mg·liter^{-1} ancymidol treatment. The slopes of the two lines differed significantly. The regressions of growth on time were also linear and significant for the 0.05- and 0.1-mg·liter^{-1} treatments. There was little additional growth of the seedlings following treatment with 0.1 mg·liter^{-1}.

Our results indicate that the growth-modifying effects of dikegulac and ancymidol on young green ash and silver maple can be detected within days following addition of these compounds to a hydroponic medium. The hydroponic bioassay system described here for evaluating plant growth retardants provides a precise method for control of the dose, timing, and duration of the treatments. Other advantages are ease of examining, sampling, and harvesting the roots (3, 5, 10).

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Potential for Juvenile Sod Production

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Additional index words. greenhouse sod, Kentucky bluegrass, perennial ryegrass, tall fescue, sod tensile strength

Abstract. **"Juvenile sod" refers to an immature sod produced in pans in a greenhouse, with only 5 to 6 weeks from seeding to harvest. Seeds were planted in peatmoss after adjusting pH to 7 and were watered with nutrient solution. Tensile strength produced in plastic pans having molded ribbed bottoms and drainage holes vs. flat-bottomed pans was compared. Covering the pans with thin plastic sheets vs. leaving them uncovered during the first 4 days of germination was examined for effect on tensile strength. Tall fescue (*Festuca arundinacea* Schreb), perennial ryegrass (*Lolium perenne* L.), and Kentucky bluegrass (*Poa pratensis* L.), seeded at 60 vs. 30, 60 vs. 30, and 30 vs. 15 g·m^{-2}, respectively, were evaluated. Ribbed-bottom, covered pans, and increased seeding rates resulted in greater tensile strength, which was sufficient for marketable handling.**

The term "juvenile sod" refers to an immature sod produced in pans in a greenhouse, with only 5 to 6 weeks from seeding to harvest. The reason for producing juvenile sod is to increase the turnover rate in sod production. It also offers advantage over the traditional field sod culture by using a soil-free sod culture medium. A juvenile sod free of weeds and with low transport weight may be widely accepted by both sod industries and consumers. In addition, soils of a field-produced sod may be incompatible with the soil of the site to be sodded. For instance, sod for a sand football field usually has to be washed free of its parent soil before sodding. Sod farms have attempted to produce juvenile sod, but have been unsuccessful because the young sod does not provide sufficient sod strength for handling. Guerin and Leboucher (1) reported a practical use of sod cultivated on flax fibers for a football field. It was an innovative demonstration of the feasibility for practical use of juvenile sod. However, no research has been conducted evaluating the culture conditions that may affect the quality of juvenile sod, especially the tensile strength.

This report provides information concerning culture conditions that may affect tensile strength of a juvenile sod. The factors studied included turfgrass species, seeding rates, seed mixture, seed germination, and texture of the underlying support of cultured sod.

Turfgrass species and seeding rates. Three turfgrass species, Kentucky bluegrass ('Baron'), perennial ryegrass ('Manhattan'), and tall fescue ('Olympic'), and 50% Kentucky bluegrass plus 50% reyegrass seeding were used. Two seeding rates were applied. The high seeding rate was 30 g·m^{-2} for Kentucky bluegrass and 60 gm·m^{-2} for tall fescue and perennial ryegrass, which provides equivalent numbers of ≈85,000 seeds for a 1-m^2 area. The low seeding rate was one-half of the high rate. For mixed seeding, perennial ryegrass was overseeded on Kentucky bluegrass 4 days after the Kentucky bluegrass was seeded. The seeding rates used for the mixed seeding were the sum of one-half high or one-half low monoculture seeding rates of the two species.

Culture medium and greenhouse conditions. Canadian peatmoss supplied by Lakeland Peat moss was used for the sod culture. The peatmoss had a pH of ≈5.5. Root development of the seedlings may be inhibited without pH adjustment, even though the shoot growth may not show any apparent retardation. Therefore, the pH of the peatmoss was raised to ≈7 by adding 10% (w/w) lime (do-

Table 1. Juvenile sod tensile strength of three turfgrass species produced by two different seeding rate and seed covering treatments.

Turfgrass species	Covered or uncovered during germination	Seeding rate (g·m^{-2})	Tensile strength (kg·dm^{-1})
Perennial ryegrass	Uncovered	60	1.50 c[z]
	Covered	60	2.42 a
	Uncovered	30	1.32 c
	Covered	30	1.99 b
Tall fescue	Uncovered	60	1.19 cd
	Covered	60	2.03 b
	Uncovered	30	0.76 e
	Covered	30	1.32 c
Kentucky bluegrass	Uncovered	30	0.65 e
	Covered	30	0.78 de
	Uncovered	15	0.70 e
	Covered	15	0.92 de
Kentucky bluegrass (50%) +	Uncovered	45	0.55 e
	Covered	45	0.83 de
Perennial ryegrass (50%)	Uncovered	24.5	0.59 e
	Covered	24.5	0.67 e

[z]Means separated by Duncan's new multiple range test, P = 1%.

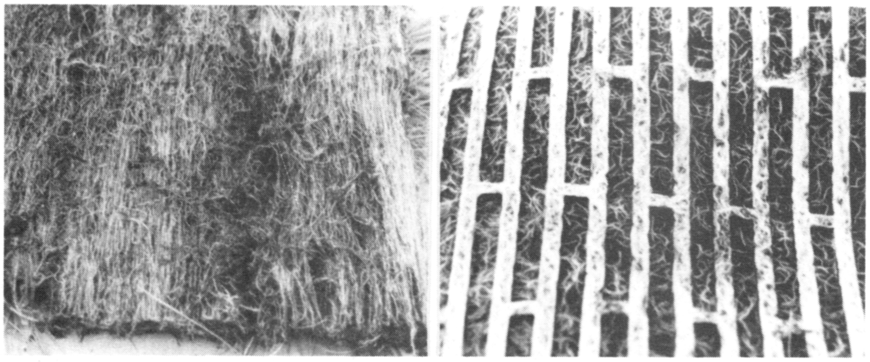

Fig. 1. Distribution of root mass of a 5-week-old perennial ryegrass juvenile sod grown in a flat-bottom plastic pan (**left**) and in ribbed-bottom pan (**right**).

Table 2. Juvenile sod tensile strength of perennial ryegrass and tall fescue produced in pans of two different bottom textures.

Turfgrass species	Bottom texture	Tensile strength ($kg \cdot dm^{-1}$)
Perennial ryegrass	Ribbed	2.63 a[z]
	Flat	1.34 c
Tall fescue	Ribbed	1.95 b
	Flat	1.21 c

[z]Means separated by Duncan's new multiple range test, $P = 1\%$.

lomite lime containing 46% $CaCO_3$, 22.7% elemental Ca, and 11.8% elemental Mg). One hundred fifty grams of peatmoss was placed in a 10 cm deep and 30 × 30 cm plastic pan. The bottom of the pan contained a 8 mm wide and 2 mm deep molded depression and rib crosses and fifteen 25-mm^2 drainage openings. The peatmoss was saturated with water prior to seeding. Seeds were evenly distributed into each pan by hand. An additional 100 g of peatmoss was added on top of seeds as mulch. Seed were either covered by a 30 × 30 cm transparent plastic sheet or left uncovered. The plastic sheets were removed on the 4th day after the seeds were sown, when the seeds began to germinate. Treatments were replicated three times for a total of 48 plastic pans (see Table 1 for treatment combinations), which were completely randomized on a greenhouse bench.

An additional experiment was conducted for examining the effect of texture of the underlying sod culture support on sod tensile strength. The high seeding rate of tall fescue and perennial ryegrass, culture medium preparation, and the dimensions of the sod culture pans used were identical to those described previously. Flat-bottom plastic pans were evaluated in addition of the ribbed bottom pans. All the plastic pans were covered by transparent plastic sheet for the first 4 days. Experimental design and replications were identical to the previous experiment.

Both experiments were started on 25 Nov. 1986 and completed on 30 Dec. 1986. To avoid overheating the seeds covered with plastic sheets, the benches were covered with cheesecloth 1 m above the bench, providing an average day light of 400 $mmol \cdot s^{-1} \cdot m^{-2}$. The greenhouse was maintained at 27° day/ 20°C night. The plant materials were watered three times a week with 0.25 concentration of Hoagland nutrient culture solution (2), until the peatmoss became saturated. The first clipping (3.25 cm high) was at the end of the 4th week after the start of the experiment. At the end of the 5th week, the sod was clipped again and the tensile strength measured. The sod was placed root face upwards on a measuring table similar to that described by Rieke et al. (3), and the opposite ends of the sod were fixed on exposed spikes on movable and fixed sections of a platform. Force was applied uniformly by adding sand to the movable platform. The force required to break the sod apart was recorded and was expressed as $kg \cdot dm^{-1}$.

The results of sod tensile strength over all seeding rates and covered vs. uncovered treatments are presented in Table 1. For perennial ryegrass and tall fescue, high seeding rate and/or plastic sheet covering had a significantly (at the 1% level) greater tensile strength than the sod of low seeding rate and/ or without seed covering. Perennial ryegrass sod produced from the high seeding rate and plastic sheet covering treatment had the highest tensile strength (2.42 $kg \cdot dm^{-1}$). The tensile strength of the covered low seeding rate of ryegrass ranked the second highest, at ≈ 2 $kg \cdot dm^{-1}$. Tall fescue sod with high seeding rate and covering treatment had tensile strength equal to the perennial ryegrass low seeding rate and covering treatment. Perennial ryegrass sod without covering at both high and low seeding rates had similar sod tensile strengths (≈1 $kg \cdot dm^{-1}$), which was equivalent to the tensile strength of tall fescue sod produced under low seeding rate with covering treatment. The tall fescue sod of low rate seeding without covering had only 0.76 $kg \cdot dm^{-1}$ tensile strength, which was not significantly different from the tensile strength of Kentucky bluegrass sod. Kentucky bluegrass sod had low tensile strength regardless of seeding rate and covering. The sod of Kentucky bluegrass and ryegrass mixed seeding showed low tensile strength. Ryegrass did not provide substantial tensile strength for the mixed seeding, probably because the ryegrass overseeding was delayed, and plants did not develop a substantial amount of roots.

Examination of the texture of the underlying sod culture support on sod tensile strength indicated (Table 2) for both ryegrass and tall fescue that sod produced in pans with the ribbed bottom had twice as much tensile strength as the sod produced in the flat-bottom pans.

Perennial ryegrass and tall fescue are characterized by extensive root systems, rapid seed germination, and growth under favorable conditions. In addition, they have a high tissue fiber content (4), which is essential for producing a tough sod strength in a short growth period. In contrast, Kentucky bluegrass seed germination is slow and its root system is weak and less extensive. The tough sod strength of Kentucky bluegrass sod produced under field conditions is provided by its underlying rhizome structure rather than its root system. Apparently, it is a species not suitable for juvenile sod production.

Supporting medium for a juvenile sod must be a light, decomposable material, favorable for turfgrass root development, economically feasible for sod production, and have high moisture retention. Peatmoss possesses most of these properties, but its pH must be adjusted. Peatmoss of different sources may have different pH values. For example, another source of Canadian peatmoss (Fisons Sunshine Peat Moss) has a pH of 4.5. Therefore, different amounts of lime additive may be needed. A piece of 30 × 30 cm peatmoss juvenile sod weighs ≈600 g. In contrast, a piece of field-produced sod of the same size usually weighs 3 kg or more. Sod strength required for sod handling is relative to its weight. Heavy sod requires greater sod strength than light sod. The tensile strength produced by the perennial ryegrass and tall fescue sod ranged from 1 (uncovered) to 2 (covered) $kg \cdot dm^{-1}$, and showed satisfactory tensile strength for handling through this experiment. In addition, if the sod culture was extended for one more week, the sod strength could increase considerably.

The present study explored the conditions of producing juvenile sod without using netting marerial. Decomposable netting materials, such as flax fibers, may be used to increase the sod strength. The turnover of sod production therefore may be accelerated further.

The underlying ribbed depressions of the plastic pan directed the roots, and formed a concentrated root matrix (Fig. 1). Consequently, this texture increased the sod tensile strength. The patterns of the underlying supporting texture should be explored further to obtain a condition providing maximal sod strength.

The perennial ryegrass and tall fescue seeds germinated within 4 days in covering treatment, vs. 7 to 8 days for the uncovered seeds. Kentucky bluegrass seed germination also was accelerated. The 3- to 4-day advance in seed germination created by the seed covering treatment was sufficient to increase tensile strength in the young sod. The plastic sheet-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

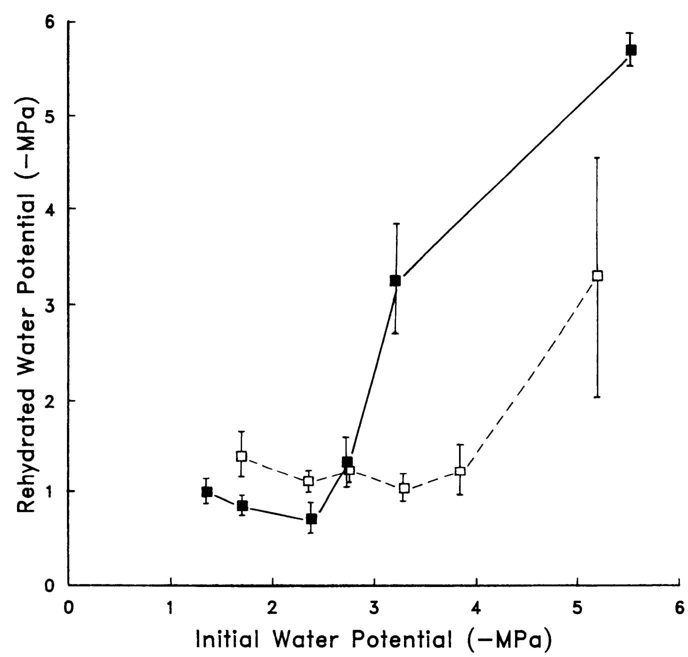

Fig. 1. Initial and rehydrated twig xylem water potential for eastern white pine (■) and Norway spruce (□) Christmas trees. Initial xylem water potential values are for the day trees were placed into water for rehydration. Rehydrated values were measured 5 days later. Bars indicate ± SE.

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