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Growth and Physiological Response of Four Shortleaf Pine Families to Herbicidal Control of Herbaceous Competition

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*ABSTRACT. Four open-pollinated families of shortleaf pine (*Pinus echinata *Mill.) seedlings were planted near Perryville, AR, in February 1988. Three herbaceous weed control treatments were tested for each family along with an untreated check. A single treatment of 3 oz ai/ac of Oust® was applied in April 1988 for spot, band, and total control of herbs. Total control was maintained with directed applications of Roundup® (3% product) as needed. Seedling survival averaged above 95% after two growing seasons for each treatment. Soil moisture, seedling growth, and seedling biomass were greatest and fascicle water potential of pines was least negative on plots receiving total control of herbs. Intermediate levels of fascicle water potentials occurred in spot- and band-treated plots where seedlings realized 91% of the height and 83% of the diameter growth potential for the site. Lowest soil moisture and growth plus most negative fascicle water potentials occurred on untreated check plots. Families differed in their physiological response when soil moisture increased. Needles and roots were the largest components of biomass. While improving pine growth, spot treatments for herbaceous weed control offer ecological and cost advantages over band treatments or total control.*

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Research has helped forest managers realize the impact of herbaceous competitors on early seedling survival and growth. However, the effect of competition control on future timber yields is not clear. One recent evaluation indicated that herbaceous weed control research yields economic gains for southern pine managers (Huang and Teeter 1990).

Early studies frequently focused on herbacide efficacy, or loblolly pine (*Pinus taeda* L.) seedling growth on Coastal Plain sites. In a comprehensive study, Zutter et al. (1986b) examined soil moisture, herb biomass, and loblolly pine growth under high, medium, and low levels of herbaceous competition. They also studied the effects of competing vegetation on loblolly pine seedling biomass (Zutter et al. 1986a). However, few studies have examined the physiology of seedlings grown under different herbaceous competition levels. Information on the relationships between herbicide efficacy, herb biomass, soil moisture, and seedling growth, fascicle water potential (FWP), and biomass on sites requiring ripping for site preparation is lacking. This study examined these relationships for shortleaf pine (*Pinus echinata* Mill.).

The objectives of this study were to evaluate: (1) first-year efficacy of a commonly used herbicide applied as total, band, and spot treatments to release seedlings of four shortleaf pine families from herbaceous competitors, (2) first-year soil moisture levels associated with herbicide treatments, (3) first-year FWPs of pine seedlings at four time intervals during the day, (4) first- and second-year seedling survival and growth, and (5) components of seedling biomass as affected by treatments.

METHODS

The test area was located near Perryville in the Ouachita Mountains of central Arkansas. Trees were clearcut and the site ripped to a depth of 18 to 24 in. in 1987. Four, bareroot, shortleaf pine families were hand-planted in February 1988. Planting stock originated from unsorted seed produced on open-pollinated females (families 103, 115, 218, and 322). The study was established as a randomized complete block design with four blocks, each with 16 randomly located treatment plots (4 families × 4 treatments). Plots contained 6 rips and 6 seedlings per rip with seedlings planted on a 9 × 6 ft spacing. Soil on the site was a stony fine sandy loam, from the Carnasaw-Pirum-Clebit series (Townsend and Williams 1982).

Three oz ai/ac of Oust®[1] (sulfometuron methyl) + water in a 10 gal/ac solution were applied in April 1988 for spot (3 ft diam.), band (3 ft wide) or total control of herbs. An untreated check served as the fourth level. Total control was initiated with the Oust® application and maintained through September 1988 with directed sprays of 3% Roundup®[2] (glyphosate) + water at 45-day intervals. Herbicides were applied during 1988 only.

Evaluations of herbicide efficacy, herbaceous biomass, soil moisture, and seedling FWP, survival, and growth were initiated in May 1988 and were continued at 45-day intervals through September 1988. During each evaluation, treated portions of plots were visually assessed for reduction of herbaceous competition in 5% intervals relative to check plots. Herbaceous biomass was clipped from within a 2 ft^2 sample frame. Six stratified samples, two light, two medium, and two heavy relative to percent cover within the plot, were collected from each check plot. Biomass was oven-dried and expressed in lb/ac. For treated plots, biomass was estimated in lb/ac in proportion to the visual assessments of herbaceous biomass reduction.

At 45-day intervals, soil samples were taken in the rip at a 6–12 in. depth within 18 in. of two small, two medium, and two large seedlings in each plot. Samples were placed in metal cans, the lids were hermetically sealed with tape and brought back to the lab for oven-drying. Soil moisture was expressed in percent of dry weight. As an additional check, an automatic recorder attached to six soil moisture tension blocks recorded daily soil moisture fluctuations in each plot of one replication. Precipitation was measured on site with an automatic recorder.

Six seedlings in each sample plot were assessed for FWP with a pressure chamber (PMS Instrument Co., Corvallis, OR) (Scholander et al. 1965). Seedlings used for FWP assessment were adjacent to the soil sample locations. However, time limitations restricted assessment of FWPs to families 103, 218, and 322. Water potentials were sampled at 5:00 A.M. (predawn), 10:00 A.M., 1:00 P.M., and 4:00 P.M. during each sample day.

Total height and groundline diameter (GLD) were measured for each seedling. Seedling measurements were initiated in February 1988 and continued at 45-day intervals from May through November 1988. Seedlings were measured again after two growing seasons in December 1989. Seedling height was measured in cm and GLD in mm. Data were converted to inches for analysis.

In December 1988, 15 shortleaf seedlings were dug from each plot in block 4 for assessment of biomass components. Seedlings were sampled with regard to relative size so that five large, five medium, and five small seedlings were selected from each plot. The excavated seedlings were brought to the lab where they were dissected into roots, stems, needles, and branches. Samples were oven-dried and weighed.

Analyses of variance and covariance (SAS Institute Inc.) were used to analyze herbicide efficacy, soil moisture, and seedling FWP, survival, growth, and biomass. Initial height and initial GLD were the covariates. Herb biomass, soil moisture, FWP, and seedling biomass samples were stratified rather than random samples. Insect damaged seedlings were included in the assessment of survival but deleted from the growth

[1] Registered Trademark of E.I. du Pont de Nemours and Co., Inc.

[2] Registered Trademark of Monsanto Chemical Co.

analysis. Trees from block 4 were not included in the 1989 analysis. Fisher's Protected LSD Test was used for mean separation, with all statistical tests conducted at the 0.05 probability level.

RESULTS AND DISCUSSION

Herbaceous Competition and Biomass

There was negligible reinvasion of herbaceous weeds on all treated plots through July 1988 (90 days after treatment) (Table 1). Dominant weeds on the study site were panic grasses (*Panicum* spp. L.), fireweed (*Erechitites hieracifolia* Raf.), and goldenrod (*Solidago* sp. L.). In the total control plots, excellent competition control was maintained through the first growing season. No differences in competition control were detected between band- and spot-treated areas. Forty-five days after treatment, herbaceous biomass averaged 1689 lb/ac in the untreated check plots, while it was estimated that treated portions of the spot, band, and total plots averaged 85, 56, and 42 lb/ac, respectively, of dried herbaceous biomass. By September, dried herbaceous biomass averaged 4375 lb/ac in untreated check plots. This measure compares to estimates of 838, 820, and 146 lb/ac in the treated areas of the spot, band, and total plots, respectively.

Soil Moisture

Through the first growing season soil moisture recorded from the soil samples remained greatest in the total control plots (Table 1). Spot and band treated plots maintained intermediate soil moisture levels while untreated check plots had the lowest percentages of soil moisture. Others have found similar increases in available soil moisture as a result of reducing herbaceous competition (Morris and Moss 1989, Zutter et al. 1986b).

Differences in moisture tension between treatments were most apparent near the end of the first growing season (Figure 1). In a study on the effects of herbaceous competition on loblolly pine, Zutter et al. (1986b) correlated seedling growth to soil moisture in late August. This was when soil moisture was lowest and probably the limiting growth factor. In the present study, normal monthly precipitation for the summer of 1988 resulted in similar soil moisture levels for all treatments through June. Highest soil moisture tensions were observed in late September when precipitation was lowest. Figure 1 illustrates the importance of herbaceous competitor control during periods of low soil moisture.

Fascicle Water Potential

Seedling FWPs were negatively related to the degree of herbaceous competition control. Seedlings grown in the untreated check plots consistently expressed the most negative FWPs through the first growing season (Table 2). Seedlings grown in plots with total herbaceous control had the least negative FWPs, while the spot and band treatments were intermediate (Table 2). Likewise, all families revealed decreasing FWPs as the growing season progressed (Table 3). Presumably the increased soil-root contact and root-to-shoot growth offset the decreased soil moisture. Seiler and Johnson (1985) found loblolly pine photosynthesis decreased when needle water potential decreased.

Seedling Survival and Growth

Seedling survival was excellent, remaining above 95% at the end of the second growing season. There were no differences in survival among herbaceous control levels or genetic families. Other studies indicate that herbaceous weed control treatments are not always necessary for establishing loblolly pine (Creighton et al. 1987, Zutter et al. 1986b).

Height and GLD differed among treatments and families. In May, seedlings receiving herbicide treatments were shorter than those in untreated check plots. However, by the end of the first growing season, plots with total control of herbaceous competition yielded the tallest seedlings (Table 2). Those in the untreated check and the band plots were the shortest (Table 2). Seedlings receiving total herbaceous control displayed the largest GLDs (Table 2). Pines on spot-treated plots averaged slightly taller in height and larger in GLD than those on band treatments. Seedlings grown in check plots yielded the smallest diameter growth.

Though differences in percent soil moisture among treatment levels were detected as early as May, first-year height-growth differences were not delineated until September. Barnes et al. (1989) reported that sulfometuron treatments decreased root growth potential of loblolly pine seedlings. Similar root stunting may have initially occurred with these shortleaf pine seedlings. However, our data indicate that the herbicide-released seedlings continued to

Table 1. Herbaceous weed control and soil moisture content among herbaceous weed control treatments.

Variable treatment	Sample period[1] May	July	August	September
Herb control	(%)[2]			
Total	98 A	92 A	95 A	97 A
Band	97 A	92 A	86 B	81 B
Spot	95 A	91 A	84 B	81 B
Soil moisture	(%[3])			
Total	10.3 A	10.9 A	10.0 A	8.9 A
Band	9.3 BC	10.4 A	7.4 B	5.7 B
Spot	9.6 B	9.7 B	7.0 B	5.4 B
Check	9.0 C	8.6 C	5.4 C	4.2 C

[1] Means within a column sharing the same letter are not statistically different (Fisher's Protected LSD Test, α = 0.05).
[2] Herb-control estimates are relative to untreated check plots.
[3] Weight of soil moisture over dry weight of sample.

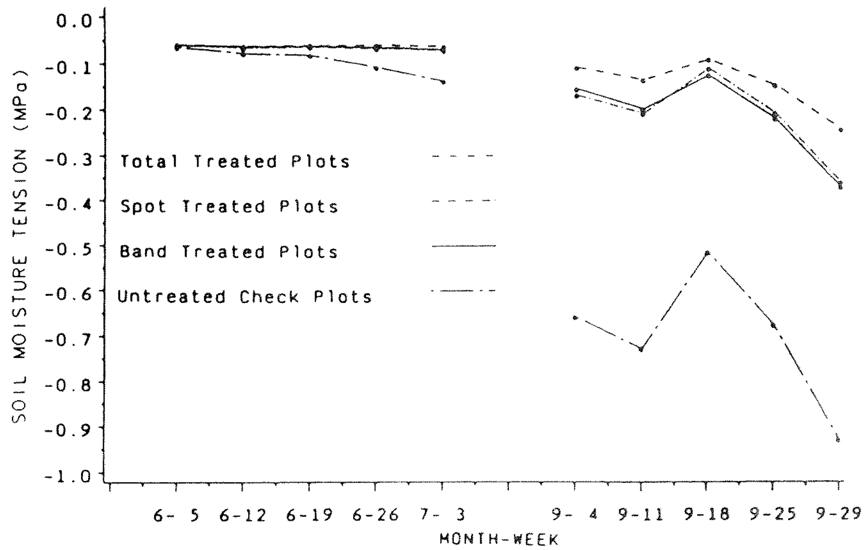

Figure 1. Weekly soil moisture tensions for June and September 1988 recorded in plots of one block that received four levels of herbaceous competition control.

grow even during dry weather and were able to capture more of the site's potential.

Average height and diameter growth advantages resulting from early competition control continued through the second growing season. Seedlings grown in total control plots averaged heights at least 4 in. taller than the spot and band treatments (Table 2). Seedlings from untreated check plots averaged 5 in. shorter than those from the spot and band treated plots. Likewise, seedling diameters in total plots remained the largest (Table 2). Trees in spot- and band-treated plots averaged 0.15 in. of diameter growth over those grown in untreated check plots. Therefore, seedlings grown in check plots realized 82% of the height and 71% of the diameter growth potential for the site, while spot- and band-treated seedlings realized an average of 91% and 83% of the height and diameter growth potential for the site, respectively.

Height and diameter ranges were smaller in magnitude for genetic family than herbicide treatment level, but seedling growth varied among genetic stock. Family 103 attained the greatest height growth through the second growing season (Table 3). However, this family exhibited the lowest GLD growth (Table 3). Family 322 grew least in height, but diameter growth ranked among the highest for all families. These results indicate differences in growth potentials among families and the ability of some to efficiently use improved growing conditions to overcome initial difference in size.

Seedling Biomass

Seedling biomass differed according to levels of herbaceous weed control and genetic family. Seedling biomass was greatest in plots that received total control of herbaceous competitors, while seedling biomass in untreated check plots was the least (Table 4). Seedlings treated with spot and band treatments were similar in biomass and produced more stem, root, and total biomass than those in untreated check plots. Seedlings grown in the total control plots produced more biomass in each class (needles, branches, stems, and roots). Family 218 used improved growing conditions to pro-

Table 2. FWPs, total heights, and GLDs for shortleaf pine seedlings receiving four herbaceous weed control treatments.

Variable treatment	Sample period[1] (1988) February[2]	May	July	August	September	November	1989 December
FWP[3]		(MPa)					
Check		−1.22 A	−0.66 A	−0.40 A	−0.44 A		
Spot		−0.98 B	−0.57 B	−0.39 A	−0.39 B		
Band		−0.96 B	−0.54 B	−0.37 BC	−0.37 B		
Total		−0.78 C	−0.44 C	−0.35 C	−0.31 C		
Height				(in.)			
Check	6.3	10.0 A	14.3 A	17.5 A	18.6 C	18.6 C	45.4 C
Spot	6.3	9.4 B	13.4 B	17.5 A	19.5 B	19.8 B	50.9 B
Total	6.3	9.2 B	13.1 B	17.4 A	20.4 A	20.8 A	55.3 A
Band	6.0	8.9 C	12.6 C	16.5 B	18.7 C	18.8 C	49.6 B
GLD				(in.)			
Check	0.11	0.15 A	0.20 A	0.24 A	0.29 D	0.32 D	0.90 C
Total	0.11	0.15 A	0.20 A	0.25 A	0.41 A	0.45 A	1.27 A
Spot	0.10	0.14 A	0.19 A	0.25 A	0.35 B	0.39 B	1.06 B
Band	0.10	0.14 A	0.18 B	0.25 A	0.34 C	0.37 C	1.04 B

[1] Means within a column sharing the same letter are not statistically different (Fisher's Protected LSD Test, $\alpha = 0.05$).
[2] Initial seedling measurements used as the covariate in analyses.
[3] Average daily fascicle water potentials measured on two large, two medium, and two small seedlings from each plot of three shortleaf pine families.

Table 3. FWPs, total heights, and GLDs for seedlings of shortleaf pine families released from herbaceous competition with herbicides.

Variable family	Sample period[1] (1988) February[2]	May	July	August	September	November	1989 December
FWP[3]		(MPa)					
103		−1.05 A	−0.57 A	−0.39 A	−0.39 A		
218		−1.01 A	−0.55 A	−0.38 A	−0.39 A		
322		−0.89 B	−0.53 A	−0.37 A	−0.35 B		
Height				(in.)			
115	7.1	10.3 A	13.6 A	17.5 A	19.6 A	19.7 A	49.7 BC
218	6.1	9.2 B	13.3 A	17.2 A	19.2 A	19.4 A	51.0 AB
103	6.4	9.1 B	13.6 A	17.6 A	19.7 A	20.0 A	51.2 A
322	5.3	8.8 C	13.0 A	16.7 A	18.7 A	18.7 A	48.7 C
GLD				(in.)			
115	0.11	0.15 A	0.20 A	0.25 A	0.34 AB	0.38 AB	1.08 A
218	0.11	0.15 A	0.20 A	0.25 A	0.35 A	0.39 A	1.08 A
322	0.10	0.14 A	0.20 A	0.25 A	0.35 A	0.39 A	1.08 A
103	0.10	0.13 B	0.19 B	0.25 A	0.33 B	0.37 B	1.03 B

[1] Means within a column sharing the same letter are not different (Fisher's Protected LSD Test, $\alpha = 0.05$).
[2] Initial seedling measurements used as the covariate in analyses.
[3] Average daily fascicle water potentials measured on two large, two medium, and two small seedlings from each plot of three shortleaf pine families.

duce the most biomass in each of the four categories. The other families yielded similar amounts of stem, root, branch, and needle biomass.

Optimum Treatment Level

Total control of herbaceous competition provided the best weed control, highest percentages of available soil moisture, least negative FWPs, and greatest pine growth. This type of treatment provides a good index of site potential although it is costly, labor intensive, and not presently feasible for ground applications on an operational scale. Spot- and band-treated plots yielded more available soil moisture, lower FWPs, and greater pine growth than untreated check plots.

After two growing seasons there were no growth advantages for applying spot treatments rather than bands. However, there were cost and ecological advantages for spot treatments. Shortleaf pines planted on a 9 × 6 ft spacing would result in 806 seedlings/ac. Typical band treatments would control vegetation on 33% of this acre. Given the same area, spot applications would control vegetation on 13% of this acre. Therefore, in a recently established plantation, a forester who prescribed spot rather than band treatments would be able to reduce the application cost per acre and not deter pine growth during the first 2 years. Furthermore, spot treatments would leave 0.20 ac more untreated herbaceous vegetation to stabilize soil on these upland sites, reduce visual offensiveness, and provide food or cover for wildlife, such as white-tailed deer (*Odocoileus virginianus*), which utilize early successional stage habitats.

Table 4. Shortleaf pine seedling biomass according to genetic family and four herbaceous weed control treatments one year after planting.

Variable	Biomass (dry weight)[1,2] Needles	Branches	Stems	Roots	Total
Treatment			(lb)		
Total	0.08 A	0.02 A	0.04 A	0.07 A	0.21 A
Band	0.05 B	0.01 B	0.02 B	0.05 B	0.13 B
Spot	0.05 B	0.01 B	0.02 B	0.05 B	0.13 B
Check	0.04 B	0.01 B	0.01 C	0.03 C	0.09 C
Female					
218	0.07 A	0.02 A	0.04 A	0.07 A	0.20 A
322	0.05 B	0.01 B	0.03 B	0.04 B	0.13 B
115	0.04 B	0.01 B	0.02 B	0.04 B	0.11 B
103	0.04 B	0.01 B	0.02 B	0.04 B	0.11 B

[1] Means are from a stratified sample of 15 seedlings taken from each plot of one block. Five large, 5 medium, and 5 small seedlings were selected from each plot.
[2] Means within a column sharing the same letter are not statistically different (Fisher's Protected LSD Test, $\alpha = 0.05$).

CONCLUSIONS

Growth of shortleaf pine seedlings was improved by reducing herbaceous competition with herbicides. This improvement appeared to be strongly related to competition for soil moisture. Seedlings of open-pollinated families differed in their physiological ability to utilize and convert increased soil moisture into stem and root biomass and growth attributes. On ripped sites, spot treatments that control herbaceous competition may offer biological and cost advantages over band treatments. □

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