Impact of Swiss Needle Cast on Postharvest Hydration and Needle Retention of Douglas-Fir Christmas Trees

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ABSTRACT

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Healthy Douglas-fir (*Pseudotsuga menziesii*) Christmas trees were compared with those infected by *Phaeocryptopus gaeumannii* for needle loss and dehydration after cutting. The presence of infected needles increased the rate of dehydration (as measured by changes in xylem water potential) of cut trees placed in water or left dry. Fungicide applications made 1 yr before harvest significantly improved retention of 1-yr-old needles on trees displayed either wet or dry, whereas applications during the year of harvest made no difference in retention of either current-season or 1-yr-old needles.

Swiss needle cast, caused by *Phaeocryptopus gaeumannii* (Rohde) Petr., is common wherever Douglas-fir Christmas trees are produced. This disease results in the premature loss of infected needles during spring and summer. Some trees retain infected needles for 3–4 yr, whereas others cast them after 1 yr.

In western Washington and Oregon, this disease is present in more than 90% of plantations growing Douglas-fir Christmas trees (9). Needles on infected trees at harvest during November and December do not show symptoms. Infected current-season needles may or may not have pseudothecia at harvest; however, careful examination of needles 1 yr or older will reveal pseudothecia of *P. gaeumannii* associated with the stomata of infected needles.

In western Washington and Oregon, infected trees usually retain two or three age classes of infected, symptomless needles at harvest. Premium quality, sheared Douglas-fir Christmas trees generally must retain a minimum of three age classes. It would be possible to consistently have three age classes of needles at harvest by controlling the disease 2 yr before harvest. Trees to be harvested in 1986 could be sprayed in 1984. Needles formed in 1984 would be protected in that year (3,6) and would be subject to few infections in 1985 and 1986 because of diminished susceptibility (4,7). Needles formed in 1985 and 1986 would be infected but retained.

In addition to the number of needles on a tree, however, tree freshness and needle retention during display are other major determinants of postharvest quality (10,12). Studies were undertaken to determine if the presence of diseased but symptomless needles would adversely affect needle retention and rate of dehydration of cut Douglas-fir Christmas trees. Nonsymptomatic diseased trees were compared with healthy trees with regard to needle retention and water loss during shipment and subsequent display.

MATERIALS AND METHODS

Fifty 8-yr-old trees were harvested from a plantation near Vader, WA, on 12 November 1981. During 1980 and 1981, these trees had received one of the following treatments: Swiss needle cast was controlled by applications of fungicides during 1980 and 1981, controlled only in 1980, controlled only in 1981, or not controlled (4).

Harvested trees were about 2 m tall and branches were removed from the lower 45 cm of the trunk to provide a "handle." Trees were individually baled with Vexar (E. I. du Pont de Nemours & Company) using a production baler (Kirk's Model 1200), then transported by truck to a

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lathhouse near Puyallup, WA, and stored in piles inside. Ten baled trees were transported to a commercial shipping facility near Shelton, WA, on 25 November, mixed with other trees on a flatbed truck, and shipped to Sacramento, CA, arriving on 29 November. On 30 November, the trees were transported to Davis, CA, unbaled, and stored outdoors until 7 December. Swiss needle cast had been controlled during 1980 and 1981 on five of the trees but had not been controlled on the other five. Development of water stress was monitored by measuring xylem water potentials before shipment, on arrival, and after storage with a pressure bomb (Model 3005, Soilmoisture Equipment Corp., Santa Barbara, CA). Xylem water potential was measured in each of two branch tips (15.2–17.8 cm long) with 1981 needles, collected randomly from each tree at each sampling.

On 30 November, trees remaining at Puyallup were unbaled and placed upright in a single row along the inside wall of the lathhouse to simulate retail display practices. These trees were brought indoors and displayed on 7 December. They were placed in a room (8.5 × 5.8 m) with a ceiling that varied in height from 3.1 to 4.9 m. A thermostatically controlled Modine forced-air hot water heater provided continuous air circulation and heating through a 0.6-m-diameter plastic polyethylene convection tube that ran the length of the room. The bottom of the convection tube was about 2.7 m above the floor. Two continuously operated, floor-mounted, 0.46-m-diameter fans were placed on either side of the room to aid in vertical mixing of air. Temperature was maintained at 20 ± 1 C and relative humidity varied between 40 and 60%. Continuous light was provided by fluorescent lamps.

Five trees from each treatment were displayed dry by affixing their bases to wooden stands. Five trees from each treatment were also displayed wet by trimming about 10 cm from the base of the handle before placement in a 19-L plastic bucket containing tap water. During the experiment, water was replenished so that the bases of the trees always remained immersed.

Trees were positioned in a randomized complete block design within the room. Branches at the base of an individual tree generally touched the basal branches of surrounding trees.

Development of moisture stress during display was determined by measuring xylem water potentials as described previously. Periodically, needle loss was determined by counting the needles and needle scars on two randomly selected 10.2-cm-long sections of stem with 1980 or 1981 growth from each tree. Average percent needle loss by year at each sampling period was calculated.

After the 24-day storage outdoors at Puyallup, the rate of rehydration of five trees on which Swiss needle cast had been controlled during 1980 and 1981 was compared with rehydration of five trees on which the disease had not been controlled. Xylem water potentials were measured as described before at intervals after the freshly cut bases of these trees were immersed in water.

RESULTS

After storage outside for 24 days, trees on which Swiss needle cast had been controlled during 1980 or 1980 and 1981 had significantly higher ($P = 0.01$) xylem water potentials than trees on which the disease was not controlled or controlled during 1981 only (−22.5 vs. −25.9 bars). Infected trees shipped to Davis were significantly drier than the healthy trees by 7 December (Fig. 1). Diseased and healthy trees that had dehydrated after cutting rapidly rehydrated when their freshly cut trunks were placed in water (Fig. 2). After 24 hr, the xylem water potentials of these trees were comparable to the xylem water potentials of freshly cut trees (G. A. Chastagner, *unpublished*), and after 48 hr, the xylem water potentials of all trees were between −7.7 and −11.1 bars, with no significant differences among treatments.

For trees displayed dry or wet, there were significant linear relationships ($P = 0.0001$) between xylem water potentials and the number of days trees had been displayed. Also, dehydration was significantly slower in trees on which Swiss needle cast had been controlled during 1980 than in trees on which the disease had not been controlled during 1980 (Fig. 3). Control during 1981 did not influence the rate of dehydration. After only 7 days, dry-displayed trees on which Swiss needle cast had not been controlled during 1980 had xylem water potentials of <−68 bars, whereas trees on which the disease had been controlled during 1980 had xylem water potentials of about −35 to 37 bars (Fig. 3A). Similar differences in dehydration rates occurred in trees displayed wet, although it took 21–23 days for any of these trees to reach xylem water potentials of <−60 bars (Fig. 3B).

Fungicide applications during 1980 resulted in a significant decrease in loss of 1980 needles when trees were first placed indoors (Table 1). Fungicide applications

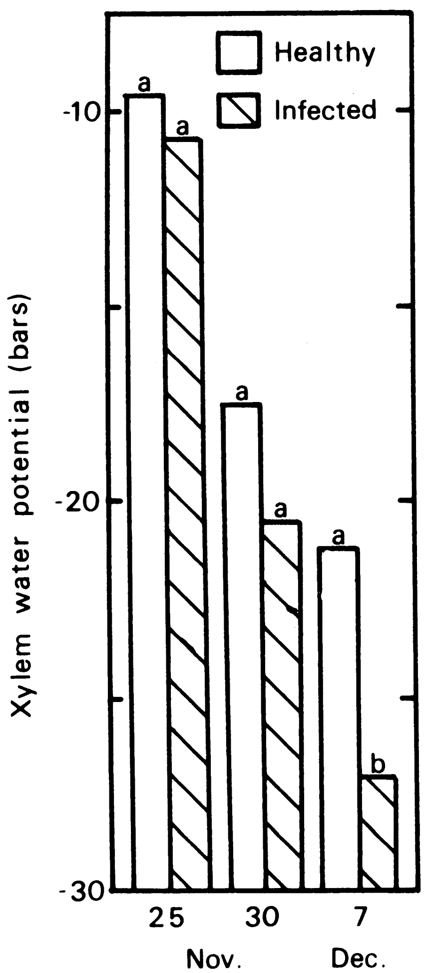

Fig. 1. Dehydration of healthy Douglas-fir Christmas trees and those affected by Swiss needle cast during 13 days that included shipment from Puyallup, WA, to Davis, CA, and subsequent storage outdoors. At each date, bars with the same letter are not significantly different ($P = 0.05$, t test).

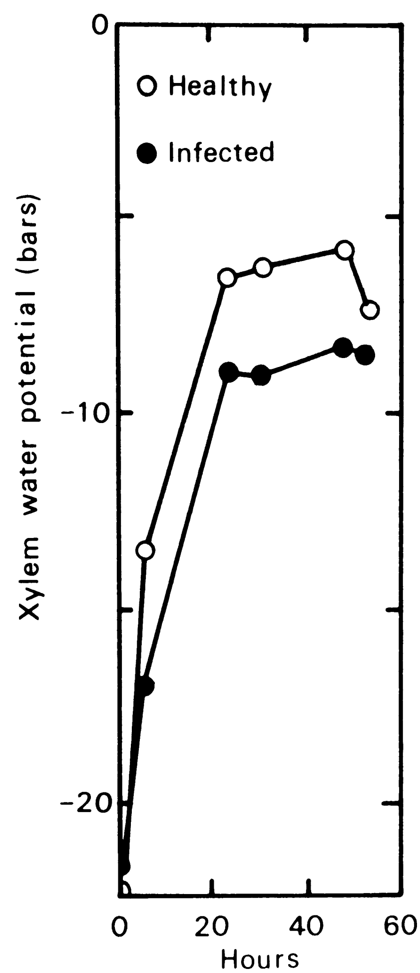

Fig. 2. Rehydration of healthy Douglas-fir Christmas trees and those affected by Swiss needle cast after storage for 24 days outdoors at Puyallup, WA. Each point represents the average xylem water potential of five trees.

during 1981 did not influence retention of 1981 or 1980 needles.

Controlling Swiss needle cast during 1980 significantly ($P = 0.05$) reduced the rate of 1980 needle loss from the trees displayed dry but not from those kept wet (Fig. 4). However, significantly ($P = 0.05$) more needles were present after 23 days (72–88%) on trees treated with fungicide in 1980 than on unsprayed trees (23–35%). Needle loss before display (Table 1), in addition to loss after display, contributed to this difference.

Loss of 1981 needles after 21 days of display ranged from 12.6 to 28.9% and from 8.4 to 15.7% for trees displayed dry and wet, respectively, and fungicide treatments had no significant effect on the rate of needle loss.

DISCUSSION

Tree freshness and needle loss are the major components that determine postharvest quality of Christmas trees. These are important from a standpoint of safety (fire hazard) and consumer acceptance (10,12). On cut, sheared trees with symptomless needles affected by Swiss needle cast, the rate of dehydration was significantly increased and needle retention was reduced. This reduction in quality occurred during outdoor storage and indoor display of trees.

Because trees in retail lots are usually stored and displayed dry, local climatic conditions influence the impact of disease on displayed trees. Many trees produced in the Pacific Northwest are shipped to and sold in the southwestern United States. Dehydration and loss of freshness would be likely to occur in these warm, relatively arid climates. Needle loss from diseased trees during storage would be expected in most situations in as much as we observed it even under the cool, moist conditions at Puyallup. When trees were displayed indoors, placing the cut surface in water delayed the adverse effects of the disease.

Controlling Swiss needle cast improves preharvest and postharvest quality of Douglas-fir Christmas trees. Growers should control the disease at least during each of the 2 yr before harvest. One properly timed application of chlorothalonil, benomyl, or mancozeb each season will accomplish this (3,6). Trees receiving these applications would retain more needles at harvest and when displayed in retail lots or indoors. They would also remain fresher than untreated, infected trees because of a reduced rate of dehydration.

After 23 days under our test conditions, trees on which Swiss needle cast had been controlled during 1980 had xylem water potentials of −35 to −40 bars (Fig. 3B). At these water potentials, needles were still dark green and pliable, giving the trees a fresh appearance. The number of days trees will appear fresh indoors would vary according to display conditions.

The mechanism by which Swiss needle cast interferes with a tree's ability to regulate water loss is not known. Lopushinsky (8) found that in Douglas-fir, a decline in transpiration rate in response to drought stress was associated with a relatively small reduction in size of stomatal aperture and concluded that mesophyll resistance played a significant role in limiting transpiration. *P. gaeumannii* colonizes mesophyll tissues intercellularly and intracellularly (5) and may disrupt this resistance. Ayres (1) indicated that foliar pathogens can disrupt stomatal function physiologically as well as mechanically. Pseudothecia of *P. gaeumannii* were only present on the

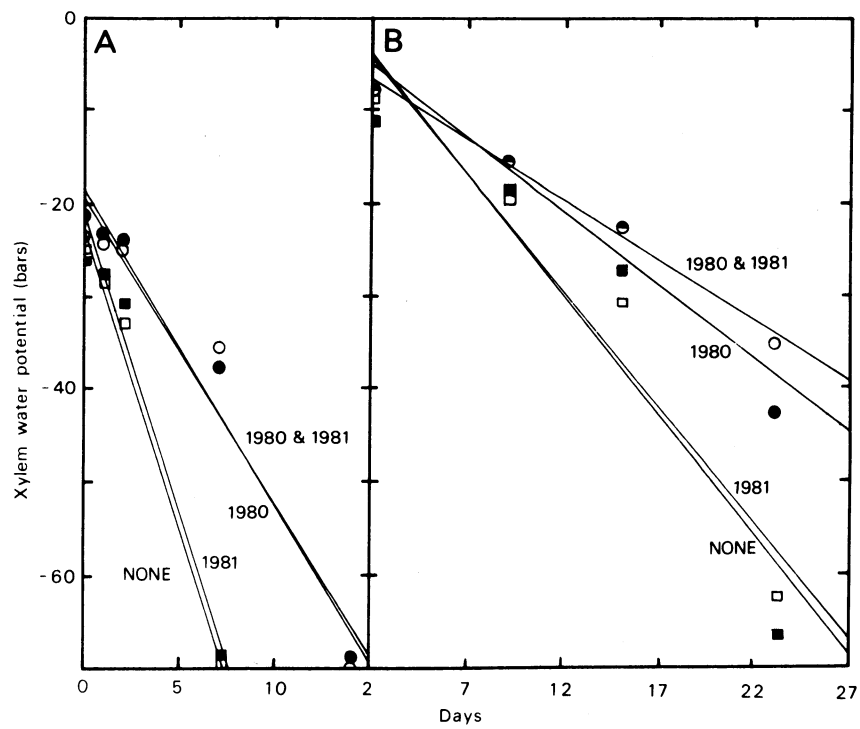

Fig. 3. Influence of controlling Swiss needle cast during 1980 and/or 1981 on dehydration of sheared Douglas-fir Christmas trees when displayed indoors **(A)** dry or **(B)** wet in 1981. Year(s) in which disease was controlled is indicated. Slopes of regression lines for trees without infected 1980 needles differ significantly ($P = 0.05$) from those with infected 1980 needles. Each data point represents the average of two measurements from five trees.

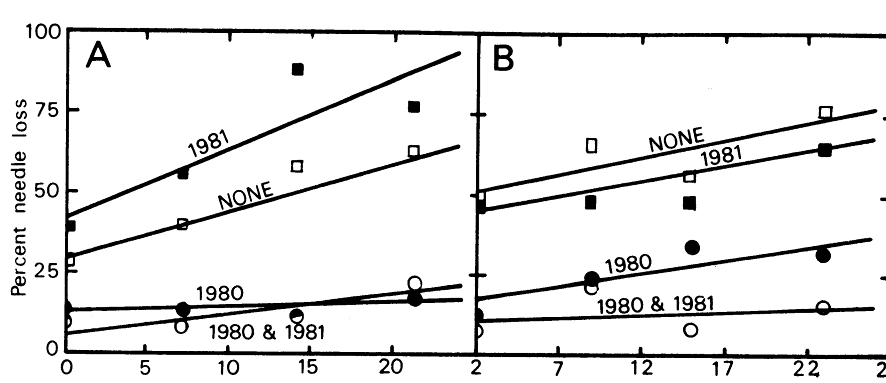

Fig. 4. Influence of controlling Swiss needle cast during 1980 and/or 1981 on the loss of 1980 needles from Douglas-fir Christmas trees when displayed indoors **(A)** dry or **(B)** wet in 1981. Year(s) in which disease was controlled is indicated. Slopes of regression lines for trees displayed dry without infected 1980 needles differ significantly ($P = 0.05$) from trees with infected 1980 needles. There was no significant interaction between treatments and rates of needle loss for trees displayed wet. Each data point represents the average of two counts from five trees.

Table 1. Percentage of 1980 and 1981 needles lost from healthy Douglas-fir trees and those infected with Swiss needle cast after 24 days of storage outdoors during November and December 1981 at Puyallup, WA[a]

Swiss needle cast controlled		Percent needle loss	
1980	**1981**	**1980**	**1981**
Yes	Yes	7.5 a	3.3 a
Yes	No	13.5 a	5.8 a
No	Yes	49.2 b	5.7 a
No	No	47.1 b	3.3 a

[a] Average of 10 trees per treatment. Within columns, numbers followed by the same letter are not significantly different ($P = 0.05$) according to Duncan's multiple range test.

1980 needles during our study, and only disease control during 1980 reduced the rate of dehydration. Presence of pseudothecia in the stomates of these needles would indicate a mechanical impediment to stomatal closure. Further studies are needed to determine the mechanism(s) by which water-loss regulation is disrupted.

It is not unusual to find Douglas-fir with infected needles (based on the presence of pseudothecia) that fail to discolor and cast prematurely (2,6). Identification and selection of seed sources to provide such "resistant" trees has been suggested as a means to avoid the economic impact caused by premature needle cast (11). Although they may retain their needles, the postharvest quality of such infected trees may be significantly impaired.

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LITERATURE CITED

1. Ayres, P. G. 1978. Water relations of diseased plants. Pages 1–60 in: Water Deficits and Plant Growth. Vol. 5. Water and Plant Disease. T. T. Kozlowski, ed. Academic Press, New York. 323 pp.
2. Boyce, J. S. 1940. A needle cast of Douglas-fir associated with *Adelopus gaeumannii*. Phytopathology 30:649-659.
3. Chastagner, G. A., and Byther, R. S. 1982. Control of Swiss needle cast on Douglas-fir Christmas trees with aerial applications of chlorothalonil. Plant Dis. 67:790-792.
4. Chastagner, G. A., and Byther, R. S. 1982. Infection period of *Phaeocryptopus gaeumannii* on Douglas-fir needles in western Washington. Plant Dis. 67:811-813.
5. Chen, Z. 1972. Adelopus needle-cast disease of Douglas-fir in central New York. Exp. For. Nat. Univ. Taiwan Tech. Bull. 103. 51 pp.
6. Hadfield, J., and Douglass, B. S. 1982. Protection of Douglas-fir Christmas trees from Swiss needle cast in Oregon. Am. Christmas Tree J. 26(2):31-33.
7. Hood, I. A., and Kershaw, D. J. 1975. Distribution and infection period of *Phaeocryptopus gaeumannii* in New Zealand. N.Z. J. For. Sci. 5:201-208.
8. Lopushinsky, W. 1969. Stomatal closure in conifer seedlings in response to leaf moisture stress. Bot. Gaz. 130:258-263.
9. Michaels, E., and Chastagner, G. A. 1982. Distribution and severity of Swiss needle-cast in Douglas-fir Christmas tree plantations. (Abstr.) Phytopathology 72:965.
10. Miller, D. R., and Bagley, W. T. 1970. Christmas tree flammability. Am. Christmas Tree J. 14(4):9-12.
11. Nicholls, T. H. 1976. Control of needle diseases—An overview. Congr. Int. Union For. Res. Organ. 16th. Div. 2:317-329.
12. Rink, G., and Thor, E. 1974. Needle retention and customer acceptance of three spruce species. Am. Christmas Tree J. 18(1):3-5.