Table 1. Flurprimidol effects on annual bluegrass (*Poa annua* var. *reptans*) and creeping bentgrass (*Agrostis palustris* 'Penncross') germination. Values presented represent means of both species.

	Germination (%)[z]	
Rate	Test date	
(kg·ha^{-1})	1	2
0.00	100	100
0.28	92.0	92.3
0.56	86.7	85.3
0.84	86.7	78.3
1.12	81.0	76.3
1.68	47.7	60.0
2.24	50.3	73.7

[z]Percent germination for the controls were normalized and treatment values were adjusted to a percentage of the control. Germination counts taken 21 days after treatment.
LSD (P = 0.05) for test date = 6.5%; LSD (P = 0.05) for rate = 8.4%.

Jan. 1985). Data were collected on the number of seed germinating per pot. Nongerminating seed were examined for evidence of radicle emergence. Pots were arranged in a randomized complete block. The rate and species factors were split on the date of test factor for a 2 × 7 × 2 factorial treatment design. On each test date, six replications were used. Mean separation was accomplished using the least significant difference (LSD) multiple comparison technique.

Results of the analysis of variance showed that flurprimidol rates and date of test were significant sources of variation. A significant rate × test date interaction also was observed; however, no variability due to species was observed. As flurprimidol rate increased, germination generally decreased. Rates ≥ 0.56 kg·ha^{-1} significantly reduced germination when compared to the control (Table 1). The significant rate × test date interaction and test date main effect result from the germination values observed for the 1.68 and 2.24 kg·ha^{-1} rates. No explanation is evident for the significant rise in germination observed for the 2.24 kg·ha^{-1} rate in test date 2.

Examination of nongerminating seed found no evidence of radicle emergence, indicating that flurprimidol may act as a germination inhibitor. Flurprimidol is in a class of plant growth regulators shown to inhibit gibberellic acid (GA) biosynthesis (3, 4). Gibberellic acid is produced in the embryo of the grass seed during germination. The GA produced stimulates the cells of the aleurone layer to manufacture α-amylase, an enzyme necessary for endosperm digestion (9). If the embryonic production of GA is inhibited by flurprimidol, the products normally made available from endosperm digestion are limited, which may account for the germination inhibition seen in this study.

Results of this experiment indicate that at low rates (0.28 kg·ha^{-1}), flurprimidol exhibits no inhibition of annual bluegrass or creeping bentgrass germination. At rates ≥ 0.56 kg·ha^{-1}, both species show the same germination response to flurprimidol application. Thus, there would be no advantage in using flurprimidol in an overseeding program in terms of reducing the competition from germinating annual bluegrass. Results also indicated that the use of flurprimidol at rates ≥ 0.56 kg·ha^{-1} should not be practiced at or near time of bentgrass overseeding. If overseeding is not planned, flurprimidol will have some preemergence activity on annual bluegrass seed present in the soil. Only one biotype of annual bluegrass was evaluated, and the extreme variability exhibited by this species should be considered when extending these results to all annual bluegrass biotypes.

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Differences in Wound Closure Rates in 12 Tree Species

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Additional index words. tree wounds

Abstract. **Purposefully inflicted wounds were observed on 12 species of trees commonly used in urban landscapes and along city streets. One group was observed in an urban environment in Nashville, Tenn., the other in a rural lawn environment in Wooster, Ohio. Wound closure in both environments was more closely correlated to species than to commonly used growth parameters. In both environments, *Fraxinus pennsylvanica* and *Liquidambar styraciflua* closed wounds more quickly than *Pyrus calleryana* 'Bradford', *Gleditsia triacanthos* var. *inermis*, and *Betula nigra*.**

Urban street trees are particularly vulnerable to mechanical damage that can lead to wood decay (2–4) and death. Wounds leave disfiguring scars that close at different rates. This study was undertaken to determine if wound closure rates are closely related to rate of growth and vigor, as measured by growth parameters, or to species.

In Nashville, Tenn., eight specimens each of 10 street tree species commonly used in the mid-south were selected. All were growing in an urban environment no further than 1.2 m (4 ft) from pavement; all replications of a taxon were within one city block of one another. Larger numbers of replicates were used in the urban environment (Tennessee) to counter the expected increase in variation. In the Wooster study, four specimens each of eight street tree species commonly used in Ohio were selected at the Shade Tree

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Table 1. Comparative mean wound closure rates for 12 tree species, Nashville, Tenn. (1982), and OARDC Shade Tree Evaluation Plot (1982 and 1983).

	Wound closure rates (mm/week)			
Species	Nashville, 1982	OARDC, 1982	OARDC, 1983	Avg. for three studies
Fraxinus pennsylvanica	0.93 a[z]	1.25 a	0.72 ab	0.97
Prunus subhirtella pendula	0.76 b	---	---	---
Magnolia grandiflora	0.75 b	---	---	---
Quercus phellos	0.69 bc	---	---	---
Liquidambar styraciflua	0.60 bc	0.92 ab	0.93 a	0.82
Acer platanoides		0.86 b	---	---
A. rubrum	0.60 c	0.60 c	---	---
Platanus occidentalis	0.58 c	---	---	---
Gleditsia triacanthos inermis	0.43 d	0.81 c	0.74 ab	0.66
Betula nigra	0.35 de	0.83 bc	0.54 bc	0.57
Pyrus calleryana 'Bradford'	0.24 f	0.62 bc	0.52 bc	0.46
A. saccharum	---	0.53 c	0.33 c	---

[z]Means within a column separated by Duncan's new multiple range test, 0.05 level.

Table 2. Stepwise multiple regression data for 10 taxa of street trees, Nashville, Tenn. (1982); dependent variable is rate of wound closure.

Independent variables	R^2
Twig extension (1981)	0.119
Twig extension (1982)	0.114
Caliper increase	0.402
Twig extension (1981 and 1982)	0.122
Twig extension (1981) and caliper increase	0.423
Twig extension (1982) and caliper increase	0.404
Twig extension (1981 and 1982) and caliper increase	0.443
Species	0.758
Species and caliper increase	0.760
Species and twig extension (1982)	0.762
Species, twig extension (1982), and caliper increase	0.762

Evaluation Plot of the Ohio Agricultural Research and Development Center (OARDC). Five species were common to both sites; all trees in both sites had a trunk diameter of 10–15 cm 1.5 m above the soil line. Wound holes were drilled 10 mm in diameter and 20 mm deep on the south facing side of the trunk, 1.5 m above the soil line. The trees in the Nashville study were wounded at budbreak in 1982; the trees in Wooster were wounded at budbreak in 1982 and 1983.

Immediately after wounding, caliper measurements were taken with a caliper tape at wound height, and subsequent readings were taken at end of growing season. Twig extension data for the current season and two previous growing seasons were taken at end of studies. Three low-growing branches on the south side of each replication were selected and measured, and an average of the three was used as a measure of twig extension growth. Wound closure was measured every 2 weeks from wounding to the end of the growing season.

Closure rate was computed by dividing 10 mm (size of the original wound) by the number of weeks it took for that wound to be completely closed. If the wound was not closed by the end of the growing season, then the number of millimeters of closure was divided by 30 (the average number of weeks from wounding until callus growth stopped for all species).

Relative rankings of wound closure rates of five species common to all three studies were consistent (Table 1). *Fraxinus pennsylvanica* had most rapid wound closure rate compared to all other taxa; *Pyrus calleryana* 'Bradford' had the slowest. Comparative rates of all taxa in the three studies are found in Table 1.

Results of this study support many current theories about wound response (4, 5, 7–9). They also raise some questions about the validity of certain growth parameters in wound closure research. Specifically, there is a suggestion that species variability is the key factor in determining a response to wounding, a suggestion consistent with reports of other studies (1, 6, 8). This study is unique in that comparisons were made for plants in very different environments and at different latitudes.

Growth parameters as a predictive factor for wound response proved to be erratic and ambiguous in these studies (Table 2). There was a general lack of consistency in the correlation of these parameters to wound closure. This is in agreement with Neely (6) and Gallagher (1, 2).

Fraxinus pennsylvanica had a mean closure rate that ranged from a low of 0.72 mm/week in the 1983 OARDC study to a high of 1.25 mm/week in the 1982 OARDC study, with an average of 0.97 mm/week for the three studies. This species had the greatest twig extension (58.3) for the current year's growth in the Nashville study. This growth rate correlated well with its wound closure rate, which was the highest among the taxa. However, when all replications of all taxa were analyzed, there was a low correlation (r = 0.33) between closure rate, the dependent variable, and twig extension.

Correlation was low (r = 0.20) between twig extension aand wound closure for the 1983 OARDC data for all species. However, for *Fraxinus pennsylvanica*, there was a positive correlation (r = 0.98). Other values were: *Betula nigra* (r = 0.42), *Gleditsia triacanthos* var. *inermis* (r = 0.01), *Liquidambar styraciflua* (r = 0.48), and *Pyrus calleryana* 'Bradford' (r = 0.13). This variability suggests that twig extension is a poor parameter for predicting wound closure.

Caliper increase presented similar problems in explaining variability of wound closure rates. For the Nashville study, the total observations had a moderate correlation (r = 0.61) between caliper increase and wound closure rate. *Fraxinus pennsylvanica* had the greatest increase and was statistically distinguishable from all other taxa. Once again, these measurements correlated well with the rapid closure rate. The wound closure rate of the other taxa followed their increase rate fairly closely.

In the OARDC study, the data present a different picture — there was a strong negative correlation between caliper increase and closure rate. Even when 5-year cumulative data for caliper increase were used, indicating long term vigor and growth, the correlation was still poor.

These studies suggest that variability among species is more closely related to closure rates than are growth rates, as measured by two common parameters — twig extension and caliper increase. We can select trees for urban use that will have quick wound closure in response to mechanical damage on the basis of the known genetic characteristics of particular taxa. Last, but perhaps most important, the data suggest that species of trees in a lawn or research environment can be used to predict closure rate for the same species of trees in urban environments and at different latitudes.

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Effects of Paclobutrazol on Growth and Flowering of *Bouvardia humboldtii*

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Additional index words. ICI-paclobutrazol, daminozide, chlormequat, CCC, growth retardants, pine bark

Abstract. **Plant height of potted *Bouvardia humboldtii* Hort. was controlled effectively by foliar or drench applications of paclobutrazol. Three foliar applications of 250 mg·liter^{-1} paclobutrazol or a drench of 2 mg/100-mm-diameter pot reduced plant height by ≈30% and increased the total number of flowers per plant by ≈35%. Overall, paclobutrazol significantly reduced total plant dry weight, and sprays were more inhibitory than drenches. Paclobutrazol altered the shoot : root ratio in favor of the shoot. Foliar sprays of daminozide (5000 mg·liter^{-1}) or chlormequat (2000 mg·liter^{-1}) were ineffective in controlling growth or flowering. It is concluded that paclobutrazol application may be a useful technique in the commercial production of *Bouvardia* as a flowering pot plant. Chemical name used: β-[(4-chlorophenyl)methyl]-α-(1,1-dimethylethyl)-1*H*-1,2,4-triazole-1-ethanol [paclobutrazol (ICI-PP333)].**

Bouvardia humboldtii, with its large terminal clusters of white fragrant flowers (2), offers great potential as a flowering pot plant. However, if the natural growth habit is permitted, the long flowering stems droop under the weight of the flowers. To exploit fully the potential of *B. humboldtii* as a pot plant, stem length must be controlled. Paclobutrazol has been reported to retard stem elongation of a broad range of ornamental plant species (8, 9). The purpose of this investigation was to test the efficacy of paclobutrazol to control stem drooping and compactness in *B. humboldtii*.

Although the growth retardant α-cyclopropyl-α-(4-methoxyphenyl)-5-pyrimidinemethanol (ancymidol) has been used successfully to restrict stem extension of *B. longiflora* (5), it was not used in this experiment. Unlike paclobutrazol, registration of ancymidol in Australia is not imminent and, therefore, it is unlikely to be used extensively in ornamental production in the near future. The growth retardants butanedioic acid mono(2,2-dimethylhydrazide) (daminozide, Alar) and 2-chloro-*N,N,N*-trimethylethanaminium chloride (chlormequat chloride, Cycocel), however, are used regularly in commercial production and therefore were included for comparison with paclobutrazol.

In early spring (30 Sept.), rooted tip cuttings were pinched to induce lateral shoot development, potted (one plant per 100-mm-diameter pot) and held under 50% shade cloth (maximum light level of 850 μmol·s^{-1}·m^{-2}) for 11 weeks (mean maximum/minimum temperatures were 20.5°/10.4°C). The potting medium was composed of 66 pine bark : 17 coarse sand : 17 brown coal (lignite) (by volume) with slow-release fertilizer added at a rate of 1 kg Osmocote (15N–5.2P–12.5K), 2 kg Osmocote (18N–4.8P–8.3K), 2 kg dolomite, 0.5 kg Micromax, and 0.5 kg iron oxide per cubic meter of mix. In early summer (16 Dec.), when the plants were ≈60–70 mm high and new shoots were 30–40 mm long, each pot was top-dressed with an additional 6 g of Osmocote (15N–5.2P–12.5K), and plants were transferred to a polyethylene greenhouse where they remained for the duration of the experiment (until 3 Mar.). The mean maximum/minimum temperature for this period was 35.0°/10.8°.

Treatments were imposed on 18 Dec. and consisted of either foliar sprays or drenches of paclobutrazol. The spray rates were three applications of 250 mg·liter^{-1}, two applications of 500 mg·liter^{-1}, and one application of 100 mg·liter^{-1}. These rates were chosen on the basis of preliminary summer trials and were applied to run-off using ≈5 ml of solution per plant. For comparison, some plants were treated with daminozide at 5000 mg·liter^{-1} or chlormequat at 200 mg·liter^{-1}, both applied as three sequential foliar sprays. For all spray treatments, the first spray was applied on 18 Dec., the second on 10 Jan., and the third on 24 Jan. For the drench treatments, an 80-ml solution of paclobutrazol was applied to moist media at rates of 1, 2, or 4 mg/pot. Control plants were not treated with any growth regulators.

Experimental design was a randomized block with seven single plant replicates per treatment. Plant height, flower number, and shoot and root dry weight were measured at the completion of the experiment (3 Mar., 11 weeks after treatment).

Plant height of *B. humboldtii* was reduced significantly by all paclobutrazol treatments but not by daminozide or chlormequat (Table 1). The 250 mg·liter^{-1} and 1000 mg·liter^{-1} spray and the 1- and 2-mg drench treatments all reduced plant height by ≈30%. These application rates thus resulted in growth re-

Fig. 1. The effect of three foliar applications of 250 mg·liter^{-1} of paclobutrazol on growth and flowering of *Bouvardia humboldtii* after 11 weeks. Control plant (**left**) illustrates the stems drooping from the weight of the flowers.

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