Effect of Paclobutrazol on Conifer Seedling Morphology and Field Performance

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Abstract.--Paclobutrazol, an inhibitor of gibberellin biosynthesis, significantly reduced the growth of jack pine, red pine, and eastern larch bareroot nursery seedlings. Application in August prior to the final complete year in the nursery was more effective than application in April of the final complete year. In many cases, the higher concentrations of paclobutrazol (10-20 mg/plant) retarded root growth as well as shoot growth, and retarded first-year growth in the field. One treatment (red pine, 5 mg/tree, applied in April) resulted in a 20% reduction in seedling height, 33% increase in root dry weight, and 35% reduction in shoot:root ratio, without carryover effects to the field. Further work is needed to optimize the shoot and root growth responses to paclobutrazol and to control its persistence in the soil.

INTRODUCTION

Paclobutrazol[2](PP333, ICI Americas, Goldsboro, NC) is a potent growth regulator of a broad range of angiosperms, including monocotyledons and dicotyledons, and herbaceous and woody species (Shearing and Batch, 1979, Quinlan, 1981, Williams and Edgerton 1983, DeJong and Doyle 1984, Wood 1984, Sterret 1985). An inhibitor of gibberellin biosynthesis (Redden and Graebe 1985), paclobutrazol has been extensively studied in horticultural species because of its ability to retard vegetative growth while improving fruit set and yield. However, little work has been done on the effects of paclobutrazol on gymnosperms, particularly conifers. Wheeler (1987) reported that paclobutrazol significantly reduced the growth of container-grown Douglas-fir (Pseudotsuga menziesii Mirb. Franco) and loblolly pine (Pinus taeda L.) when applied as a soil drench to newly germinated seedlings, but did not affect growth when injected into 3- to 9-year old trees.

Paclobutrazol has several potentially important uses in forest tree nurseries. It (1) is an alternative to shoot pruning, (2) manipulates seedling size and proportions to meet specifications, (3) improves seedling adaptation to water stress by decreasing the shoot:root ratio, and (4) is a means to hold over unneeded stock an additional year. Realizing any of the benefits on this "wish list" depends on the effectiveness of paclobutrazol on a particular species, and on developing appropriate application rates and methods. This paper-reports the results of a study of paclobutrazol applied to bareroot jack pine (Pinus banksiana Lamb.), red pine (Pinus resinosa Ait.), and eastern larch (Larix laricina (Du Roi) K. Koch) seedlings at different stages of growth.

METHODS

The study was conducted at the USDA Forest Service J.W. Toumey Forest Nursery at Watersmeet, MI. Jack pine was seedlot 0477, Nicolet National Forest, zone 4; red pine was seedlot 0009, Hiawatha National Forest, zone 6; and eastern larch was seedlot 0152, Ottawa National Forest, zone 5.

Six rates of paclobutrazol were applied to each species at two times in the cultural

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[2]Trade names are included for the information of the reader and do not constitute endorsement by the USDA Forest Service.

period (early versus late). Applications were made either in August prior to the final complete year in the nursery or in April of the final complete year. Figure 1 shows the treatment times. Existing beds of seedlings were used for the study. Each species and application time was a separate test. Plots were 30-cm (1-ft) sections of bed with 30-cm buffers between treatments and the three replications. Rates of paclobutrazol (50% wettable powder) applied were 0, 0.5, 1, 5, 10, and 20 mg active ingredient/seedling in 5 ml water. The total amount applied to each plot was based on average seedling density (100-125/lineal foot) for each species and bed. Solutions were applied to seedling foliage with a garden sprayer; the plots were isolated with panels during spraying. The beds were irrigated 24 hr after application to standardize uptake time. Thus, the treatments consisted of foliar plus soil application of paclobutrazol, as in normal practice.

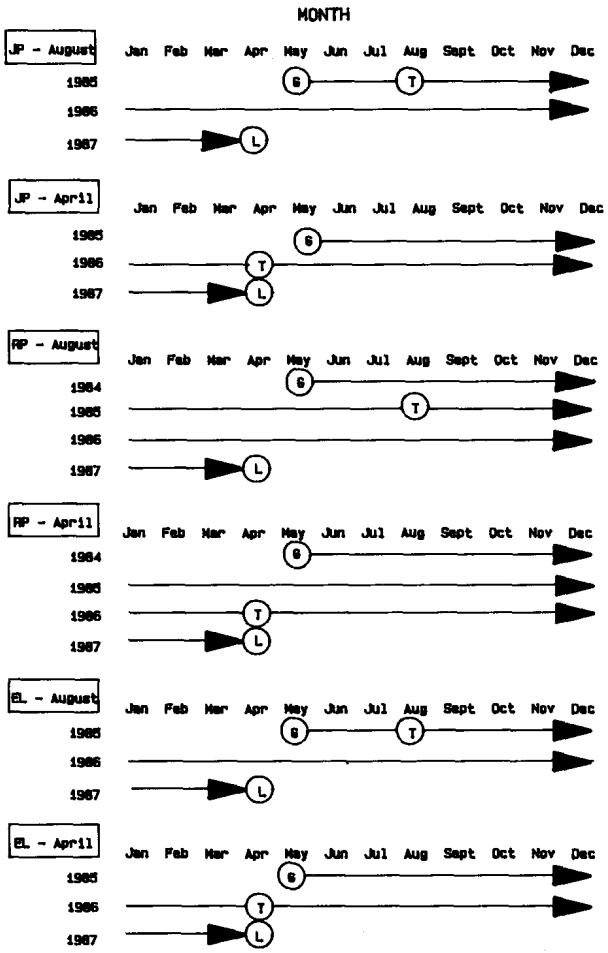

Figure 1.--Diagrams depicting growing periods and paclobutrazol application times for conifer nursery stock used in the study. Jack pine (JP) is normally grown to 2+0, red pine (RP) to 3+0, and eastern larch (EL) to 2+0. G = Germination, T = Treatment, and L = Lifting.

Seedling growth activity at time of application varied with age of plant. 2+0 and 3+0 jack pine and red pine had developing terminal buds at the August application, but 1+0 jack pine and 1+0 and 2+0 eastern larch were actively growing. The April application was made just prior to budburst for all species.

Seedlings were grown under normal nursery culture during the study. In April 1987 the seedlings were hand lifted and root pruned to a length of 20 cm. The three replications were combined, then a 15-seedling random sample was taken for morphology measurements, and a 30-seedling random sample was taken for a field test. Morphology measurements taken were: height, root collar caliper, root area index (using a Delta-T area meter), shoot dry weight, root dry weight, and shoot:root ratio (g/g). The field test consisted of three 10-seedling replications of each combination of species, application time, and chemical concentration planted under a rainshelter. Soil water potential was allowed to drop to -3.0 bars between irrigations. Survival, height growth, and caliper growth were measured at the end of one growing season.

Morphology data were analyzed for significant differences using one-way analysis of.variance (ANOVA) and Tukey's multiple comparison test using a = 0.05. Field performance variables were analyzed using arcsin transformation, ANOVA, Tukey's test for survival data, analysis of covariance (using initial height and caliper as covariates), and Scheffe's multiple comparison test using a = 0.05 for height growth and caliper growth data.

RESULTS

Paclobutrazol treatments significantly affected all measures of growth and all species, primarily at the higher rates (table 1). In general: (1) order of sensitivity was eastern larch > jack pine > red pine; (2) application early in the culture period (August) was more effective than application late in the culture period (April); (3) the highest concentrations significantly reduced seedling size (height, caliper, shoot dry weight) and height growth in the field; and (4) effects on root growth were variable, but less than effects on shoot growth. Specific responses are presented by species and application time, focusing on significant differences from the control (0 mg/tree) treatment.

Jack pine--August application.--High concentrations of paclobutrazol effectively reduced overall seedling size. The 20 mg/tree concentration reduced height 54%, caliper 42%, shoot dry weight 48%, and root dry weight 46%. Height growth in the field test was also reduced 47%.

Jack pine--April application.—Paclobutrazol treatments only affected height growth in the field test, e.g. a 27% reduction by the 20 mg/tree concentration.

Red pine--August application.--The 20 mg/tree concentration reduced height 27%, caliper 23%, root area index 12%, and shoot dry weight 26%.

Red pine--April application.--The 5 mg/tree concentration reduced height 20%, increased root area index 51%, increased root dry weight 33%, and reduced shoot:root ratio 35%. Height growth in the field was reduced 69% by the 20 mg/tree concentration.

Eastern larch--August application.--The response was similar to jack pine--August, but to a greater degree. The 20 mg/tree concentration reduced height 65%, caliper 39%, shoot dry weight 59%, shoot:root ratio 25%, survival 41%, height growth 56%, and caliper growth 52%.

Eastern larch--April.--The two highest concentrations reduced seedling height, 17% for the 20 mg/tree concentration.

DISCUSSION

Paclobutrazol is effective in controlling seedling growth of coniferous species. The results of this study generally agree with Wheeler's (1987) in that young seedlings were most responsive. However, in this study root growth was inhibited nearly as much as shoot growth. The most notable (and usable) exception occurred in April-treated 3-year-old red pines at the 5 mg/tree rate (table 1). This retarded-shoot-growth/stimulated-root-growth response occurred in only one species and application time; therefore, its validity should be evaluated in further testing. Other investigators have also noted that paclobutrazol can either increase (Atkinson and Crisp 1983) or decrease (Williamson et al. 1986) root growth. This variability may be due to the concentrations and methods of application used. Treatments that maximize the effects on shoot growth relative to root growth (i.e., foliar sprays) may result in increased root growth, whereas treatments that expose the roots to high concentrations of paclobutrazol may reduce both root and shoot growth.

It is uncertain whether the responses observed in roots of treated plants are a direct effect of paclobutrazol on root growth or an indirect effect resulting from shoot growth modification (such as a shift in resource allocation to the roots). Williamson et al. (1986) reported reductions in root growth of peach seedlings that received foliar treatments. If transport of the compound is primarily via the xylem (Lever et al. 1982), this would suggest an indirect effect on root growth by paclobutrazol.

In all species, application of paclobutrazol early in the cultural period generated a stronger response. Paclobutrazol is quite stable in the soil and is readily carried over in the field from one season to the next (Williams 1984), and accumulates in leaf tissues (Early and Martin 1988). Thus it seems reasonable to suggest that application late in the previous season (August) will allow greater uptake and will have a greater effect on growth the following season than application in April just prior to growth initiation.

Although paclobutrazol offers promise as a tool for manipulating conifer seedling growth in the nursery, the variable responses are discouraging. Moreover, the inhibitory effects on root growth in the nursery and persistent retardation of growth in the field are also unwanted. Controlling the degree and duration of paclobutrazol's effects is complicated by the influence of tree vigor (Tukey 1983), the method of application (Barrett and Bartuska 1982), its persistence in the soil (Williams 1982), and time of application (this paper). Future work should concentrate on (1) attaining the "optimum" response where shoot growth is retarded and root growth is stimulated, and (2) controlling the persistence of paclobutrazol in soil.

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Table 1.--Effect of paclobutrazol on morphology and field performance of Jack pine, (JP). red pine, (RP), and Eastern larch (EL) seedlings. Morphology measurements are based on 15 seedlings, field responses are based on 30 seedlings.

			Morphology						Field performance		
Species	Appl time	Tmt. (mg/ plant)	Height (cm)	Caliper (mm)	Root area index	Shoot dry weight (g)	Root dry weight (g)	Shoot/ root (g/g)	Survival (%)	Height growth (cm)	Caliper growth (mm)
JP	Aug	0	29.4 a[1]	6.4 a	66.6	6.628 a	0.975 a	7.0	90.0	13.3 a	1.5
		0.5	25.8 ab	5.5 ab	73.5	5.362 ab	0.969 a	6.5	93.3	11.2 ab	1.5
		1.0	22.2 b	5.1 bc	64.3	4.730 bc	0.806 ab	7.2	96.7	11.2 ab	1.4
		5.0	15.3 c	4.3 cd	54.8	4.027 bc	0.600 ab	7.1	90.0	8.0 be	1.3
		10.0	16.0 c	3.7 d	50.9	3.245 c	0.496 b	7.0	83.3	7.6 c	1.3
		20.0	13.6 c	3.7 d	50.9	3.045 c	0.527 b	6.7	100.0	7.0 c	1.3
JP	Apr	0	29.0	5.2	49.2	4.817	0.630	7.8	90.0	10.8 a	1.0
		0.5	30.3	5.9	71.4	6.646	0.869	7.9	73.3	10.8 a	1.1
		1.0	28.9	5.0	60.6	5.016	0.635	8.5	80.0	10.6 ab	0.7
		5.0	27.4	4.9	54.5	4.957	0.659	8.2	93.3	9.7 ab	0.9
		10.0	28.9	5.3	66.2	5.618	0.786	7.7	76.7	7.6 b	0.8
		20.0	27.0	5.6	71.6	6.435	0.933	7.4	100.0	7.9 b	0.9
RP	Aug	0	22.2 a	4.7 ab	47.1 ab	4.986 bc	0.640	8.8	43.3	5.4	0.8
		0.5	21.0 ab	4.3 abc	45.2 b	4.816 bc	0.515	9.8	56.7	5.2	0.8
		1.0	22.8 a	4.8 a	45.6 ab	5.967 a	0.574	11.0	60.0	4.0	0.8
		5.0	17.3 be	3.8 c	49.1 ab	4.250 bc	0.450	10.9	33.3	3.2	0.6
		10.0	18.0 be	3.9 bc	61.7 a	5.078 bc	0.704	7.7	40.0	3.9	0.7
		20.0	16.3 c	3.6 c	41.3 b	3.675 c	0.480	8.0	36.7	2.9	0.7
RP	Apr	0	24.8 a	5.0	47.4 b	6.778	0.781 ab	8.9 a	70.0	4.9 a	0.5
		0.5	22.5 ab	4.4	41.7 b	4.974	0.579 b	9.0 a	36.7	4.6 a	0.6
		1.0	21.9 ab	4.2	52.7 ab	5.730	0.568 b	10.4 a	26.7	3.4 ab	0.1
		5.0	19.8 b	5.1	71.5 a	5.892	1.041 a	5.8 b	56.7	4.2 a	0.3
		10.0	22.2 ab	4.6	50.6 b	6.299	0.688 ab	9.6 a	40.0	3.4 ab	0.1
		20.0	24.3 a	4.9	49.8 b	6.665	0.720 ab	9.7 a	43.3	1.5 b	0.1
EL	Aug	0	24.8 a	5.2 a	40.7	2.716 ab	1.253	2.4 ab	96.7 a	13.9 a	3.1 a
		0.5	26.4 a	5.7 a	43.8	3.367 a	1.409	2.5 ab	96.7 a	9.5 ab	2.6 ab
		1.0	26.3 a	5.2 a	39.3	2.635 ab	1.403	2.0 b	93.3 ab	12.5 a	3.1 a
		5.0	23.4 ab	5.3 a	43.0	3.362 a	1.154	3.1 a	96.7 a	10.5 ab	3.4 a
		10.0	13.2 be	3.9 b	27.9	1.669 bc	1.207	2.1 b	90.0 ab	11.7 a	3.5 a
		20.0	8.6 c	3.2 b	28.5	1.108 c	0.661	1.8 b	56.7 b	6.1 b	1.5 b
EL	Apr	0	31.2 a	4.7	52.2	1.929	0.825	2.5	83.3	7.9	1.5
		0.5	26.4 ab	5.1	61.2	2.336	1.037	2.5	100.0	9.9	2.0
		1.0	28.7 ab	4.6	67.3	2.023	0.971	2.4	96.7	9.4	1.9
		5.0	28.8 ab	4.9	60.8	2.265	0.913	2.7	96.7	9.2	1.9
		10.0	25.6 b	5.0	57.5	2.387	1.030	2.5	96.7	9.6	2.0
		20 0	25.9 b	5.1	6 .0	2.505	1.002	2.9	96.7	9.0	2.2

[1]Values within each group followed by the same letter are not significantly different at the 5% level. Groups without letters had no significant differences.

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