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Woody Seedling Response to Growth Retardants in Hydroponics

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Abstract. **Two- to 3-month-old seedlings (10 to 12 cm tall) were grown in solution culture to which varying levels of ancymidol or dikegulac were added. Height growth of green ash (*Fraxinus pennsylvanica* Marsh.) at 11 days after treatment was inhibited ≈50% by 12.5 mg·liter^{-1} dikegulac. Growth of green ash and silver maple (*Acer saccharinum* L.) at 7 days was inhibited 75% to 80% by 0.125 mg·liter^{-1} ancymidol. Growth responses of these seedlings were linearly related to the logarithm of dikegulac and ancymidol concentrations. Chemical names used: 2,3:4,6-bis-*O*-(1-methylethylidene)-α-L-*xylo*-2-hexulofuranosonic acid)(dikegulac); α-cyclopropyl-α-(4-methoxyphenyl)-5-pyrimidinemethanol (ancymidol).**

Mature woody plants respond more slowly than annuals to growth retardants applied to foliage or soil. Sterrett (9) reported that bean (*Phaseolus vulgaris* L. 'Black Valentine') plants responded to injections of dikegulac in 10 days, whereas California privet (*Ligustrum ovalifolium* Hassk.) required 4 weeks. From 4 to 7 weeks were required for foliarly applied dikegulac to inhibit growth of various woody species (7, 8). Granular soil applications, soil drenches, and foliar-applications of ancymidol inhibited growth of a number of woody species in 5 to 8 weeks (6). Growth retardants modify plant growth in several ways. Ancymidol, a subapical meristematic (gibberellin biosynthesis) inhibitor, interferes with internodal growth (2), and dikegulac inhibits apical cell growth by interfering with DNA synthesis (1). The objective of this investigation was to develop a hydroponic bioassay for root-applied growth retardants. Ancymidol and dikegulac were used to validate the method.

Green ash and silver maple seeds were collected in the fall, air-dried, and stored at 4°C until use. Samples were removed from dry storage at 6- to 8-week intervals and stratified at 4° between layers of moist paper towels for 10 weeks. Seeds were planted in 1.5-liter plastic pots containing 1 vermiculite : 1 perlite (v/v) and placed in a growth chamber at 8° to 10° with a 16-hr photoperiod. A low level of light [40 to 50 μmol·s^{-1}·m^{-2} photosynthetically active radiation (PAR)] was provided from a combination of incandescent and fluorescent lamps. Seedlings 3 to 5 cm tall (40 to 75 days after planting) were transplanted into 1-liter opaque plastic containers containing 0.5-strength Hoagland and Arnon's nutrient solution (4) modified to provide a chelated source of iron rather than ferric tartrate. the solution was adjusted to pH 6 with 0.1 M KOH. Trees were supported by inserting the stems into split-rubber stoppers, which were then placed in precut holes in the container lids. Lids were painted silver to reduce thermal absorption and algal growth. Initially, four seedlings were planted in each container of nutrient solution, which was aerated continuously with filtered air bubbled into the liquid. Plants were thinned to two per container after 7 to 10 days. Aeration was controlled separately to each con-

Table 1. Inhibition of growth of green ash seedlings at 20 days after application of dikegulac to nutrient solution.

Dikegulac (mg·liter^{-1})	Growth[z] (cm ± SE)	Inhibition (%)
0	10.1 ± 2.0	0
12.5	5.2 ± 0.7	49
25.0	3.8 ± 0.7	62
50.0	2.2 ± 0.5	78

[z]Growth is the change in height over 20 days. Means for eight replicates of two trees each.

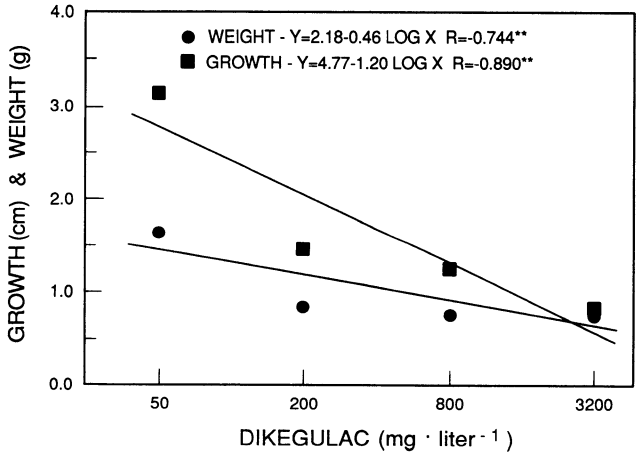

Fig.1. Height growth and root fresh weight of green ash seedlings 14 days after treatment with 50, 200, 800, or 3200 mg·liter^{-1} dikegulac in the hydroponic solution. **Significant at the 1% level.

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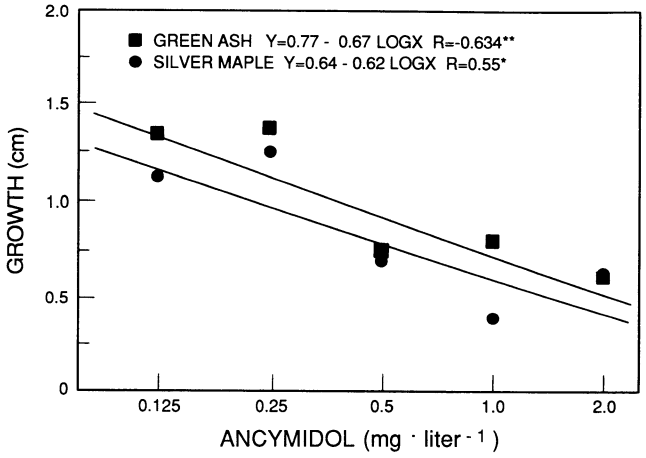

Fig. 2. Height growth of green ash and silver maple seedlings 7 days after treatment with 0.125, 0.25, 0.5, 1.0, or 2.0 mg·liter^{-1} ancymidol in the hydroponic solution. *,** Significant at the 5% and 1% levels, respectively

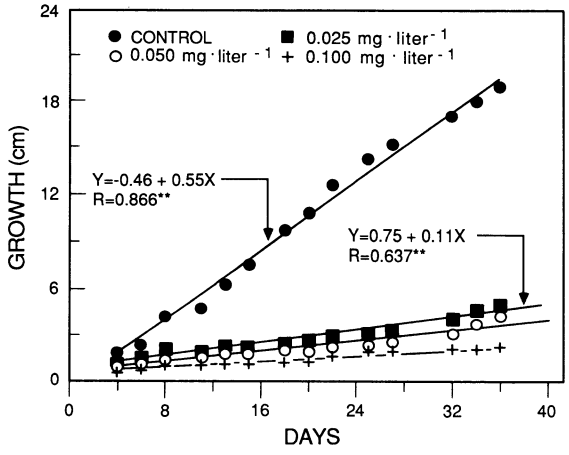

Fig. 3. Height growth of green ash seedlings over a 36-day period following treatment with 0, 0.025, 0.05, or 0.10 mg·liter^{-1} ancymidol in the hydroponic solution. ** Significant at 1% level.

tainer by a needle valve connected to a supply manifold. The liquid in the containers was replenished every 2 to 3 days by alternately adding distilled water or nutrient solution.

Hydroponic conditions were established in an air-conditioned plexiglass greenhouse with temperatures controlled at 25° ± 4°C, and a 16-hr photoperiod was provided by fluorescent lamps. Light levels were maintained at 75 ± 15 μmol·s^{-1}·m^{-2} PAR. Preliminary experiments indicated that rapidly growing plants 10 to 12 cm tall were highly responsive to plant growth retardants. They were treated 14 to 20 days after transplanting by adding the retardants to the nutrient solution in which they were growing. Dikegulac concentrations ranged from 12.5 to 3200 mg·liter^{-1}.

Table 2. Inhibition of growth of green ash seedlings 4 days after application of ancymidol to nutrient solution.

Ancymidol (mg·liter^{-1})	Growth[z] (cm ± SE)	Inhibition (%)
0	3.2 ± 0.2	0
0.015	1.9 ± 0.3	41
0.030	1.8 ± 0.5	44
0.060	1.4 ± 0.4	56
0.120	1.4 ± 0.1	56

[z]Growth is the change in height over a 4-day period. Means for four replicates of two trees each.

Ancymidol concentrations used in the dose-response comparison of green ash and silver maple were 0.125 to 2 mg·liter^{-1}. The concentrations used in subsequent experiments varied from 0.015 to 0.12 mg·liter^{-1}.

All experiments were randomized complete blocks with at least four replications. Each experimental unit consisted of two plants in a container. Data obtained included change in height and, in one instance, fresh weight of roots. All experiments were repeated at least once. Data were subjected to analysis of variance and linear regression analyses.

Effect of dikegulac on green ash. We terminated the initial dose-response study after 14 days because of phytotoxicity at the high dose levels. Inhibition of height growth was evident 7 days after treatment and ranged from 60% and 50 mg·liter^{-1} to 90% at 3200 mg·liter^{-1}. At 14 days, there was a significant log-linear decrease in height growth and root fresh weight as the concentration of dikegulac increased from 50 to 3200 mg·liter^{-1} (Fig.1). The slope of the regression equation for roots was considerably less than that of the equation for height growth (slope ± SE; -0.462 ± 0.048 vs. -1.204 ± 0.072, respectively), indicating that over the range of concentrations evaluated, root growth was less sensitive to changes in concentration than was shoot growth.

Growth was markedly inhibited by all concentrations of dikegulac (Table 1) and there was no evidence of phytotoxicity. Growth decreased linearly with the logarithm of dikegulac concentration over the range employed ($y = 10.70 - 4.98 \log X$; $r = -0.568$, significant at the 1% level). Green ash is apparently very sensitive to relatively small changes in concentration of dikegulac applied via the roots. To evaluate growth inhibition of green ash more precisely, we treated seedlings with the same range of dikegulac concentrations as used previously but started height measurements sooner and measured at more frequent intervals. At 8 days, 50 mg·liter^{-1} inhibited growth 57% (control, 4.4 cm ± 1.4 SE; treated, 1.9 cm ± 0.5 SE) and, by 11 days, growth was inhibited 47% (control, 6.2 cm ± 1.4 SE; treated 3.3 cm ± 0.8 SE) by 12.5 mg·liter^{-1}. Cumulative growth was regressed over time (6 to 34 days) for each concentration. We found a significant (1% level) linear increase in growth for the control plants and those treated with 12.5 mg·liter^{-1} of dikegulac (data not shown). The slope (± SE) of the line for the 12.5 mg·liter^{-1} treatment (0.166 ± 0.028) was significantly less (1% level) than that for the control (0.613 ± 0.096), indicating a markedly slower growth rate for the treated plants. No injury was observed other than minor chlorosis of lower leaves, which occurred mostly on plants treated with 50 mg·liter^{-1}.

Effect of ancymidol on green ash and silver maple. We conducted a 16-fold dose-response study to determine active, but non-phytotoxic levels of ancymidol for retarding growth in hydroponic culture. At 7 days, the lowest concentration (0.125 mg·liter^{-1}) reduced growth of green ash 75% (control, 5.5 cm ± 0.8 SE; treated, 1.4 cm ± 0.3 SE) and silver maple 82% (control, 6.2 cm ± 0.5 SE; treated, 1.1 cm ± 0.3 SE). As the concentration of ancymidol increased from 0.125 to 2 mg·liter^{-1}, there was a significant and similar linear decrease in growth of both species (Fig. 2). Neither the intercepts nor the slopes differed significantly. Since ancymidol was much more active on both species than was anticipated, we adjusted the treatment levels in subsequent experiments.

When green ash seedlings were treated with 0.015 to 0.12 mg·liter^{-1} and measured at 2-day intervals, we found marked inhibition of growth at 4 days with all concentrations (Table 2). A significant linear relationship occurred between growth and the logarithm of ancymidol concentration at 10, 12, and 14 days (slopes: -1.56, -1.70, and -2.22, respectively). To validate further the sensitivity of the bioassay with green ash, we treated seedlings with 0.025 to 0.1 mg·liter^{-1} of ancymidol and measured growth at 2- or 3-day intervals for 36 days. At 6 days, 0.05 mg·liter^{-1} of ancymidol inhibited growth 60% (control, 2.5 cm ± 0.6 SE; treated, 1.0 cm ± 0.3 SE) (Fig. 3). By 8 days, all levels of ancymidol markedly inhibited growth of the seedlings. A significant linear increase in cumulative growth regressed on time (4 to 36 days) was found for the control and the 0.025-

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%.