Table 3. Percentage of stumps with fiber pull and barber-chair by felling method.

Tract	Felling method	Fiber pull		Barber-chair	
		Pine	Hwd.	Pine	Hwd.
1	Shear	83	86	3	0
2	Shear	56	84	13	0
3	Shear	78	91	12	4
Mean		74	87	9	1
4	Sawhead	36	25	30	25
5	Sawhead	85	44	12	4
6	Sawhead	4	3	22	7
Mean		41	24	23	14

ft^3 of hardwood and 15.2 ft^3 of pine/ac. Using a conversion rate of 33 ft^3/ton and stumpage values of $12/ton for pine and $6/ton for hardwood, estimated revenue loss to the landowner from a per-unit sale was $12.04/ac. If the timber was sold lump-sum, the purchasing forest products company lost the chip value of the residual volume left in high stumps, since it is assumed that the alternative felling method would be shearing, and the recovered material would be lily-pad chips. At $10/ton chip value, this amounts to $15.45/ac for the three sawhead study tracts.

As stated earlier, high stumps may also increase site preparation costs. Tract 6, where hardwood stumps averaged 10.32 in. high, may be an example. If shearing were required to reduce the stumps prior to chopping, site preparation cost could increase by as much as $60/ac (Dubois et al. 1991).

Loggers are capable of cutting low (3–4 in.) stumps with continuous disk sawheads. This study shows, however, that under normal operating conditions, sawhead operators are cutting high stumps. This is probably due to concern over disk damage and the desire to achieve high production from an expensive piece of equipment. The gains in productivity and product quality from sawheads may be an acceptable tradeoff for high stumps to the logger operating on a cut and haul contract or the procurement forester purchasing timber on a per unit payment basis. To the timber company or landowner who loses revenue from fiber left in high stumps or pays increased site preparation costs, the deal is not so good. Foresters, loggers, and landowners need to be aware of the current trend of sawhead stumps and rededicate themselves to the time-honored goal of optimum resource utilization. As the bumper sticker once so prevalent on southern timber company pickup trucks used to read—Cut Low Stumps!□

Literature Cited

DUBOIS, M., W.F. WATSON, T.J. STRAKA, AND K.L. BELLI. 1991. Costs and cost trends for forestry practices in the South For. Farm. (Manual Ed.) 50(3):26–32.

GALLAGHER, T.V., R.M. SHAFFER, AND W.B STUART. 1985. An assessment of shear damage to southern pine sawlogs. For Prod. J. 35(11/12):87–91.

GREENE, W.D. 1991. Cost estimates for saw felling heads in the South. For. Prod. J 41(2):21–26.

GREENE, W.D., AND J.F. MCNEEL. 1989. Potential costs of shear damage in a southern pine sawmill. For. Prod. J. 39(5):12–18.

SWIATLO, J.A., R.M. SHAFFER, W.B. STUART, AND E.M. WENGERT. 1990. An analysis of shear damage at two southern pine sawmills. For. Prod. J. 40(6):33–36.

TANKERSLEY, M. 1991. Brunswick stew Timber Harv. 39(8):12–18.

Prodiamine: A Herbicide for Pine and Hardwood Nurseries[1]

David B. South, *School of Forestry and Alabama Agricultural Experiment Station, Auburn University, AL 36849-5418.*

*ABSTRACT. Tolerance to applications of prodiamine was examined in field experiments with loblolly pine (*Pinus taeda *L.), slash pine (*Pinus elliottii *Engelm. var el-*liottii*), longleaf pine (*Pinus palustris *Mill.), shortleaf pine (*Pinus echinata *Mill.), and eastern white pine (*Pinus strobus *L.) seedlings at nine southern nurseries in 1979 and at six nurseries in 1980. No significant injury was observed when 0.5 kg ai/ha (7.1 oz ai/ac) was applied after sowing (preemergence) or 4 to 6 wk after sowing (postemergence). When applied just after sowing at 1.0 kg ai/ha (13.3 oz. ai/ac), a reduction in emergence was observed with loblolly pine, shortleaf pine, and eastern white pine. Tolerance of various hardwoods was also examined. Sycamore (*Platanus occidentalis *L.) was sensitive, and seedling production was reduced with both preemergence and early postemergence applications. Green ash (*Fraxinus pennsylvanica *Marsh.), sweetgum (*Liquidambar styraciflua *L.), and two species of oaks (*Quercus alba *L. and* Q. nigra *L./*Q. phellos *L.) tolerated rates as high as 1.0 kg ai/ha.*

South. J. Appl. For. 16(3):142–146

Research by the Auburn University Southern Forest Nursery Management Cooperative has found several effective herbicides for pine nurseries. Members of the diphenylether family have proven to be very effective (South 1986) Bifenox (South et al. 1978), oxy-

[1] This research was supported by the Auburn University Southern Forest Nursery Management Cooperative. Alabama Agricultural Experiment Station Journal Series 9-912953P.

fluorfen (South and Gjerstad 1980), and lactofen (South 1986) have been labeled for use on pine seedbeds based on data collected by the Cooperative (see Table 1 for chemical and trade names). However, although once commonly used in southern pine nurseries (Boyer and South 1984), bifenox is no longer sold in the United States. To ensure effective weed control, it is important to have effective alternatives in case preferred herbicides are suddenly withdrawn from the market. In addition, reliance on one family of herbicides can, in some cases, lead to a buildup of resistant weed species. For example, populations of prostrate spurge (*Euphorbia humistrata* Engelm. ex Gray) and spotted spurge (*Euphorbia maculata* L.) have increased since nursery managers began using diphenylether herbicides.

In 1978, the Cooperative began testing a new member of the dinitroaniline family: prodiamine. This herbicide can control common nursery weeds such as large crabgrass (*Digitaria sanguinalis* [L.] Scop.), goosegrass (*Eleusine indica* [L.] Gaertn.), carpetweed (*Mollugo verticillata* L.), Florida pusley (*Richardia scabra* L.), and pigweeds (*Amaranthus* sp.). In addition, it also has herbicidal activity on spurges (WSSA 1989). It has a relatively low vapor pressure and remains active when left on the soil surface. When applied to the soil, the herbicide prevents seed germination and can inhibit root growth of susceptible species (Bond 1988). The material has no contact activity and will not control weeds that are established at time of application.

MATERIALS AND METHODS

During 1978, 1979, and 1980, regional herbicide experiments were conducted at 15 forest nurseries in 12 states (Table 2). Herbicide plots (1.8 m by 2 m) were arranged in a randomized complete block design with four replications at each nursery. At the International Paper Company Nursery at Natchez, MS, the plot size was extended to 1.8 by 3.9 m. For the preemergence studies, the herbicide was usually applied right after sowing and mulching. Prodiamine was formulated as a wettable powder (50% active ingredient) and was mixed in 3.8 L of water and applied with a CO_2 powered sprayer. Soon after treatment, the area was irrigated with 1.3 to 1.9 cm of water.

For the postemergence studies in pine nurseries, the nursery manager was allowed the option of applying a preemergence herbicide application just after sowing. As a result, napropamide (1.1 kg ai/ha) was applied at the Hauss nursery, bifenox (3.4 kg ai/ha) was used at the Munson Nursery, and a combination of bifenox (3.4 kg ai/ha) and napropamide (1.1 kg ai/ha) was applied at the Pinson Nursery. Weed populations were very low at the Ft. Towson and Coastal Nurseries and therefore no preemergence herbicides were applied.

All plots were handweeded when necessary, and weeding times were recorded for each plot. At the Ft. Towson Nursery, no weeding was necessary, while at other nurseries, several weedings were needed throughout the season. Since herbicides used in these studies would not control purple and yellow nutsedge (*Cyperus rotundus* L. and *C. esculentus* L., respectively), handweeding of nutsedge was not included in the weeding times. Seedling tolerance to each treatment was evaluated within each plot during November and December by counting the number of Grade 1 and Grade 2 seedlings (Wakeley 1954) for pines and the total number of seedlings for hardwoods. In addition, samples of pines were weighed, and heights were measured for hardwoods. Statistical differences between treatments and controls were tested using Dunnett's T-test (Steel and Torrie 1960). For weed control, the statistical analyses were conducted on handweeding times but the data are expressed in terms of percent reduction. Percent weed control for the first handweeding was determined by: percent handweeding reduction = [1-(handweeding time for herbicide treatment/handweeding time for control plot)] × 100.

Table 1. Chemical identification of selected herbicides tested in forest nurseries.

Common name	Formulation	Trade name	Chemical name
Bifenox	4F	Modown	methyl 5-(2,4,-dichlorophenoxy)-2-nitrobenzoate
Lactofen	2EC	Cobra	(±)-2-ethoxy-1-methyl-2-oxoethyl 5-[2-chloro-4-(trifluoromethyl)phenoxy]-2-nitrobenzoate
Napropamide	50WP	Devrinol	2-(a-naphthoxy),*N*,*N*-diethylpropionamide
Oryzalin	4AS	Surflan	4-(dipropylamino)-3,5-dinitrobenzenesulfonamide
Oxyfluorfen	1.6E	Goal	2-chloro-1-(3-ethoxy-4-nitrophenoxy)-4-(trifluoromethyl)benzene
Prodiamine	65WDG	Barricade	N^3,N^3-di-*n*-propyl-2,4-dinitro-6-(trifluoromethyl)-*m*-phenylenediamine
	50WP	Rydex	
Trifluralin	4EC	Treflan	a,a,a-trifluoro-2,6-dinitro-*N*,*N*-dipropyl-*p*-toluidine

RESULTS

Weed Control

Even though the plot size was rather small, very good weed control was demonstrated at most of the pine nurseries where prodiamine (0.5 kg ai/ha) was applied just after sowing (Table 3). Weed populations on the control plots were very low at the Claridge Nursery, and therefore there was no reduction in handweeding time. The lack of significant weed control when applied after pine germination is due primarily to the use of effective preemergence herbicides (at the Hauss, Munson, and Pinson Nurseries) which resulted in low and variable weeding times.

Pine Seedling Tolerance

A significant reduction in seedling production was recorded at

Table 2. Nurseries, sowing dates, treatment dates, and soil characteristics of herbicide studies for 1978–1980.

Nursery	Location	Sowing date	Application date	Mulch	Soil texture	pH	Organic matter (%)
Preemergence to pines							
Baucum-1	AR	5/14/79	5/22/79	hydromulch	silt loam	5.5	0.8
Baucum-2	AR	4/20/80	4/24/80	none	silt loam	5.5	1.8
Cedar Springs	GA	5/13/80	5/13/80	hydromulch	loamy sand	5.0	1.0
Kentucky Dam-1	KY	5/29/80	5/29/80	wheat straw	loam	5.5	1.1
Columbia	LA	4/23/80	4/23/80	pine straw	silt loam	4.6	1.1
Miller	AL	5/ 4/79	5/ 4/79	pine straw	sandy loam	5.1	1.1
Ashe	MS	4/16/80	4/22/80	wood chips	sandy loam	5.3	1.9
Kentucky Dam-2	KY	5/30/79	5/30/79	wheat straw	loam	5.2	1.7
Claridge	NC	10/ ?/79	4/17/80	wood chips	loamy sand	5.4	1.2
Kentucky Dam-3	KY	5/29/79	5/30/79	wheat straw	sandy loam	5.6	1.1
Postemergence to pines							
Hauss	AL	5/ 8/79	6/ 7/79	pine straw	sandy clay loam	5.5	2.6
Munson	FL	4/21/79	6/ 9/79	hydromulch	loamy sand	5.7	1.3
Claridge	NC	5/ 2/79	6/13/79	wood chips	sandy loam	5.1	1.3
Ft. Towson	OK	4/24/79	6/ 4/79	hydromulch	loamy sand	4.5	1.7
Coastal	SC	9/21/78	6/12/79	pine straw	loamy sand	6.0	1.1
Pinson	TN	6/14/79	7/17/79	sawdust	silt loam	5.3	2.5
Preemergence to hardwoods							
Hammermill	AL	4/ 1/78	4/ 2/78	wood chips	sandy loam	5.0	1.0
Miller	AL	4/ 8/78	4/20/78	pine straw	sandy loam	5.3	0.8
Union Camp-1	VA	5/ 3/78	5/11/78	sawdust	loamy sand	6.3	0.6
Natchez	MS	4/ 4/78	4/ 4/78	hydromulch	silty loam	5.2	1.0
Union Camp-2	VA	5/ 2/78	5/11/78	sawdust	loamy sand	6.2	0.5
Union Camp-3	VA	5/ 3/78	5/11/78	sawdust	loamy sand	6.2	0.7
Union Camp-4	VA	4/24/78	5/11/78	sawdust	loamy sand	6.2	0.6
Postemergence to hardwoods							
Natchez	MS	5/ 1/79	6/ 6/79	hydromulch	silty loam	5.8	1.0
Union Camp-1	VA	5/ 8/79	5/25/79	sawdust	loamy sand	6.0	0.6
Union Camp-2	VA	5/ 8/79	5/25/79	sawdust	loamy sand	5.9	1.1
Union Camp-3	VA	5/ 8/79	5/25/79	sawdust	loamy sand	5.8	0.9
Miller	AL	11/15/78	4/ 4/79	pine straw	sandy clay loam	5.2	1.2

the Kentucky Dam Nursery when 1.0 kg ai/ha of prodiamine was applied to shortleaf pine just after sowing (Table 3). Although not statistically significant, a reduction in seedling density was also noted on loblolly pine (at the Cedar Springs Nursery) and on eastern white pine (at the Kentucky Dam Nursery). However, when used at the lower rate (0.5 kg ai/ha) no statistically significant reductions in either density or weights were observed. Fresh weight production at the low rate was numerically higher in eight of the nine preemergence studies where weights were measured. At the

Table 3. Initial weed control (at the 0.5 kg ai/ha rate), plantable seedling densities and fresh weights of pine seedlings following applications of prodiamine.

Nursery	Species	Handweeding reduction (%)	Herbicide rate (kg ai/ha) 0	0.5	1.0	0	0.5	1.0
Preemergence to pines			[density (#/m^2)]			[weight (g/m^2)]		
Baucum-1	loblolly	84 **	145	149	144	1839	2002	1941
Baucum-2	loblolly	88 **	57	96	48	1276	1937	1096
Cedar Springs	loblolly	45	112	112	42	1039	1261	528
Kentucky Dam-1	loblolly	55 **	11	68 **	50	192	770 *	743 *
Columbia	loblolly	75 **	121	113	102	2274	2520	1794
Miller	slash	94 **	310	273	267	2822	2836	2725
Ashe	shortleaf	42	110	109	90	3720	3750	3141
Kentucky Dam-2	shortleaf	89 **	154	107	19 *	1332	1006	259 *
Claridge	longleaf	0	165	157	150	3486	3522	3528
Kentucky Dam-3	white	88 **	69	48	28	—	—	—
Postemergence to pines								
Hauss	slash	40	166	147	—	2779	2264	—
Munson	slash	71	120	130	—	1517	1393	—
Claridge	slash	83	390	378	—	4745	4637	—
Ft. Towson	loblolly	—	275	206	—	—	—	—
Coastal	shortleaf	43	133	129	—	—	—	—
Pinson	longleaf	53	254	240	—	6290	5347	—

* Significantly different from the controls at the 5% level of probability. Means were compared using Dunnett's T-test.
** Significantly different from the controls at the 1% level of probability.

Table 4. Seedling densities and average heights of hardwood seedlings following applications of prodiamine.

		Herbicide rate (kg ai/ha)							
Nursery	Species	0	0.5	1.0	2.0	0	0.5	1.0	2.0
Preemergence		[density (#/m²)]				[height (cm)]			
Hammermill	sycamore	40	0 *	0 *	—	—	—	—	—
Miller	sycamore	46	13 *	6 *	—	100	99	86	—
Union Camp-1	sycamore	29	21	15	—	70	66	66	—
Natchez	sweetgum	24	12	—	—	62	59	—	—
Union Camp-2	sweetgum	80	86	73	—	26	28	28	—
Union Camp-3	green ash	73	69	71	—	69	73	75	—
Union Camp-4	water-willow oak	53	56	58	—	28	28	27	—
Postemergency to hardwoods									
Natchez	sycamore	49	21 *	13 *	13 *	118	124	130	136
Union Camp-1	sycamore	52	44	32	40	59	61	55	62
Union Camp-2	sweetgum	78	77	69	64	45	47	46	43
Union Camp-3	green ash	84	72	71	58 *	46	43	45	41
Miller	white oak	127	134	129	150	53	51	56	53

* Significantly different from the controls at the 5% level of probability. Means were compared using Dunnett's T-test.

Kentucky Dam Nursery, seedling production was significantly increased when high weed populations (untreated plots required 10.9 minutes of handweeding per m^2) were controlled.

No significant injury was observed when newly germinated seedlings were treated with prodiamine at 0.5 kg ai/ha (Table 3). In most cases, the treatment was made only 4 to 6 wk after sowing (Table 2). Although the fresh weights of treated seedlings were numerically less than control seedlings, no visual injury symptoms were observed with postemergence applications.

Hardwood Seedling Tolerance

A preemergence application of prodiamine was evaluated at four nurseries in 1978. A significant reduction in sycamore density was observed at two nurseries (Table 4), while no injury was observed on sweetgum, green ash, or water-willow oak. In 1979, applications made soon after germination also reduced the production of sycamore seedlings, but no injury was observed on sweetgum or white oak. Growth and density of green ash were significantly reduced only when 2.0 kg ai/ha (28.6 oz. ai/ac) was applied less than 3 wk after sowing.

DISCUSSION

When prodiamine at the 0.5 kg ai/ha rate was applied just after sowing, no apparent injury was observed on the pines, oaks, sweetgum, or green ash. Severe seedling reduction was observed at two pine nurseries with a 2× (1.0 kg ai/ha) rate. All rates tested caused severe injury to sycamore. Previous research demonstrated that emergence of sycamore is reduced when trifluralin, another herbicide in the dinitroaniline family, was applied just after sowing (South 1984). Differences in seed size among species may partially explain the observed differences in herbicide selectivity. The embryo of the sycamore seed is very small and was the most sensitive, while the larger seeds of pines and oaks were much more tolerant to preemergence applications of prodiamine.

For most tree species, the mode of action makes prodiamine relatively save to apply once the trees have established a sufficiently deep root system. A postemergence application to established seedlings has been successful when applying herbicides such as napropamide and oryzalin to various woody species. Both prodiamine and oryzalin are members of the dinitroaniline family, and both have similar herbicidal properties (Weber 1990). Oryzalin is currently registered for use on a number of field-grown "established" tree species including pines, oaks, maples, and sweetgum. It is likely that the use pattern of prodiamine will be similar to that of oryzalin. A national turf label for the WDG formulation of prodiamine has been approved by the U.S. Environmental Protection Agency. State registrations (24-C labels) could be obtained for use in tree nurseries.

Prodiamine has several possible advantages for use in a forest nursery weed control program. First, it is relatively insoluble in water (0.013 ppm), and therefore should not leach appreciably into the root zone. Second, since it has no contact activity, it should have a wide range of tree species on which it can be safely applied (once the trees have germinated and have an established root system). Third, it has some activity on prostrate spurge and spotted spurge. And finally, it will not cause "white lesions," which sometimes occur when diphenylether herbicides are applied just after sowing (South and Mexal 1983). □

Literature Cited

BOND, W. 1988. Comparative tolerance of different plant species to prodiamine. Crop Protect. 7:75–79.

BOYER, J.N., AND D.B. SOUTH. 1984. Forest nursery practices in the South. South. J. Appl. For. 8(2):67–75.

SOUTH, D.B. 1984. Chemical weed control in southern hardwood nurseries. South. J. Appl. For. 8(1):16–22.

SOUTH, D.B. 1986. Diphenylether herbicides in southern pine nurseries. P. 441–453. Proc. Internat. Symp. on Nursery Management Practices for the Southern Pines, South, D.B. (ed.). Ala. Agric. Exp. Stn., Auburn University, AL.

South, D.B., and D.H. Gjerstad. 1980. Oxyfluorfen: An effective herbicide for southern pine nurseries. South. J. Appl. For. 4(1):36–39.

South, D.B., D.H. Gjerstad, and R.H. Crowley. 1978. Bifenox: A promising new herbicide for southern pine nurseries. South. J. Appl. For. 1(1):11–14.

South, D.B., and J.G. Mexal. 1983. Effects of bifenox and oxyfluorfen on emergence and mortality of loblolly seedlings grown under growth chamber conditions. P. 418–426. Proc. 2nd Bienn. South. Silvic. Res. Conf. Jones, E.P., Jr. (ed.). USDA For. Serv. Gen. Tech. Rep. SE-24.

Steel, R., and J. Torrie. 1960. Principles and procedures of statistics. McGraw-Hill, New York. 481 p.

Wakeley, P.C. 1954. Planting the southern pines. USDA Agric. Monogr. No. 18 233 p.

Weber, J.B. 1990. Behavior of dinitroaniline herbicides in soils. Weed Tech 4:394–406.

Weed Science Society of America. 1989 Herbicide handbook. Ed. 6. Champaign, IL. 301 p.

Response of Nine-Year-Old Plantation Sweetgum to Nitrogen Fertilization in Mississippi[1]

L.E. Nelson *and* **G.L. Switzer,** *now deceased, Mississippi Agricultural and Forestry Experiment Station, Mississippi State University, Mississippi State, MS 39762.*

*ABSTRACT. Nine-year-old planted sweetgum (*Liquidambar styraciflua *L.) consisting of four half-sib seed sources were refertilized with nitrogen in 1981 at the beginning of the tenth field-growing season. Increases in periodic annual height, diameter at breast height, basal area, stem volume (ob), and woody biomass increments of all four half-sib seed sources from applied nitrogen were observed during the 9 years following application. Periodic annual stem volume (ob) increments averaged over all half-sib seed sources were 120, 152, 192, and 266 ft^3/ac/yr for the 0, 89, 178, and 356 lb/ac N rates, respectively. The half-sib seed sources from alluvial sites were superior to those from upland sites in terms of productivity and response to N. The response of all half-sibs to N was immediate, occurring during the year of application; however, the increased growth rates due to N persisted for only 3 years. This suggests that on responsive sites, applications of N may be necessary every fourth year to maintain maximum growth rates.*

South. J. Appl. For. 16(3):146–150.

The use of hardwood timber accelerated in the 1980s. New technology promoted many hardwood species to a favored status for particle board and kraft pulp production (Harpole 1988, USDA Forest Service 1988). For example, the fraction of pulpwood consumption derived from hardwoods increased from 14% in 1950 to 31% in 1989 (Slinn 1990).

Because of its wide distribution over a range of soil and climatic conditions, sweetgum exhibits considerable genotypic variation. In 1972 a field experiment was undertaken to determine (1) the response to N and P fertilization under plantation culture, and (2) the variation in response among half-sib seed sources. The results of the first 9 growing seasons were reported by Nelson and Switzer (1990). This report summarizes the results of the second 9 growing seasons following refertilization at the beginning of the tenth growing season.

During the first 9 years, there was a response to N but not to P. Half-sib seed sources responded differently. During the ninth growing season, mean current annual volume increment (ob) of the fertilized plots was 33% greater than that of the unfertilized, averaged over the four half-sib seed sources. However, relative growth rates were the same for fertilized and unfertilized treatments (Nelson and Switzer 1990). Hence, it seemed desirable to refertilize with N to determine what growth responses can be expected when additional N was applied to 9-yr-old plantation-grown sweetgum. The N treatments were modified to determine (1) if a split application of N would prolong response and (2) if a higher N rate would give additional response.

METHODS

The experimental site was on the J.W. Starr Memorial Forest of Mississippi State University in Winston County. The soil is a Mathiston silt loam, a member of the fine-silty, siliceous, acid, thermic family of the Aeric Fluvaquents. Square plots 0.08 ac in area with an interior measurement plot of 0.06 ac containing 25 trees (10 × 10 ft spacing) were employed with a single border row shared by contiguous plots.

Seed for the planting stock was obtained from trees in the vicinity of the Starr Memorial Forest. Maternal parents of half-sibs U-1 and U-2 were from an upland site, while half-sibs A-3 and A-4 were from an alluvial site. Although the trees were chosen at random, it is not known how closely the four half-sib selections represent the natural population.

[1] This is Journal Contribution no. J-7609 of the Mississippi Agricultural and Forestry Experiment Station. This research was part of MAFES Project 0692, supported in part by McIntyre-Stennis funds. The assistance of M.G. Shelton in data collection and J.A. Mobley for statistical computations is greatly appreciated.

[2] Corresponding author: Box 5248, Mississippi State, MS 39762.