CIRCULAR 192
AUGUST 1971

Tolerance of Newly Planted Slash and Loblolly Pine Seedlings to Some Selective Herbicides

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Cover photo shows weed control with trifluralin at 4.0 lb./A. at the Florida site.

FIRST PRINTING 3M, AUGUST 1971

Tolerance of Newly Planted Slash and Loblolly Pine Seedlings to Some Selective Herbicides[1]

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INTRODUCTION

WITH the current interest in applying fertilizers at or soon after tree planting on intensively prepared infertile forest sites in the South *(13)*, new weed control problems are being encountered. When existing vegetation is removed during site preparation, native grasses and weeds of the 300 important species in the southern United States *(1)* rapidly appear. Pine seedlings can compete successfully with this type of vegetation, although their early development may be slow. However, when planting sites are fertilized to correct nutrient deficiencies, growth of both weeds and trees is stimulated, with the weeds sometimes becoming dominant. Such experiences, and the problem of direct damage by fertilizer salts, have generally discouraged the use of fertilizers in young forest plantings *(9,10)*.

In a number of recent experiments on prepared sites in the southeastern United States, substantial tree seedling responses to fertilization have been recorded despite weed competition *(4,6, 12,14)*. Cultivation following planting has also been found to improve growth of seedlings and cuttings *(2,16)*. In situations where cultivation has been combined with fertilization on infertile sites, fertilizer response by the trees has been greatly enhanced *(3,15)*. These results have encouraged foresters to consider early fertilization combined with weed control as a means of multiplying the benefits of the individual practices.

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Control of weeds in forest plantations by cultivation is possible, but it is difficult and expensive *(17)*. Cultivation is currently being used on a fairly large scale in intensively managed cottonwood plantings in the Mississippi Delta *(2)*. Recent work by Martin and Carter *(11)* suggests that herbicides, or a combination of herbicides and cultivation, could do a satisfactory job of weed control in cottonwood plantings, perhaps at lower total cost than cultivation alone if application techniques were perfected.

Considerable work has been done in Europe *(18)* and in the northeastern and north-central United States *(7,8,20,21)* on herbicide use in young forest tree plantation culture. However, except for information developed by Martin and Carter *(11)* on herbicide tolerances of cottonwood, little information is available on tolerances for other important southern forest tree species. New herbicides of potential usefulness in silviculture are constantly being introduced, with little or no information supplied by the manufacturers on their toxicity to forest tree seedlings.

The experiment reported here was the first in a series undertaken to develop this type of information for foresters in the South who are interested in using herbicides along with fertilizers in the practice of intensive silviculture. Primary objective was to measure the range of application rates over which several commercially available selective herbicides could be applied to 1-0 seedlings of slash and loblolly pines without significant tree growth reduction or mortality. Also of interest was the gaining of information on effectiveness of the various herbicides for controlling weeds commonly found in young forest plantings, persistence of various herbicide-induced effects, and the practical problems of applying the chemicals under forest plantation conditions.

METHODS AND MATERIALS

Two identical field layouts were used. One was established in Citrus County, Florida, on a deep sandy soil of the Lower Coastal Plain (Lakeland fine sand). This soil and site are representative of the "Sandhills" Provinces of Florida, Georgia, and the Carolinas. A second was installed on a moderately well-drained soil (Sango silty clay loam) of the Limestone Valley Province in Colbert County, Alabama. Most soils of this latter group are used for field crops, although pine plantings are sometimes established on them when they are taken out of crop production. These two soils represent the extremes in the fertility and textural ranges over which southern pines are grown.

The Florida site had recently been cleared of a scrub oak overstory. Chopping and disking had removed the brush understory and the perennial wiregrass. It was plowed and disked immediately prior to etablishment of this experiment. Annual grass and herbaceous weed seeds were abundant on and around all sides of the cleared area. The soil was marginally deficient in N and K and had no history of fertilization.

TABLE 1. COMMON AND SCIENTIFIC NAMES OF PLANTS MENTIONED IN TEXT

Common name	Scientific name
Redroot pigweed	*Amaranthus retroflexus* L.
Common ragweed	*Ambrosia artemisiifolia* L.
Broomsedge	*Andropogon virginicus* L.
Wiregrass	*Aristida stricta* Michx.
Common lambsquarters	*Chenopodium album* L.
Large Crabgrass	*Digitaria sanguinalis* (L.) Scop.
Little barley	*Hordeum pusillum* Nutt.
Pokeweed	*Phytolacca americana* L.
Slash pine	*Pinus elliottii* Engelm.
Loblolly pine	*Pinus taeda* L.
Cottonwood	*Populus deltoides* Marsh.

The Alabama site had once been used as a tree seedling nursery but had supported a lush growth of native weeds and grasses for several years prior to use in this experiment. The soil had a history of heavy fertilization. As in Florida, the area was plowed and disked several times prior to establishment of plots for this experiment.

Six herbicides were tested, each at four rates in five randomized blocks. The rates for each herbicide bracketed the rates recommended by the manufacturer, Table 2.

Treatment plots were 12 feet wide by 30 feet long, with two rows of trees oriented parallel to the long axis of the plot. The rows, containing 28 trees, were 6 feet apart with trees 2 feet apart in the row.

The trees were hand-planted either immediately before or after herbicide treatment, depending upon the recommended mode of application of the material, Table 2. One-year-old (1-0) nursery stock was planted in both areas; slash pine in Florida, loblolly pine in Alabama. The experiments were installed in succeeding weeks in mid-January 1967. The soil had been cultivated a few weeks previously and all treatments were applied to bare soil.

Herbicides were applied in 2-foot-wide bands centered on the tree rows. Where incorporation was required, a garden-type roto-

TABLE 2. CHEMICALS AND METHODS OF APPLICATION USED IN THE EXPERIMENT

Common name and formulation[1]	Chemical name	Timing[2]	Application method	Rates[3]
				Lb./A.
Amizine, 60% wp	3-amino-*s*-triazole (amitrol) (15%) 2-chloro-4, 6-bis(ethylamino)-*s*-triazine (simazine) (45%)	Preplant	Sprayed on soil surface	1.6 to 6.4[4]
Fluometuron, 80% wp	1,1-dimethyl-3-(a,a,a trifluro-*m*-tolyl) urea	Preplant	Sprayed on soil surface	2.0 to 8.0
Dichlobenil, 4% g	2,6-dichlorobenzonitrile	Postplant	Broadcast and incorporated	2.0 to 8.0
Diuron, 80% wp	3-(3,4-dichlorophenyl)-1, 1-dimethylurea	Preplant	Sprayed on soil surface	1.0 to 6.0
Simazine, 80% wp	2-chloro-4, 6-bis(ethylamino)-*s*-triazine	Preplant	Sprayed on soil surface	1.6 to 6.4
Trifluralin, 4 lb./gal.	*a,a,a,* trifluoro-2,6-dinitro-*N,N*-dipropyl-p-toluidine	Preplant	Sprayed on soil surface and incorporated	0.5 to 4.0

[1] wp = wettable powder, g = granules.
[2] All herbicides were applied to clean-cultivated soil prior to weed emergence.
[3] Rates are expressed as pounds of active ingredients per acre of treated surface. Since only ⅓ of total area was treated, herbicide use per acre of plantation was ⅓ the application rate.
[4] Expressed as pounds of simazine per acre.

tiller was used, with supplemental hoeing used in areas inaccessible to the tiller. The rototiller was adjusted to run approximately 2 inches deep.

Liquid herbicides were applied with an experimental hand sprayer fitted with a T-jet nozzle (No. 8003). The rate of application of liquid was 25 gallons per acre at a spraying pressure of 20 p.s.i. Granular materials were broadcast by hand over the soil surface within the treatment band.

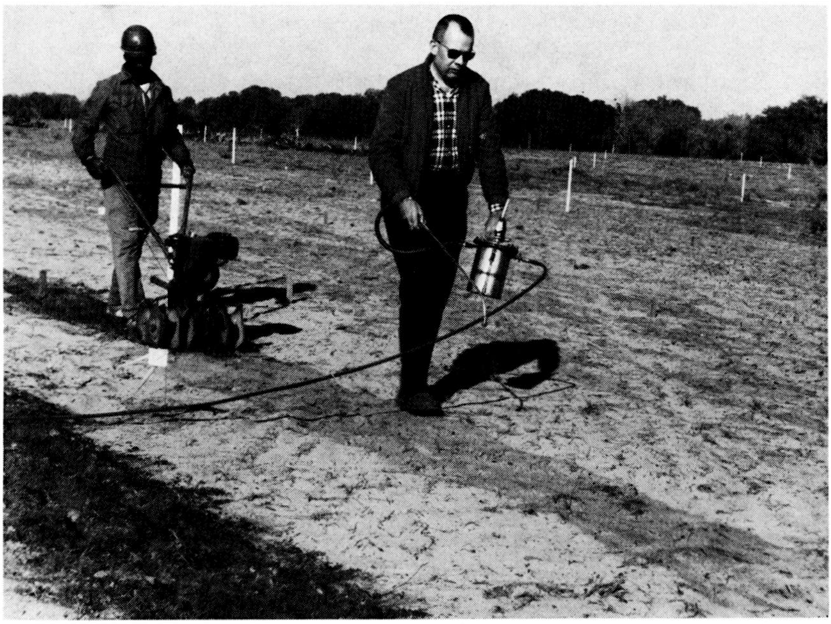

FIG. 1. Equipment used for applying liquid herbicides and incorporating when necessary.

Rainfall at the two sites was recorded daily. Weed control was evaluated on a subjective scale in early spring and late summer of 1967. In January 1968, the surviving seedlings in alternate planting spots (maximum of 14 trees per plot) were counted, cut at the ground line, dried at 70° C, and weighed. A year later, height, number of survivors, and dry weight of the remaining trees were determined. Thus, data on seedling survival and dry matter production for 1967 and 1968 are based on two independent samples from each plot.

To provide an overall measure of effectiveness of the various treatments with regard to tree growth, seedling dry weight production per plot after 2 years was determined by multiplying the number of surviving seedlings by the average dry weight per tree in each plot. These values, along with the number of surviving trees, the average dry weight per seedling, and the average tree height for each observation date, were subjected to analysis of variance. Multiple-range tables were developed from which treatment means showing significant differences from controls were identified.

RESULTS AND DISCUSSION

Rainfall immediately following installation of the experiments was adequate at both locations to move the surface-applied herbicides into the soil. Therefore, lack of herbicide activation was not regarded as a factor influencing relative effectiveness of any of the materials. Soil moisture was also adequate at both installations to give excellent initial survival of the planted trees. Rainfall was favorably distributed at the Alabama location in both seasons. However, March and April of 1967 were unusually dry in Florida and this may have reduced the aggressiveness of the weed population on this site.

Bimonthly rainfall (inches) at the two test sites during the 1967 growing season

	Florida	*Alabama*
January-February	7.3	6.0
March-April	0.6	5.7
May-June	8.6	11.3
July-August	19.7	14.8
September-October	1.7	4.8

The Florida Site

Important differences in toxicity to pine seedlings among herbicides and rate of herbicide application became apparent at the Florida site within 2 to 3 months. By April 1 many trees in plots treated with the higher rates of fluometuron, dichlobenil, and diuron – where adequate weed control was obtained – were dead or dying, whereas amizine and simazine caused no damage or only minor and temporary foliage chlorosis at rates giving acceptable weed control. Trifluralin caused no apparent damage to the trees even at the highest rate applied, Table 3.

The herbicides differed little in apparent selectivity of weeds controlled in the Florida experiment, perhaps because the number of invading species was limited. Amizine and simazine gave good broad-spectrum weed-grass control for the first 3 to 4 months.

Table 3. Herbicide Effects on Native Weeds and on Survival and Growth of Slash Pine, Lakeland Fine Sand, Central Florida

Treatment	Rate	Seedling survival		Dry wt. of surviving trees		Dry wt. production per plot[1]	Seedling height	Weed control rating[2]
		1967	1968	1967	1968	1968	1968	
	Lb./A.	*Pct.*	*Pct.*	*G./tree*	*G./tree*	*G.*	*Ft.*	
Control (none)	----	96	94	14	55	720	1.3	3
Amizine[3]	1.6	93	87	17	75	936*	1.8	2
	3.2	96	93	19	77	1,011*	1.6	2
	4.8	96	89	17	76	917	1.6	2
	6.4	94	81	13	56	685*	1.2	1
Fluometuron	2.0	93	91	12	57	720	1.3	3
	4.0	74*	70*	9	44	472*	1.3	2
	6.0	50*	47*	7	37	289*	1.0	2
	8.0	53*	56*	10	32	244*	1.0	2
Dichlobenil	2.0	84	89	19	85	1,010*	1.6	3
	4.0	61*	61*	17	104*	869	1.8	2
	6.0	49*	41*	19	105*	637*	1.7	2
	8.0	51*	49*	15	69	498*	1.3	1
Diuron	1.0	91	80	18	76	887	1.5	3
	2.0	67*	76	19	105*	1,104*	1.7	2
	4.0	53*	46*	10	39	272*	1.1	2
	6.0	26*	21*	10	53	159*	1.2	2
Simazine	1.6	99	87	18	76	888	1.6	2
	3.2	99	99	18	69	953*	1.4	2
	4.8	93	94	18	67	901	1.4	1
	6.4	79	84	16	75	920	1.5	1
Trifluralin	0.5	96	96	18	81	1,076*	1.6	2
	1.0	99	97	20	85	1,163*	1.7	1
	2.0	99	99	20	107*	1,474*	1.8	1
	4.0	99	96	18	85	1,145*	1.7	1

* Significantly different from control at 0.05 level.
[1] Number of surviving trees × dry weight per tree.
[2] A subjective visual evaluation of degree of reduction in cover of native weeds through the first growing season (3 = poor, 2 = fair, 1 = good performance).
[3] Expressed as pounds of simazine per acre.

With the onset of heavy rains in June and July, the treated strips were invaded by the same grasses which had earlier appeared on the untreated areas, i.e., mainly large crabgrass and broomsedge. By the fall of 1967 the treated zones on most plots were barely distinguishable. Trifluralin, on the other hand, held most of the grasses in check through the first season and, because it reduced the stand of the perennial broomsedge, showed visible effects into the second growing season after treatment.

In the Florida planting, the grass competition which developed during the summer was not sufficiently aggressive to reduce seedling survival. Thus, the tree *survival* differences in Table 3 may be assumed to accurately reflect herbicide toxicities. On the other hand, the *dry matter* per tree data for specific herbicide treatments on this area must be evaluated with an eye to corresponding seedling survival. On this droughty site and with close spacing, a stand reduction of as little as 10 to 20 per cent could result in a significant increase in average dry matter production of the surviving trees by the end of the second growing season. Data for the dichlobenil treatments illustrate this, Table 3. An increase in dry weight over the controls at the lowest dichlobenil rate is associated with a slight reduction in the pine stand and no apparent reduction in weed competition. At the next two higher rates, larger seedlings were produced and a modest improvement in weed control was observed but the pine stand was reduced 40 to 60 per cent, Table 3. The highest herbicide rate further improved weed control but also reduced growth of surviving seedlings. The dry weight per plot data show the net effect; i.e., the lowest rate, while yielding slightly smaller trees than the next two higher rates, gave the largest increase in dry matter production by the stand.

The improved tree growth at the lowest rate of dichlobenil, which occurred in the absence of any recorded reduction in weed competition, could have resulted from some subtle effect upon plant metabolism *(19)*. However, it seems more probable that this herbicide caused a slight delay in weed development or reduction in stand which was not detectable by our crude visual evaluation.

Considering both survival and growth of the pines, trifluralin at 2.0 pounds per acre gave the best result on the Florida site, followed in order by the other trifluralin rates, the 3 lowest rates of simazine and amizine, and the lowest rate of dichlobenil and diuron. Fluometuron tended to reduce pine seedling survival at all rates that gave significant weed control.

The Alabama Site

Weed competition at the Alabama site, unlike that in Florida, became a very important factor in tree survival by the latter part of the first growing season. Hence, the survival data reflect both direct herbicide effects on the pines and indirect effects of weed control by the herbicides. In general, however, survival rates lower than the control, such as with the higher rates of fluometuron and diuron, Table 4, can be taken as evidence of herbicide damage to the trees.

TABLE 4. HERBICIDE EFFECTS ON NATIVE WEEDS AND ON SURVIVAL AND GROWTH OF LOBLOLLY PINE, SANGO SILTY CLAY LOAM, NORTHWESTERN ALABAMA

Treatment	Rate	Seedling survival		Dry wt. of surviving trees		Dry wt. production per plot[1]	Seedling height	Weed control rating[2]
		1967	1968	1967	1968	1968	1968	
	Lb./A.	*Pct.*	*Pct.*	*G./tree*	*G./tree*	*G.*	*Ft.*	
Control (none)	----	43	19	4	40	125	1.9	3
Amizine[3]	1.6	67	44*	5	41	254	2.0	3
	3.2	58	37	5	37	184	1.9	2
	4.8	51	46*	6	48	297	2.1	2
	6.4	49	39	6	43	250	2.1	1
Fluometuron	2.0	57	41	6	50	330	2.0	3
	4.0	36	17	3	39	116	1.9	2
	6.0	21	4	4	----	------	----	2
	8.0	21	4	2	----	------	----	1
Dichlobenil	2.0	59	51*	6	79	544*	2.5	2
	4.0	54	37	5	64	349	2.4	2
	6.0	46	37	7*	78	499*	2.6	2
	8.0	57	31	8*	68	264	2.3	1
Diuron	1.0	43	33	4	52	255	2.1	3
	2.0	50	44*	4	39	263	2.0	3
	4.0	27	9	6	----	------	----	2
	6.0	19*	9	4	----	------	----	1
Simazine	1.6	76*	54*	7*	57	470	2.3	2
	3.2	74*	59*	11*	87	721*	2.7	2
	4.8	59	40	8*	72	405	2.2	1
	6.4	76*	40	8*	69	420	2.4	1
Trifluralin	0.5	73*	31	3	53	219	1.9	3
	1.0	69	31	4	50	210	2.0	3
	2.0	71*	31	4	45	187	1.9	3
	4.0	54	31	3	49	213	1.8	3

* Significantly different from control at 0.05 level.
[1] Number of surviving trees × dry weight per tree.
[2] A subjective evaluation of reduction in cover of native weeds through the first growing season (3 = poor, 2 = fair, 1 = good performance).
[3] Expressed as pounds of simazine per acre.

The tree survival data, combined with informal observations on the trees early in the season, indicate that despite the differences in soil, rainfall, and tree species inherent in the two sites, there was little herbicide x location interaction regarding the tolerance of the pines to the herbicides. The most apparent herbicide x location interaction upon seedling tolerance occurred with amizine and simazine. In Florida the two herbicides performed similarly, as expected, since the rates of amizine had been chosen to provide equivalent amounts of simazine as in the pure simazine series, and since at the time of herbicide application no weeds had yet emerged on the site (which might have been affected by the amitrole component of the amizine). Since survival and growth of the loblolly pines on amizine-treated plots in Alabama were reduced below that with simazine, despite roughly similar weed control by the two materials, it appears that the amitrole component of the amizine must have been the causal factor; possibly because (1) it was more toxic to loblolly pine than to slash pine or (2) the amitrole component of amizine was leached from seedlings' root zone in the excessively drained Florida soil by the rains which fell soon after the treatments were established. Since amitrole is generally found to be rapidly degraded and deactivated in contact with soil *(5)*, these speculations are not very satisfying.

Simazine effects were more persistent in Alabama than in Florida, probably because less leaching of the herbicide occurred on the finer textured soil. Trifluralin gave acceptable control of little barley but was not effective in controlling common ragweed which formed a dense, nearly pure stand on the treated strips. These weeds quickly dominated the pines.

On the control plots and in those plots where herbicides were applied at low rates, the trees were quickly overtopped and completely shaded. Even where good control of little barley was obtained within the 2-foot zone, rank weed growth – including ragweed, pokeweed, red root pigweed, and common lambsquarters – encroaching from both sides closed in quickly and by late summer was overhanging the pines. When these weeds – averaging 4 to 6 feet in height – were killed by frost, they contributed further to seedling mortality by falling upon the overtopped trees, breaking stems of some trees and creating heavy shade. This severe competition accounts for the reduction in tree survival from 1967 to 1968, and for the overall poor survival and growth of the trees in the Alabama planting. It also accounts, at least in part, for the low dry weight/height ratio shown by these trees, which tended to be somewhat spindling.

Using the criteria of pine seedling survival and growth, simazine at 3.2 pounds per acre gave the best overall performance on the Alabama site. The 1.6-pound simazine rate and the lowest rate of dichlobenil were close behind. Trifluralin was not as effective at the Alabama site as at the Florida location, apparently because of its failure to control common ragweed, a very vigorous competitor on the Alabama site. There was no indication that any of the herbicides affected weed growth in the second season.

Despite the extremely aggressive competition found on the Alabama site, most of the trees which survived through the second season were in a position to gain dominance over the weeds in successive seasons. The trees in Florida were clearly free to grow. Thus, the survival figures in Tables 3 and 4 can be taken as an indication of the number of trees per acre that might be obtained with the various treatments on similar sites. Had the herbicides been applied to the whole plot area or if the untreated "middles" had been cultivated, the performance of the nontoxic herbicides would doubtless have been much better on the Alabama site and at least somewhat improved at the Florida site.

FIG. 2. Simazine, as shown here, at the Alabama location, gave good control of broadleaf weeds.

CONCLUSIONS

These results show that from among these herbicides there are several, most notably simazine and trifluralin, which give good control of many of the common weeds found in southern forests at rates that are nontoxic to young slash and loblolly pine seedlings. With these two materials the seedling tolerances are fairly wide, allowing some margin for error in difficult-to-control large-scale operations in rough woodlands.

Our results also demonstrate the importance of matching the herbicide to the weed spectrum on a given site. Trifluralin is much more effective upon grasses than broadleaf weeds and was the most effective compound tested in Florida, where grasses predominated. But simazine, with its broader spectrum of activity, gave the best weed control in Alabama, where broadleaf weeds were abundant.

While species-site effects are confounded and cannot be clearly distinguished in this experiment, there is no evidence that slash and loblolly pine differed to an important degree in their tolerances of types and rates of the herbicides tested. Differences in soil characteristics between the two areas also appeared to be of minor importance insofar as herbicide toxicity to seedlings was concerned. The herbicidal effectiveness of all materials tested appeared to be exhausted on both sites by the middle to latter part of the first growing season.

Unfortunately, two of the materials which show some promise, trifluralin and dichlobenil, must be incorporated into the soil. With dichlobenil, incorporation is especially difficult because it must be worked in after the trees are planted to avoid root-herbicide contact.

The unaccountable inferiority of amizine to simazine at the Alabama site and the suggestion of herbicidal stimulation of tree growth without corresponding weed control for some of the herbicides are subjects for future study.

The results also suggest that additional work is needed on mixtures of herbicides to achieve broad-spectrum, long-lasting weed control. Other studies should include evaluation of combinations of herbicides in pre- and postplant applications, development and testing of herbicide-fertilizer combinations, and use of mechanical weed control in conjunction with band-applied herbicides.

SUMMARY

Newly outplanted 1-0 slash pine and loblolly pine were subjected to various rates of six pre-emergence herbicides to assay seedling susceptibility and general effectiveness of the herbicides.

On Lakeland fine sand in central Florida, slash pine proved quite tolerant to trifluralin and to simazine, showing no damage at rates up to 4.0 and 4.8 pounds per acre active for the two herbicides, respectively. Trifluralin was the most effective herbicide in controlling the predominant competition (large crabgrass and

broomsedge), and at 2 pounds per acre doubled dry weight increment of the pine seedlings over controls in a 2-year observation period. Simazine (3.2 pounds), dichlobenil (2.0 pounds), and diuron (2.0 pounds) also showed good overall performance.

In northwestern Alabama on Sango silty clay loam, loblolly pine showed herbicide tolerances generally similar to those observed with slash pine in Florida, although amizine produced slight detrimental effects not observed in Florida. Simazine held native weeds in check until late summer, somewhat longer than in Florida, and at 3.2 pounds per acre, significantly increased pine seedling growth. Dichlobenil at 2.0 pounds also performed well. Trifluralin proved ineffective because of its failure to control common ragweed, which quickly dominated the pines.

At both locations, diuron and fluometuron were in overall performance inferior to the other herbicides tested.

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