CHEMICAL WEED CONTROL IN SOUTHERN FOREST NURSERIES

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CONTENTS

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INCREASED production of hardwoods in southern forest nurseries has stepped up the need for development of modern chemical weed control practices. This is true since most hardwood seedlings are injured by standard mineral spirits applications.

A vast array of agronomic herbicides is available. The task of selecting ones suitable for use in forest nurseries must begin with determining relative tolerance of important species to materials available.

TOLERANCE STUDIES

Seedlings of 6 species were used to screen 13 herbicides (Table 1) in the greenhouse. The species were loblolly pine, slash pine, Arizona cypress, yellow poplar, sweetgum, and sycamore. Results from tolerance studies on cottonwood cuttings conducted in the nursery are reported in Bulletin 372 of this Station.[2]

Sandy loam soil from the Auburn Forest Nursery was steam sterilized and placed in greenhouse flats. Half of each flat was sown with a conifer and the other half with a hardwood. The species were paired as follows: loblolly pine with yellow poplar, slash pine with sycamore, and Arizona cypress with sweetgum. One hundred seeds each of loblolly, slash, or sweetgum were planted per flat, while 200 seeds of the other species were used. After sowing the seeds were covered with one-fourth to one-half

[1] Resigned.
[2] Martin, James W. and Carter, Mason C. *Tolerance of Cottonwood to Certain Herbicides.* Auburn Univ. Agr. Exp. Sta. Bull. 372. 1966.

TABLE 1. CHEMICALS USED IN THE INVESTIGATION

Common name and formulation	Chemical name	Trade name and supplier
Ametryne 50% wp	2-ethylamino-4-isopropylamino-6-methylmercapto-*s*-triazine	Ametryne — Geigy Chemical Corp.
Atrazine 80% wp	2-chloro-4-ethylamino-6-iso-propylamino-*s*-triazine	Atrazine — Geigy Chemical Corp.
Chloroxuron 50% wp	*N'*-4(4-chlorophenoxy) phenyl-*N,N*-dimethylurea	Tenoran — CIBA Corp.
Cotoran 80% wp	*N*-(3-trifluoromethyl-phenyl)*N,N* dimethylurea	Cotoran — CIBA Corp.
DCPA 5% G	Dimethyl-2,3,5,6-tetra-chloroterephthalate	Dacthal — Diamond Alkali Co.
Dichlobenil 4% G	2,6-dichlorobenzylnitrile	Casoron — Thompson-Hayward Chemical Co.
Diphenamid 80% wp	*N,N*-dimethyl-2,2-diphenyl-acetamide	Dymid — Eli Lilly & Co. (Elanco)
Diuron 80% wp	3-(3,4-dichlorophenyl)-1,1-dimethylurea	Karmex — E. I. DuPont de Nemours & Co.
DNBP 5 lb./gal	dinitro-*o*-*sec*-butylphenol	Dow General Weed Killer Dow Chemical Co.
Eptc 10% G	ethyl-*N,N*-dipropylthiol-carbamate	Eptam — Stauffer Chemical Co.
Norea 80% wp	3-(hexahydro-4,7-methaniondan-5-yl)-1,1-dimethylurea	Herbam — Hercules Powder Co.
Paraquat 2 lb./gal	1,1'-dimethyl-4,4'-dipyridinium salt	Chevron Chemical Co.
Prometryne 80% wp	2,4-bis(isopropylamino)-6-methyl-mercapto-*s*-triazine	Caparol — Geigy Chemical Co.
Simazine 80% wp	2-chloro-4,6-bis(ethylamino)-*s*-triazine	Simazine — Geigy Chemical Co.
Trifluralin 4 lb./gal	*a,a,a*, trifluoro-dinitro-*N,N*-dipropyl-*p*-toluidine	Treflan — Eli Lilly and Co.

inch of sawdust mulch and herbicides were sprayed or dusted over the sawdust surface. Flats were watered by surface application.

Six to 8 weeks after planting, data were collected on survival, height, and general appearance of the seedlings. With one exception, survival was found to be the best measure of tolerance. Herbicides causing injury symptoms also reduced survival except for Eptc, which produced needle malformations on the two pines without any other signs of injury.

Listed in Tables 2, 3, and 4 are survival values for the six species. The results are summarized in Table 5. In comparing these results, several factors should be taken into account. For instance, the soil used was a light sandy loam. When the clay content of a soil increases, the toxicity of many herbicides decreases because of the binding of the herbicides by soil colloids.

TABLE 2. SURVIVAL PERCENTAGE OF LOBLOLLY PINE AND YELLOW POPLAR SEEDLINGS FOLLOWING PRE-EMERGENCE TREATMENT WITH HERBICIDES

Chemical treatment	Rate per acre	Survival	
		Loblolly pine	Yellow poplar
	Pounds	*Pct.*	*Pct.*
Control	----	71.0	11.4
EPTC	3	87.3	5.3
	6	87.0	1.5
DCPA	4	91.0	15.5
	8	86.6	13.3
Dichlobenil	4	0.0	0.0
	8	0.0	0.0
Simazine	3	30.3	6.3
	6	1.3	1.3
Atrazine	3	12.3	3.0
	6	0.0	1.1
Prometryne	3	89.0	9.5
	6	84.0	4.1
Ametryne	3	88.0	11.8
	6	72.6	2.6
Cotoran	2	49.3	8.8
	4	28.0	7.8
Chloroxuron	2	92.0	12.5
	4	91.6	13.8
Trifluralin	1	91.6	13.6
	2	86.6	11.6
Diphenamid	4	91.3	14.3
	8	93.0	14.0
Norea	1	94.6	15.0
	2	85.6	15.0
Diuron	1	55.3	11.6
	2	21.3	7.6

Therefore, use of a heavier or lighter soil could have altered the results. The herbicides were applied to a sawdust mulch that no doubt bound some of the chemicals. Use of a different mulching material could have changed the results.[3] The studies were conducted in greenhouse flats at high seedling densities which probably resulted in a greater amount of herbicide being absorbed per seedling than had the studies been conducted under field conditions where root systems were less restricted. Hence, tolerances in the field probably exceed those observed in the greenhouse. Field studies reported later bear out this prediction.

However, useful information can be drawn from the work herein reported. Dichlobenil, simazine, atrazine, and cotoran appear too toxic to be used pre-emergence on the species tested. Several other materials show promise if good weed control can be obtained at safe rates of application. Yellow poplar, sweetgum,

[3] Audus, L. J. *The Physiology and Biochemistry of Herbicides.* Academic Press, N.Y., N.Y. 1964.

TABLE 3. SURVIVAL PERCENTAGE OF SLASH PINE AND SYCAMORE SEEDLINGS FOLLOWING PRE-EMERGENCE TREATMENT WITH HERBICIDES

Chemical treatment	Rate per acre	Survival	
		Slash pine	Sycamore
	Pounds	*Pct.*	*Pct.*
Control	----	73	7.1
Eptc	3	72	7.6
	6	59	2.7
DCPA	4	66	7.2
	8	75	7.0
Dichlobenil	4	0.2	0.1
	8	0	0.0
Simazine	3	59	0.0
	6	0	0.0
Atrazine	3	58	0.0
	6	22	0.0
Prometryne	3	78	0.7
	6	67	0.0
Ametryne	3	72	0.0
	6	61	0.1
Cotoran	2	59	1.0
	4	18	0.0
Chloroxuron	2	77	6.3
	4	72	6.3
Trifluralin	1	76	6.1
	2	77	4.0
Diphenamid	4	70	8.6
	8	72	5.2
Norea	1	74	6.8
	2	75	1.3
Diuron	1	70	0.5
	2	66	3.2

and the two pines apparently have some resistance to several herbicides, but sycamore and Arizona cypress appear quite sensitive to most of the chemicals tested.

FIELD STUDIES

Results of the screening studies have been extensively field tested to date on only one species – yellow poplar. The seven chemicals listed as promising for yellow poplar in Table 5 plus prometryne, which appeared only slightly injurious, were tested on 4 × 5 foot plots at the Auburn Forest Nursery (sandy loam soil). Each chemical was applied at two rates and replicated three times. Treatments were applied to sawdust mulched nursery beds that had been seeded 2 days earlier. Liquid formulations were applied with a hand sprayer, whereas granular materials were applied with a large salt shaker.

Effectiveness of the weed control was evaluated on the basis of hand-weeding time required for each plot. Plots were weeded

TABLE 4. SURVIVAL PERCENTAGE OF CYPRESS AND SWEETGUM SEEDLINGS FOLLOWING PRE-EMERGENCE TREATMENT WITH HERBICIDES

Chemical treatment	Rate per acre	Survival	
		Arizona cypress	Sweetgum
	Pounds	*Pct.*	*Pct.*
Control	----	13.0	56.0
Eptc	3	9.8	38.9
	6	8.5	13.0
DCPA	4	12.4	50.2
	8	10.0	58.7
Dichlobenil	4	0.0	0.0
	8	0.0	0.0
Simazine	3	1.2	13.2
	6	0.8	9.5
Atrazine	3	0.5	4.8
	6	0.2	2.2
Prometryne	3	4.9	53.3
	6	0.4	44.8
Ametryne	3	2.5	44.8
	6	0.6	50.2
Cotoran	2	7.7	53.8
	4	5.1	41.5
Chloroxuron	2	7.7	61.3
	4	10.2	46.7
Trifluralin	1	10.9	50.7
	2	10.2	56.3
Diphenamid	4	12.5	42.7
	8	8.8	64.7
Norea	1	11.4	52.5
	2	11.4	63.2
Diuron	1	2.8	52.2
	2	1.2	46.3

May 3, June 7, and July 26. Tree heights and bed densities were measured in early December. Results are given in Table 6. Prometryne at 2 pounds per acre significantly reduced hand-weeding time below the control without affecting density or height growth.

There were several apparent discrepencies in the data in which the low rate of a chemical appeared to give better weed control than the high rate. Highly variable weed populations account for these results; therefore, more replications would have been desirable. The variation was so great that a reduction of nearly 50 per cent in hand-weeding time was necessary to be statistically significant at the 5 per cent level. Nevertheless, the results do indicate that appreciable savings can be attained from use of herbicides.

Additional work with dichlobenil was conducted because of excellent weed control obtained in preliminary trials. This chemical is quite active in the vapor state and is most effective against weed seed. However, screening studies indicated nearly complete mortality of all tree species when dichlobenil was applied to seed-

TABLE 5. TREATMENTS THAT APPEARED NONINJURIOUS IN GREENHOUSE TRIALS

Chemical treatment	Rate per acre	Chemical treatment	Rate per acre
	Pounds		*Pounds*
Loblolly pine		**Sweetgum**	
Eptc	3 and 6	DCPA	4 and 8
DCPA	4 and 8	Prometryne	3 and 6
Prometryne	3 and 6	Ametryne	3 and 6
Ametryne	3 and 6	Cotoran	2 and 4
Chloroxuron	2 and 4	Chloroxuron	2 and 4
Trifluralin	1 and 2	Trifluralin	1 and 2
Diphenamid	4 and 8	Diphenamid	4 and 8
Norea	1 and 2	Norea	1 and 2
		Diuron	1 and 2
Slash pine			
Eptc	3	**Sycamore**	
DCPA	4 and 8	Eptc	3
Prometryne	3 and 6	DCPA	4 and 8
Ametryne	3 and 6	Chloroxuron	2 and 4
Chloroxuron	2 and 4	Trifluralin	1
Trifluralin	1 and 2	Diphenamid	4
Diphenamid	4 and 8	Norea	1
Norea	1 and 2		
Diuron	1 and 2	**Yellow poplar**	
Arizona cypress		DCPA	4 and 8
		Ametryne	3
DCPA	4 and 8	Chloroxuron	2 and 4
Trifluralin	1 and 2	Trifluralin	1 and 2
Diphenamid	4 and 8	Eiphenamid	4 and 8
Norea	1 and 2	Norea	1 and 2
		Diuron	1

beds (Tables 2, 3, and 4). Therefore, studies were carried out with young seedlings shortly after germination.

Treatments of dichlobenil at 0, 4, 8, and 16 pounds per acre were applied after the first hand weeding. The granular material was applied with a large salt shaker. Each treatment was replicated four times in a randomized block design. Hand-weeding time, density, and height measurements were taken as previously described for the pre-emergence study.

Studies on yellow poplar and sycamore were conducted at the Auburn Nursery. Dichlobenil treatments were applied on May 20, to 4 × 5 foot plots. At time of treatment, yellow poplar seedlings were 3 to 4 inches tall while sycamore seedlings were 1 to 2 inches. Yellow poplar plots were hand weeded June 7 and July 26. Sycamore plots were hand weeded June 17, July 20, and August 5.

Studies with sycamore, loblolly pines, and willow oak were conducted at the Kimberly-Clark Corporation Nursery near Childersburg, Alabama. These studies were designed as previously described except that plots used for sycamore and loblolly pine were 4 × 10 feet. The dichlobenil treatments were applied on June 3.

TABLE 6. THE EFFECTS OF EIGHT PRE-EMERGENCE CHEMICALS ON WEEDING TIME, DENSITY, AND HEIGHT GROWTH OF YELLOW POPLAR SEEDLINGS AT THE AUBURN NURSERY

Treatment	Weeding time[1, 2]	Seedling density[2]	Average seedling height[2]
	Man-hr	*Trees/ft.*^{2}	*Ft.*
Check	145.2	11.9	1.9
DCPA 8 lb./a.	115.0	10.6	2.1
DCPA 16 lb./a.	100.8	14.5	2.1
Prometryne 2 lb./a.	74.7*	14.2	2.2
Prometryne 4 lb./a.	99.6	10.7	2.2
Ametryne 2 lb./a.	89.2*	9.1	1.9
Ametryne 4 lb./a.	85.5*	9.2	2.2
Chloroxuron 3 lb./a.	94.7	12.6	2.5*
Chloroxuron 6 lb./a.	131.0	13.5	2.3*
Trifluralin 2 lb./a.	92.8	10.3	2.2
Trifluralin 4 lb./a.	98.9	10.8	2.4*
Diphenamid 4 lb./a.	146.0	15.7	2.3*
Diphenamid 8 lb./a.	112.9	11.9	2.1
Norea 2 lb./a.	109.7	11.4	2.1
Norea 4 lb./a.	83.1*	11.2	2.3*
Diuron 1 lb./a.	73.8*	11.6	2.0
Diuron 2 lb./a.	88.7*	8.3	2.0

[1] Total hand-weeding time for three weedings based on acres of actual nursery bed exclusive of alleys.

[2] Averages followed by an asterisk are significantly different from the check at the .05 level (Duncan, 1955).

At that time the seedling height averaged 2.5, 3, and 5.5 inches for sycamore, pine, and willow oak, respectively. The sycamore plots were weeded June 21 and August 3 and willow oak plots were weeded August 3.

Dichlobenil proved to be highly toxic to young loblolly pine. By June 21, 4 pounds per acre of dichlobenil had caused an estimated 60 to 70 per cent mortality, while 8 to 12 pounds per acre killed more than 90 per cent of the seedlings.

In all studies, dichlobenil significantly reduced hand-weeding time when compared with the check (Tables 7, 8, 9, and 10). No significant differences in weeding time between the three rates of chemical in studies on yellow poplar and willow oak were apparent, but a significant difference was observed in 4 and 8 pounds per acre rates on both sycamore studies. Dichlobenil at 8 and 12 pounds per acre significantly reduced survival in yellow poplar and willow oak (Tables 7 and 10). In sycamore studies, dichlobenil significantly reduced survival only at 12 pounds per acre (Tables 8 and 9). Considerable mortality was noted on check plots in December at the Kimberly-Clark Nursery. These dead trees were 5 to 6 inches tall, very spindly, and were appar-

TABLE 7. THE EFFECTS OF A POST-EMERGENCE APPLICATION OF DICHLOBENIL ON HAND-WEEDING TIME, DENSITY, AND HEIGHT GROWTH OF YELLOW POPLAR SEEDLINGS AT THE AUBURN NURSERY

Treatment	Weeding time[1, 2]	Seedling density[2]	Average seedling height[2]
	Man-hr.	*Trees/ft.²*	*Ft.*
Check	86.6 a	12.4 a	2.1 a
Dichlobenil 4-G 4 lb./a.	49.4 b	9.8 a	2.2 a
Dichlobenil 4-G 8 lb./a.	44.6 b	3.9 b	1.9 a
Dichlobenil 4-G 12 lb./a.	33.2 b	1.2 b	2.2 a

[1] Total hand-weeding time for three weedings based on acres of actual nursery bed exclusive of alleys.

[2] Averages followed by the same letter are not significantly different at the .05 level (Duncan, 1955).

ently shaded out by the dominant seedlings on the plots. The low densities observed in check plots at the Kimberly-Clark Nursery were probably because of natural mortality. This apparent natural mortality was not observed at the Auburn Nursery even though seedling density was much higher. Height growth was not affected by dichlobenil in any of the studies.

It appears that dichlobenil is safe at 4 pounds per acre for weed control in yellow poplar, sycamore, and willow oak seedlings. Slightly higher rates might be used on sycamore since it appears to be more tolerant than the other two species.

The 4 per cent granular formulation of dichlobenil should be used since the majority of 50 per cent wettable formulation will be quickly lost by volatilization if applied to the soil surface in warm weather. Germination should be complete and existing

TABLE 8. THE EFFECTS OF A POST-EMERGENCE APPLICATION OF DICHLOBENIL ON HAND-WEEDING TIME, DENSITY AND HEIGHT GROWTH OF SYCAMORE SEEDLINGS AT THE AUBURN NURSERY

Treatment	Weeding time[1, 2]	Seedling density[2]	Average seedling height[2]
	Man-hr.	*Trees/ft.²*	*Ft.*
Check	672.0 a	16.5 a	1.7 a
Dichlobenil 4-G 4 lb./a.	36.0 b	14.7 a	1.8 a
Dichlobenil 4-G 8 lb./a.	268.0 bc	12.7 a	1.8 a
Dichlobenil 4-G 12 lb./a.	178.0 c	4.7 b	1.9 a

[1] Total hand-weeding time for three weedings based on acres of actual nursery bed exclusive of alleys.

[2] Averages followed by the same letter are not significantly different at the .05 level (Duncan, 1955).

TABLE 9. THE EFFECTS OF A POST-EMERGENCE APPLICATION OF DICHLOBENIL ON HAND-WEEDING TIME, DENSITY, AND HEIGHT GROWTH OF SYCAMORE SEEDLINGS AT THE KIMBERLY-CLARK NURSERY

Treatment	Weeding time[1, 2]	Seedling density[2]	Average seedling height[2]
	Man-hr.	*Trees/ft.*[2]	*Ft.*
Check	40.0 a	6.20 a	3.1 a
Dichlobenil 4-G 4 lb./a.	23.6 b	6.90 a	3.0 a
Dichlobenil 4-G 8 lb./a.	17.0 bc	6.40 a	2.9 a
Dichlobenil 4-G 12 lb./a.	12.2 c	3.85 b	3.0 a

[1] Total hand-weeding time for three weedings based on acres of actual nursery bed exclusive of alleys.

[2] Averages followed by the same letter are not significantly different at the .05 level (Duncan, 1955).

weeds removed by hand weeding prior to application of dichlobenil.

DISCUSSION AND CONCLUSIONS

This study investigated less than 20 of the many herbicides available for use. Such studies must continue since new materials are appearing each year and costs and returns in the nursery business are continually changing.

At least four compounds are worthy of further testing in southern tree seedling production – prometryne, ametryne, norea, and diuron. Dichlobenil also appears useful if applied after germination.

Trifluralin and diphenamid may be worthy of further test. Trifluralin is a volatile compound and best results are obtained

TABLE 10. THE EFFECTS OF A POST-EMERGENCE APPLICATION OF DICHLOBENIL ON HAND-WEEDING TIME, DENSITY, AND HEIGHT GROWTH OF YELLOW OAK SEEDLINGS AT THE KIMBERLY-CLARK NURSERY

Treatment	Weeding time[1, 2]	Seedling density[2]	Average seedling height[2]
	Man-hr.	*Trees/ft.*[2]	*Ft.*
Check	15.8 a	5.90 a	1.4 a
Dichlobenil 4-G 4 lb./a.	11.6 b	5.00 ab	1.3 a
Dichlobenil 4-G 8 lb./a.	9.2 b	3.50 bc	1.2 a
Dichlobenil 4-G 12 lb./a.	10.6 b	2.70 c	1.2 a

[1] Total hand-weeding time for three weedings based on acres of actual nursery bed exclusive of alleys.

[2] Averages followed by the same letter are not significantly different at the .05 level (Duncan, 1955).

when the material is incorporated into the soil. However, incorporation may increase seedling injury.

While pre- and post-emergence herbicides appear quite useful, it is clear that they are not going to eliminate hand weeding, particularly where a heavy weed population exists. Most agronomic herbicides are designed to act against light-seeded weeds germinating at or near the soil surface, which permit the deep-rooted crop seedling to emerge without injury. The majority of the desirable tree species are light-seeded and are planted on the soil surface where most herbicides are most active.

Where severe weed populations have built up, the only successful answer is soil fumigation followed by an intensive sanitation campaign against reinvasion. Weeds along fences, alleys, irrigation lines, ditches, and roads should be eliminated or kept well under control. Atrazine at 8 to 12 pounds per acre has proved quite effective in retarding weed growth on such areas. Even nutsedge may be controlled by this material. Care must be taken to keep the material off of nursery beds. Paraquat or DNBP, effective contact herbicides, are also useful in a sanitation program. All mulch and organic matter (e. g. pine straw) should be fumigated to eliminate weed seed.

Nurseries should be fumigated in blocks as large as possible, but preferably the entire nursery. Contamination from unfumigated areas can be controlled by cleaning all tractors, implements, and other objects that might transport weeds to the fumigated area. Irrigation water from ponds or streams is a potential source of weed seed, but may have to be tolerated.

Once fumigation has reduced the weed population to low leve's, judicious use of herbicides and strict sanitation practices will maintain the weed populations at a level where very little handweeding is needed.

Fumigation is expensive, but the cost should be prorated over 3 to 5 years. This series of studies indicates that this is the only good solution to severe weed problems.

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