and eastern white pine Christmas trees. HortScience 32:1252-1254.
Hinesley, L.E. 1990. Grower postharvest handling of Christmas trees. N.C. Coop. Ext. Serv., Christmas Tree Notes, CTN-015, 2 pp.
Hinesley, L.E. and W.T. Huxster, Jr. 1991. Retail merchandising of North Carolina Fraser fir. N.C. Coop. Ext. Serv., Christmas Tree Notes, CTN-017, 3 pp.
Hinesley, E. and G. Chastagner. 1993. Common myths and questions: the handling and care of cut Christmas trees. Amer. Christmas Tree J. 37(4):16-19.
Hummel, R.L. 1996. Cold hardiness and dormancy. Amer. Christmas Tree J. 40(2):24-26.
Koelling, M. 1998. Christmas trees do not cause fires C some facts! Amer. Christmas Tree J. 42(4):4, 6, 8, 10, 12, 14, 16, 18-21.
Kubiske, M.E., M.E. Abrams, and J.C. Finley. 1990. Keepability of Pennsylvania versus West Coast Grown Douglas-fir Christmas trees: genotypic variation in relation to subfreezing temperatures. Northern J. Appl. For. 7:86-89.
McKinley, C.R. and L.E. Hinesley. 1995. Handling Christmas Trees on Retail Lots. N.C. Coop. Ext. Serv., Christmas Tree Notes, CTN-026, 2 pp.
Miller, D.R. and W.T. Bagley. 1970. Christmas tree flammability. Amer. Christmas Tree J. 14(4):9-12.
Mitcham-Butler, E.J., L.E. Hinesley and D.M. Pharr. 1987. Soluble carbohydrate concentration of Fraser fir foliage and its relationship to postharvest needle retention. J. Amer. Soc. Hort. Sci. 112:672-676.
Mitcham-Butler, E.J., L.E. Hinesley and D.M. Pharr. 1988. Effects of harvest date and storage temperature on the postharvest needle retention of Fraser fir branches. J. Environ. Hort. 6(1):1-4.
Montano, J.M. and W.M. Proebsting. 1986. Storage of cut Douglas-fir: relationship to the damage threshold. HortScience 21:1174-1175.

Seiler, J.R., T.J. Nichols, and D.J. Paganelli. 1988. Rehydration characteristics of cut white pine and Norway spruce Christmas trees. HortScience 23:164-166.
Tilton, E.W. and A.K. Burditt, Jr. 1983. Insect disinfestation of grain and fruit. In: E.S. Josephson and M.S. Peterson (eds) Preservation of foods by ionizing radiation. Vol. 3, CRC Press, Boca Raton FL, pp. 215-229.
USDA. 1947. Treating spruce and balsam fir Christmas trees to reduce fire hazard. Forest Service, Forest Prod. Lab. Tech. Note 250.
USDA. 1977. Handbook of plant tolerances to methyl bromide. Animal and Plant Health Inspection Serv., Hoboken NJ.
USDA. 1989. United States standards for grades of Christmas trees. USDA, AMS, 9 pp.
Van Wagner, C.E. 1967. Flammability of Christmas trees. Forestry Branch Pub. No. 1034. Ottawa, Canada, 19 pp.

Table 1. Postharvest quality ratings for Christmas trees, displayed dry or in water. Trees are assumed to be cold hardened.

Species	**Displayed Dry**	**Displayed Wet**
Arizona corkbark fir	F	E
balsam fir	F	G/E
California red fir	G	E
Canaan fir	F	G/E
Concolor fir	P/G*	P/E*
European silver fir	P	G/E
Fraser fir	G	E
Grand fir	P	G/E
Greek fir	P	G/E
Korean fir	G	G/E
Noble fir	G	E
Nordmann fir	P/G*	E
Pacific silver fir	F	G/E
Turkish fir	P/G*	E
Shasta fir	P/F	F/G
Veitch fir	G	E
Douglas-fir (coastal)	P/F	G
Douglas-fir (Intermountain)	F/G*	G/E
Eastern white pine	G	G/E
Monterey pine	F	G
Scotch pine	F/G	G
Virginia pine	F	F
Western white pine	G	G/E
Colorado blue spruce	F	G/E
Norway spruce	P	G
White spruce	P	G
Arizona cypress	P/F	F/G
Atlantic white cedar	P	P/F
Eastern red cedar	P	F
Leyland cypress	F	G/E

Ratings: Excellent (E), has potential to last 4 to 6 weeks under typical household conditions. Good (G) can last 3 to 4 weeks. Fair (F) can last 10 days to 3 weeks. Poor (P) lasts only 7 to 10 days. (*), results vary greatly among seed sources. It is never a good practice to display Christmas trees dry.

Table 2. Common and scientific names of Christmas tree species listed in Table 1. Based on Griffiths (1994). Index of garden plants: the new Royal Horticultural Society dictionary, Timber Press, Portland, Oregon.

Common Name	**Scientific name**[z]
European silver fir	*Abies alba* Mill.
Pacific silver fir	*Abies amabilis* Douglas ex Forbes
Balsam fir	*Abies balsamea* L.
Canaan fir	*Abies balsamea* (L.) Mill. *var. phanerolepis* Fern.
Greek fir	*Abies cephalonica Loud.*
Concolor fir	*Abies concolor* (Gordon & Glend.) Lindl. ex Hildebr.
Fraser fir	*Abies fraseri* (Pursh) Poir.
Grand fir	*Abies grandis* (Douglas ex D. Don) Lindl.
Korean fir	*Abies koreana* Wils.
Arizona corkbark fir	*Abies lasciocarpa (Hook.) Nutt. ssp. arizonica (Merriam) E. Murray*
California red fir	*Abies magnifica* A. Murray
Shasta fir	*Abies magnifica* A. Murray var. *shastensis* Lemmon
Nordmann fir	*Abies nordmanniana* (Steven) Spach.
Turkish fir	*Abies nordmanniana* ssp. *equitrojani* (Asch. & Sint. Ex Boiss.) Coode & Cullen] (Syn. *Abies x bornmuelleriana* Mattf.)
Noble fir	*Abies procera* Rehd.
Veitch fir	*Abies veitchii* Lindl.
Atlantic white cedar	*Chamaecyparis thyoides* (L.) BSP.
Leyland cypress	X *Cupressocyparis leylandii* (Dallim. & A. B. Jackson) Dallim.
Arizona cypress	*Cupressus arizonica* Green var. *glabra (Sudw.) Little* `Carolina sapphire’
Eastern red cedar	*Juniperus virginiana* L.
Norway spruce	*Picea abies* (L.) Karst.
White spruce	*Picea glauca* (Moench) Voss
Colorado blue spruce	*Picea pungens* Engelm.
Western white pine	*Pinus monticola* Douglas ex D. Don
Eastern white pine	*Pinus strobus* L.
Scotch pine	*Pinus sylvestris* L.
Virginia pine	*Pinus virginiana* Mill.
Douglas-fir(Rocky Mt)	*Pseudotsuga menziesii* (Mirb.) Franco ssp. *menziesii*
Douglas-fir (Coastal)	*Pseudotsuga menziesii* ssp. *glauca* (Beissn.) E. Murray