covered pans might create conditions of high CO_2, low O_2 concentrations, and increased temperature, and these conditions may affect seed germination. More studies on plastic sheet covering accelerating seed germination are needed.

The intensity of light for seed germination and for juvenile sod development may not be as important as for the field-grown sod. The average light energy used for this study was nearly equivalent to 35% full sun light. Therefore, the low light conditions may be satisfactory for sod production in the greenhouse. The sod culture bench may be installed as shelves, and the greenhouse space can be used efficiently. Greenhouse sod production thus may be economically feasible; however, this aspect needs further research.

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Rehydration Characteristics of Cut White Pine and Norway Spruce Christmas Trees

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Additional index words. *Pinus strobus, Picea abies,* xylem water potential, moisture content

Abstract. **Rehydration characteristics of cut eastern white pine (*Pinus strobus* L.) and Norway spruce [*Picea abies* (L.) Karst.] Christmas trees were evaluated over a wide range of xylem water potentials and storage periods. Cut pines failed to rehydrate fully when initial xylem water potential was less than −3.00 MPa. Norway spruce trees completely rehydrated at xylem water potentials as low as −3.50 MPa, with partial rehydration occurring below −4.0 MPa. Twig water content closely paralleled xylem water potential. All sample trees rehydrated fully when outdoor storage periods were < 6 weeks during the months of December and January.**

Maintaining Christmas tree freshness is of major concern to both growers and consumers. Freshness is determined largely by the water content of foliage. Cut trees continually transpire water through their foliage; this water can be replenished only through use of stem water reserves or through basal absorption once the trees are put in water. In all species, however, a critical water potential is reached where trees fail to rehydrate, even after the cut stem is placed into water (9).

Two measures of tree freshness are percent water content (PWC) and xylem water potential (XWP). Fraser fir [*Abies fraseri (Pursh)* Poir.] trees will completely rehydrate at PWC and XWP values of 90% and −3.0 MPa, respectively (6). Similarly, rehydration and needle retention in Douglas-fir [*Pseudotsuga menziesii* (Mirb.) Franco] decrease when trees dry below a XWP of −3.0 MPa (3) and −3.5 MPa (7).

The objective of this study was to determine the critical water potential and twig moisture content below which harvested eastern white pine and Norway spruce Christmas trees fail to rehydrate when placed in water. White pine was chosen since it represents the most important Christmas tree species in Virginia (5). Norway spruce was chosen because it is notorious for early needle loss, which may be associated with rapid drying and poor rehydration characteristics (8).

Norway spruce and eastern white pine trees, ranging in height from 1.5 to 2.0 m, were obtained from two separate Christmas tree fields located in Floyd County, Va. Trees were cut on 1 Dec. and remained outside, unbaled, through Jan. 1986 to simulate lot storage conditions. Trees were laid on the ground in rows unprotected from the wind or rain. Randomly sampled Norway spruce and white pine were measured for XWP using a Scholander pressure chamber. Preliminary investigation, and studies of others (6), indicated little variation in XWP between twigs on the same tree, so XWP was measured on a single twig from the upper one third of each crown. When average XWP for each species reached the next higher treatment group (Fig. 1), five Norway spruce or 13 white pine were taken at random for rehydration. Trees were recut at the base (at least 5 cm was removed) and ends immediately

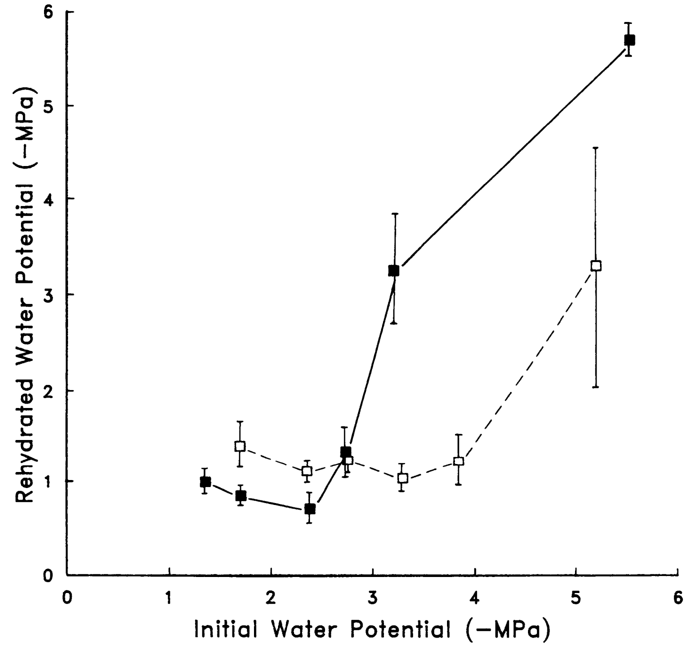

Fig. 1. Initial and rehydrated twig xylem water potential for eastern white pine (■) and Norway spruce (□) Christmas trees. Initial xylem water potential values are for the day trees were placed into water for rehydration. Rehydrated values were measured 5 days later. Bars indicate ± SE.

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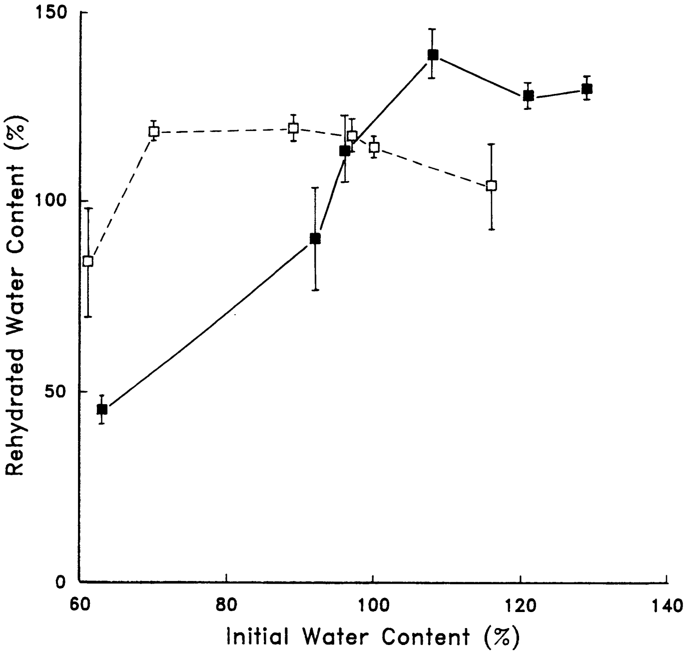

Fig. 2. Initial and rehydrated twig percent water content for eastern white pine (■) and Norway spruce (□) Christmas trees. Initial twig percent water content are for the day trees were placed into water for rehydration. Rehydrated values were measured 5 days later. Bars indicate ± SE.

Table 1. Average maximum and minimum temperatures and precipitation for Dec. 1986 and Jan. 1987 for Montgomery County, Va.

	Temperatures °C (monthly average)				Precipitation (mm)	
Month	Maximum	Minimum	Average	Normal^z	Observed	Normal
December	6.9	−3.6	1.7	1.2	105	74
January	3.3	−6.7	−1.7	−1.0	76	75

^{z}Normal represents the long-term average.

placed in water in a large, heated (15° to 23°C) room located on the Virginia Tech Horticultural Research Farm (Montgomery County, Va.) to simulate in-home conditions. Trees were supported by a wooden frame and were placed in 5-liter buckets for rehydration, with their basal ends ≈1 m apart. Trees were remeasured for XWP after 5 days of rehydration. After each XWP measurement, fresh twig weights were determined and twigs were dried at 65° to a constant weight. Twigs then were reweighed and PWC calculated on a dry-weight basis.

Measurement intervals were chosen to obtain a wide range of water potentials. During 8 weeks of outdoor storage, the trees dried very little and average XWP only decreased to −2.5 MPa. Trees then were moved indoors to accelerate drying so that lower water potentials could be obtained within a reasonable time.

The study had a completely randomized design with each tree representing a replicate. To determine the critical range of XWP and PWC below which trees will fail to rehydrate, the data were analyzed by grouping the initial water potential measurements (XWP prior to placing the trees in water) into one of six groups. For white pine, the groups were: greater than −1.51, −1.51 to −2.00, −2.01 to −2.50, −2.51 to −3.00, −3.01 to −3.50, and less than −3.50 MPa. For Norway spruce, initial water potentials were slightly lower: greater than −2.01, −2.01 to −2.50, −2.51 to −3.00, −3.01 to −3.50, −3.51 to −4.00, and less than −4.00 MPa.

A critical water potential was reached in both species where little or no rehydration occurred (Fig. 1). In white pine, XWP values averaging below −2.7 MPa resulted in no rehydration. Norway spruce failed to rehydrate fully below −3.8 MPa; however, some rehydration occurred even at the lowest water potentials measured. For example, spruce twigs that averaged −5.2 MPa rehydrated to −3.3 MPa after 5 days in water.

In both species, PWC values paralleled XWP very closely (Figs. 1 and 2), similar to findings with Fraser fir (4). White pine twigs rehydrated fully at an average initial PWC of 108% but, at PWC values of 96%, they failed to rehydrate fully. At initial PWC values <92% no rehydration occurred. Norway spruce completely rehydrated at initial PWC values as low as 70%, and partly rehydrated at values as low as 61%.

During the first five sampling periods, when the trees were stored outdoors, both species dried very slowly and always rehydrated when brought indoors. Norway spruce and white pine reached XWP of only −2.8 MPa after 42 and 58 days of outdoor storage, respectively, which was within the range of rehydration for both species (Fig. 1). It was only after trees were brought indoors that XWP began to fall rapidly and levels were reached where trees failed to rehydrate. These data and previous studies with other species of Christmas trees indicate that cut Christmas trees under some conditions can undergo long periods of outdoor storage and still rehydrate to the level of freshly cut trees (2, 9).

This conclusion needs to be viewed cautiously, since drying patterns vary tremendously depending on local weather conditions (i.e., temperature, relative humidity, solar radiation). For example, Douglas-fir trees under controlled temperatures of 20°C dehydrated below −6.0 MPa in 1 week (4). In another study, Fraser fir Christmas trees held indoors dried below −3.0 MPa within 13 days at daytime temperatures averaging 20° (6). In this study, temperatures for December and January were near normal. Precipitation was well above normal for December and near normal for January (Table 1). However, there was an unusually high amount of snowfall for the month of January, and this increased precipitation and snowcover undoubtedly contributed to the slow drying.

Norway spruce appears capable of rehydrating from lower XWP than white pine. Therefore, needle loss, which is often cited as a problem with Norway spruce (1), is not likely related to a failure to rehydrate nor does it occur immediately following rehydration. Needle loss varied widely among trees and was unrelated to XWP (data not shown). In contrast, needle drop can occur when Douglas-fir trees rehydrate after passing −3.5 MPa, and trees dried below -6.0 MPa may drop needles prior to rehydration (3).

In summary, white pine and Norway spruce can rehydrate fully when placed in water if they have not dried to XWPs of less than −3.0 MPa and −4.0 MPa, respectively. In addition, these levels of moisture stress were not reached when trees were stored outdoors under the winter conditions experienced in this study.

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Plant Growth Regulator Reduction of Bypass Shoot Development in Azalea

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Additional index words. growth retardant, flowering, azalea, daminozide, chlormequat chloride, ancymidol, paclobutrazol, fluometralin, NAA, IBA, *Rhododendron obtusum*

Abstract. **Foliar spray applications to 'Gloria' azalea (*Rhododendron obtusum*) of daminozide, chlormequat chloride, daminozide/chlormequat chloride combination, ancymidol, paclobutrazol, fluometralin, NAA, and IBA were applied prior to bypass shoot development. All treatments except IBA reduced bypass shoot length. NAA treatments were phytotoxic, and fluometralin inhibited flowering. Rate of flower development was retarded by daminozide, chlormequat chloride, and daminozide/chlormequat chloride combination, but was unaffected by ancymidol, paclobutrazol, fluometralin, NAA, and IBA. Paclobutrazol was the most efficient and effective treatment in reducing bypass shoot length without affecting flower size or time to flower. Chemical names used: butanedioic acid mono (2,2-dimethylhydrazide) (daminozide); 2-chloro-*N,N,N*-trimethyl-ethanaminium chloride (chlormequat chloride): α-cyclopropyl-α-(4-methoxyphenyl)-5-pyrimidinemethanol (ancymidol): β,[(4-chlorophenyl)methyl]-α-(1,1-dimethylethyl)-*1H*-1,2,4-triazole-1-ethanol (paclobutrazol): 2-chloro-*N*-[2,6-dinitro-4-trifluoromethyl)phenyl]-*N*-ethyl-6-fluorobenzenemethanamine (fluometralin): 1-naphthaleneacetic acid (NAA): *1H*-indole-3-butyric acid (IBA).**

Vegetative shoots subtending the floral apexes of azalea (bypass shoots) develop during flower differentiation. Bypass shoots reduce the quality of the budded and flowering plant and, if vigorous and abundant, may result in flower bud abortion. Removal of these undesirable shoots is tedious and labor-intensive.

Limited research has been conducted to control bypass shoot development. Stuart (5) suggested that daminozide and chlormequat chloride inhibit bypass shoot development; however, quantitative data were unavailable to support this observation. NAA has been effective in suppressing rootsucker growth on apple trees (3) and trunk sprouts on pyracantha (1). Fluometralin, a dinitroaniline, inhibits tobacco axillary shoot development (2). This study was conducted to evaluate the potential of reducing bypass shoot development with these chemicals and the growth retardants ancymidol and paclobutrazol.

Pinched 'Gloria' azalea liners were planted in sphagnum peat in 11.5-cm plastic pots after shipment from a propagator. Plants were grown in a double polyethylene greenhouse providing a maximum photosynthetic photon flux (PPF) of 550 μmol·s^{-1}·m^{-2}. Temperatures ranged from 21° to 24°C (days) and 15° to 18°C (nights). Plants were fertilized weekly with 300 ppm N from a 20N–4.4P–16.6K commercial soluble fertilizer and irrigated as needed. Shoots were reduced to three per plant. Treatments were applied when bypass shoots were <0.25 cm long, 7 weeks prior to cold temperature treatment, as foliar sprays at 12 ml per plant using a hand-held sprayer. The treatments were daminozide at 2000, 4000, or 6000 ppm; chlormequat chloride at 2000, 4000, or 6000 ppm; daminozide/chlormequat chloride combination at 4000/2000 ppm; ancymidol at 33, 66, or 132 ppm; paclobutrazol at 50, 100, or 200 ppm; fluometralin at 500, 1000, or 2000 ppm; NAA at 250, 500, or 1000 ppm; and IBA at 200, 400, or 800 ppm. The experiment was in a randomized complete block design with four blocks per treatment with one plant as the experimental unit.

Plants were cooled in the dark at 4°C for 6 weeks and forced into flower under the greenhouse conditions previously discussed. Flowering shoots were dated at first sign of flower color and when flowers were fully open to quantify rates of flower development and flower opening. Bypass shoot length and flower diameter were measured when flowers were fully open.

All treatments except IBA effectively reduced bypass shoot length compared to the untreated control (Table 1). Chlormequat chloride and fluometralin inhibited bypass shoot development at all concentrations tested, but increased concentrations did not lead to increased effect; however, efficacy of daminozide, ancymidol, and paclobutrazol was rate-dependent. Optimum treatments for each chemical are compared in Table 1, which includes highest rates of daminozide, chlormequat chloride, ancymidol, paclobutrazol, and IBA. The lowest rates for fluometralin

Table 1. Plant growth regulator effects on flower and bypass shoot development of *Rhododendron obtusum* cv. Gloria.

Treatment (ppm)	Days to flower color[z]	Days to open flower[z]	Flower diam (cm)	Bypass length (cm)
Control	29	37	8.2	8.0
Daminozide (6000)	37	48	7.6	1.8
Chlormequat chloride (6000)	36	48	8.0	0.6
Daminozide/ chlormequat chloride (4000/2000)	38	49	7.2	1.1
Ancymidol (132)	29	38	8.0	2.8
Paclobutrazol (200)	28	37	7.9	0.8
Fluometralin (500)	26	36	6.3	<0.2
NAA (250)	26	33	7.5	3.6
IBA (800)	29	39	8.6	7.8
Waller–Duncan at 0.5%	3	5	0.7	1.1

[z] Days calculated from time plants moved from cooler to greenhouse.

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