for measurement. This should allow assessments of chemical efficacy based on different measured attributes to be compared directly. As might be expected, efficacy results changed from year to year, but the pattern of change was different for highly soil-active herbicides and among seasons of harvest.

Significant reductions in hardwood competition are possible with very low investment in materials and equipment. Since hardwood basal area on Piedmont sites rarely exceeds 150 ft^2/ac, only \$15–\$20 per acre would be spent on the less expensive chemicals. Landowners able to consider only a limited investment expense for site preparation should find cut-stump treatments a viable option. Areas relying on natural regeneration for stocking in the new stand could benefit significantly from its use for the control of undesirable species and stumps not capable of producing quality coppice regeneration. ☐

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Effect of Triadimefon on Development of Mycorrhizae from Natural Inoculum in Loblolly Pine Nursery Beds

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ABSTRACT. Three or four applications of triadimefon at a rate of 6 oz/ac/application to loblolly pine (Pinus taeda *L.*) *nursery beds in the spring to control fusiform rust did not significantly affect mycorrhizal development from natural inoculum, as determined in the autumn and/or winter; higher rates (12 oz/ac and 24 oz/ac) significantly decreased amounts of mychorrhizal roots. The symbiont* Pisolithus tinctorius *(Pers.) Coker & Couch was more drastically affected than were other mycorrhizal fungi, based on Pt indices. Use of triadimefon at a 4× rate (24 oz/ac/application) for three consecutive years yielded no evidence of a buildup in soil.*

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Triadimefon (Bayleton®, 1-4(4-chlorophenoxy)-3,3-dimethyl-1-(1H-1,2,4,-triaxol-1-yl)-2-butanone) is the fungicide of choice for control of fusiform rust (caused by *Cronartium quercuum* (Berk.) Miyabe ex Shirae f. sp. *fusiforme* Burdsall & Snow) in southern forest nurseries. Current recommendations for using triadimefon have resulted from work conducted by several researchers (Kelley 1982, Kelley et al. 1984, Mexal and Snow 1978, Rowan 1984, Snow et al. 1979).

Although extremely effective as a control of fusiform rust, triadimefon also is known to affect mycorrhizal fungi (Cordell and Marx 1984, Kelley 1982, 1983, Snow et al. 1979). However, little is known concerning either the effects of various rates of triadimefon applied as foliar sprays on development of mycorrhizal roots or the buildup of triadimefon in the soil over several seasons.

This study was conducted to determine (1) whether development of mycorrhizal roots on loblolly pine (*Pinus taeda* L.) seedlings in nursery beds is affected by the rate of triadimefon applied as foliar sprays to control fusiform rust, and (2) whether a buildup of triadimefon, as determined by mycorrhizal development, occurs in the soil following its use in consecutive years.

METHODS

Field tests were established at the McMillan-Bloedel nursery near Camden, AL and at the Taylor State Nursery near Trenton, SC. Plots at the McMillan-

Bloedel nursery were maintained through three successive seedling crops (1981–83); plots at the Taylor nursery were maintained for only one seedling crop (1982). Soil at the McMillan-Bloedel nursery was a Lucedale fine sandy loam containing 67.6% sand, 17.6% silt, and 14.8% clay; soil at the Taylor nursery was a Wagram sand containing 90.5% sand, 6.7% silt, and 2.8% clay. Soil organic matter content was 2.2% at McMillan-Bloedel and 1.1% at Taylor. Plots were laid out in randomized complete blocks with three replicate plots per treatment; plot size was 18 × 100 ft (3 beds wide and 100 ft long) for triadimefon-treated plots and 18 × 25 ft for control plots. Treatments were: (a) untreated control; (b) triadimefon (Bayleton® 50WP) foliar spray at 6 oz ai/ac; (c) triadimefon foliar spray at 12 oz ai/ac; and (d) triadimefon foliar spray at 24 oz ai/ac. Dates of sowing, applying the fungicide, and collecting samples for mycorrhizal analyses are shown in Table 1.

Sample seedlings were collected each year immediately after the beds in the study area had been undercut for operational lifting; thus, sampling dates were not fixed in advance. The 20 seedlings from each plot for mycorrhizal analyses were taken randomly from a composite of approximately 500 seedlings that had been taken from throughout the plot. Seedling roots were wrapped carefully in wetted paper towels immediately after lifting, and mycorrhizal analyses were completed within 48 hr.

In the 1981–82 test, mycorrhizae were assessed by counting the numbers of mycorrhizal and nonmycorrhizal feeder roots on 4 in. of feeder roots as described by Anderson and Cordell (1979). For 1982–83 and 1983–84, sample seedlings were transported to the USDA Forest Service Institute for Mycorrhizal Research and Development (Carlton Street, Athens, GA) for assessment of mycorrhizae. Code numbers were used on seedling samples to ensure that the evaluator would not know the treatment involved. Seedlings were examined individually for the presence of *Pisolithus tinctorius* mycorrhizae and the percentage of seedling roots mycorrhizal with *P. tinctorius*; the total percentage of mycorrhizal roots was determined subjectively for seedling samples representing the various plots.

Data were subjected to analysis of variance and, where appropriate, means were compared for significant differences ($P = 0.05$) by Duncan's multiple range test.

RESULTS AND DISCUSSION

Examination of seedlings collected from the McMillan-Bloedel nursery at the end of the 1981–82 season revealed no significant differences in percentages of mycorrhizal roots among the treatments (Table 2). However, samples were lifted late in the season (January 20, 1982).

Table 2. Effect of various rates of triadimefon on numbers of mycorrhizal feeder roots at the McMillan-Bloedel nursery in 1981–82.

Treatment	Rate (oz/ac/appl)	Percentage of feeder roots with mycorrhizae
Control	—	53
Triadimefon	6	55
Triadimefon	12	49
Triadimefon	24	45

Significant differences in percentages of mycorrhizal roots were observed among seedling samples from both the McMillan-Bloedel and the Taylor nurseries following the 1982–83 season (Table 3). The samples were collected early in the lifting season (November 22, 1982, for McMillan-Bloedel, and December 1, 1982, for Taylor). At each nursery, the 2× and 4× rates of triadimefon resulted in significantly fewer mycorrhizal roots; however, the decrease observed with the 1× rate was not significant.

Examination of samples from the McMillan-Bloedel nursery following the 1983–84 season revealed that significantly more mycorrhizal roots were present on seedlings from triadimefon-treated plots than on seedlings from controls (Table 3). As in 1981–82, samples were lifted late in the season (January 16, 1984)

There can be little question that more comparable data among years could have been obtained had the lifting date been the same each year. However, the study as conducted answered several important questions.

First, results show that certain rates of triadimefon, applied as a foliar spray to control fusiform rust, can affect development of mycorrhizal roots on loblolly pine seedlings in nursery beds. More important, perhaps, was the observation that any effect on the development of mycorrhizae resulting from triadimefon applied at a 1× rate in the spring was not evident on seedlings at the earliest lifting date in the autumn. However, the significant decreases in mycorrhizal roots that were evident on seedlings from plots receiving the 2× and 4× rates suggest that similar but less drastic decreases probably occurred ear-

Table 1. Sowing dates, triadimefon spray dates, and seedling sampling dates for the McMillan-Bloedel and the Taylor nurseries.

Nursery	Year	Sowing date	No. of triadimefon foliar sprays	Triadimefon spray dates (first and last)	Mycorrhizal sample dates
McMillan-Bloedel	1981-82	April 24	3	May 12–June 17	Jan. 20, 1982
	1982-83	April 23	3	May 7–May 24	Nov. 22, 1982
	1983-84	May 2	3	May 14–June 9	Jan. 16, 1984
Taylor	1982-83	April 19	4	May 1–June 15	Dec. 1, 1982

Table 3. Effect of various rates of triadimefon on percentage of ectomycorrhizal roots at the McMillan-Bloedel and the Taylor nurseries in 1982–83 and 1983–84.

Nursery	Rate of triadimefon (oz/ac/appl)	Total % ectomycorrhizal development	
		1982–83	1983–84
McMillan-Bloedel	0	62 a*	30 b
	6	53 a	57 a
	12	37 b	52 a
	24	37 b	50 a
Taylor	0	77 a	—
	6	63 a	—
	12	42 b	—
	24	27 b	—

* Means for each nursery followed by the same letter do not differ significantly ($P = 0.05$ according to Duncan's multiple range test.

lier in the season on plots receiving the 1× rate. In the latter case, sufficient time had passed to allow the concentration of triadimefon in the seedlings to reach a level low enough to allow mycorrhizae to recover.

Second, the study demonstrated that seedlings continue to recover throughout the lifting season from effects on mycorrhizae due to triadimefon; thus, seedlings lifted late in the season (e.g., late January) may not exhibit any negative effects, even on areas that receive a high rate. Conversely seedlings lifted earlier (e.g., late November) may exhibit some negative effects on mycorrhizae, especially on areas that receive a high rate.

Third, results of this study provide no evidence that triadimefon builds up in the soil over several seasons. Even in the plots at McMillan-Bloedel nursery that received a 4× rate of triadimefon through three successive seedling crops, no evidence of a buildup in soil was found, based on development of mycorrhizae.

In addition to providing answers to the above questions, the study also raised a question. The observation that percentages of ectomycorrhizal roots on seedlings from triadimefon-treated plots following the 1983–84 season were significantly higher than the controls (Table 3) is a paradox whose explanation is beyond the scope of this study. Inhibitory effects by triadimefon on mycorrhizal fungi are well documented (Cordell and Marx 1984, Kelley 1982, 1983); thus, any role triadimefon plays in increasing numbers of mycorrhizal roots must be indirect, and may be worthy of further study.

Seedlings at the McMillan-Bloedel nursery have *P. tinctorius* (Pt) mycorrhizae from natural inoculum; no natural Pt occurs at the Taylor nursery. The sensitivity of Pt to triadimefon was reported earlier (Kelley 1982). In the present study, data from the field plots indicate that Pt also is sensitive to field-applied triadimefon. Although the percentage of seedlings with Pt ectomycorrhizae in 1982–83 was not affected by the 1× rate, the Pt index was decreased (Table 4); more drastic decreases in Pt indices were recorded from 2× and 4× plots. These data indicate that triadimefon slows development of ectomycorrhizae by Pt even though inoculum may be present. Similar results have been reported in other studies (Marx, Cordell, and France 1986).

Table 4. Effect of various rates of triadimefon on percentage of seedlings with *Pisolithus tinctorius* (Pt) mycorrhizae and on Pt index for seedling at the McMillan-Bloedel nursery during the seedling crop years of 1982–1983 and 1983–84.

Treatment	Rate (oz/ac/appl)	1982-83		1983-84	
		% of seedlings with Pt	Pt index*	% of seedlings with Pt	Pt index
Control	0	77	25	5	1
Triadimefon	6	73	16	45	19
Triadimefon	12	51	6	35	11
Triadimefon	24	36	6	13	2

* Pt index = $a \times (b/c)$ where a = percent of seedlings with Pt ectomycorrhizae, $b = \bar{X}$ percent of feeder roots with Pt ectomycorrhizae (including 0 percent for those without Pt), and $c = \bar{X}$ percent of feeder roots with ectomycorrhizae formed by Pt and other fungi.

The paucity of Pt ectomycorrhizae on seedlings from control plots in 1983–84 precluded making comparisons between years. However, among the triadimefon-treated plots both the percentages of seedlings with Pt ectomycorrhizae and the Pt indices were similar to those of 1982–83.

One can conclude from this study (1) that inhibition by triadimefon at a 1× rate of mycorrhizae from natural inoculum is largely overcome by lifting season, (2) that Pt may be more drastically affected than other symbionts, and (3) that triadimefon concentration in the soil does not build up following its use in consecutive years.

The 1× rate in this study was 6 oz/ac/application. The current recommendation (Kelley 1985) for triadimefon in forest nurseries is 4 oz/ac/application; thus, effects on ectomycorrhizae should be even less in the future. ☐

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Regenerating Wet Sites with Bare-Root and Containerized Loblolly Pine Seedlings[1]

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ABSTRACT. Seedling survival on a 1983 planted test site with a perched water table was 99% for both containerized and bare-root seedlings planted in May after the perched water table receded and 15% for seedlings planted in February while soils were saturated. Also, differences in survival for May 1984 plantings on an upland flatwoods site, a terrace along an ephemeral stream, and a river floodplain site, indicate that each site possesses inherent properties uniquely influencing seedling survival. After the perched water table had receded, first-year mean survival of containerized seedlings was 19% higher than for bare-root seedlings. Some families showed tolerance to excessive soil moisture and are probably well suited for general planting on wet sites. The higher cost of containerized seedlings can be justified if a replant or marginal survival can be avoided.

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Numerous loblolly pine (*Pinus taeda* L.) sites in the South lack good internal drainage due to the presence of pans and fine-textured subsoils. With heavy precipitation prior to planting season, these sites develop a perched water table. When planted early in the planting season, seedlings must tolerate long periods of excessive moisture to survive. Seedlings poorly adapted to excessive moisture often die.

Improvements in seedling survival on wet sites may be realized through the use of both genetically improved seedlings and implementation of site-specific cultural practices. Byram et al. (1984) reported that early survival can be improved by selecting and breeding families of loblolly pine tolerant of excessive moisture. Culturally, bedding and improved external drainage are used to enhance planting success (Haines and Haines 1978, Terry and Hughes 1978).

Wet sites also subject to spring flooding pose a special regeneration problem. If bare-root seedlings are planted in the winter, spring inundation often causes high mortality. If bare-root seedlings are planted in May after flood waters have receded, dry summers cause high mortality. Therefore, planting stock is needed that, planted late, becomes established sufficiently to survive both the imminent summer drought and subsequent spring flooding.

The objectives of this study were to compare (1) the survival of February planted bare-root seedlings with May planted bare-root and containerized seedlings on a site known to develop a perched water table, (2) the survival of May-planted, open-pollinated families of bare-root and container-grown loblolly pine on three sites known to develop a perched water table during the traditional planting season and (3) the economics of planting bare-root and containerized seedlings on these three wet sites.

MATERIALS AND METHODS

Employees of Weyerhaeuser Company at Magnolia, AR grew all bare-root seedlings as operational stock. Seedlings were lifted during mid-February of 1983 and again in 1984, packaged in plastic bags with tops loosely secured with a rubber band, bundled in a Kraft seedling bag and placed in a cooler a 36°F for 13 weeks prior to planting. Seedlings appeared in excellent condition when planted

Employees of Potlatch Corporation at Warren, AR grew all containerized seedlings. Seeds for containerized seedlings were sown in December of 1983 and again in 1984 in Styroblock® containers (No. 8) filled with a 1:1 mixture of peat moss and vermiculite. Seedlings grew until late May when the desired $1.5 \leq 1$ shoot:root ratio was achieved. Reduced water and natural temperatures "hardened-

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[1] This paper is approved for publication by the director, Arkansas Agricultural Experiment Station, and director of public relatins, Southern Division Potlatch Corporation.