Herbicides for Southern Pine Seedbeds[1]

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ABSTRACT. Prior to 1970, nursery managers relied primarily on methyl bromide fumigation, mineral spirits, and hand-weeding for weed control. Since 1970, registration of herbicides for use in forest nurseries has been facilitated by tests conducted by the Auburn University Southern Forest Nursery Management Cooperative. Various herbicides can be applied prior to sowing, just after sowing, or after emergence of the pine seedlings. It has been estimated that for all nurseries in the South, use of these herbicides has reduced weed control costs by over two million dollars per year. This paper describes some of the herbicides that have been registered for use in southern pine nurseries.

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Weeds are the major pest problem in forest nurseries (Miller 1975, Abbott and Fitch 1977, Boyer and South 1984). A survey of southern forest nursery practices in 1980 (Boyer and South 1984) indicated that more seedlings were lost to weeds than to any other pest. Twenty-five percent of the nurseries surveyed required more than 100 work-hours of hand-weeding per acre. Cost of hand-weeding at one nursery exceeded $1,700 per acre.

Since 1970, the Auburn University Southern Forest Nursery Management Cooperative has screened herbicides for use in pine seedbeds. Uniform studies were conducted at various southern forest nurseries in order to identify herbicides that have potential for use in seedbeds of loblolly (*Pinus taeda* L.), slash (*P. elliottii* Engelm. var. *elliottii*), shortleaf (*P. echinata* Mill.), and longleaf (*P. palustris* Mill.) pine seedbeds (South et al. 1978, Gjerstad et al. 1979, South and Gjerstad 1980, South and Gjerstad 1982, South and Gjerstad 1984). It has been estimated that use of these herbicides has reduced cost of hand-weeding and mineral spirits for Cooperative nurseries by over two million dollars per year (Table 1). This paper summarizes results with some of the herbicides that have been used in pine nurseries in the South.

HERBICIDE SELECTIVITY

To kill weeds in pine seedbeds without injuring seedlings, a herbicide application must be selective. Selectivity can be based on physiological and/or morphological differences between crop and weeds. For example, a physiological difference between pines and grasses may comprise the basis of selectivity for herbicides like sethoxydim. Seedlings tolerant of sethoyxdim may metabolize sethoxydim at a faster rate than susceptible grass species (Swisher and Corbin 1982).

Morphological differences in leaf anatomy between pines and weed species could explain differential tolerance. The thick cuticular wax layer present on pine needles can protect pine seedlings from herbicides like oxyfluorfen and bifenox. Only newly formed tissue is injured when young loblolly seedlings are treated with oxyfluorfen (1984). Under greenhouse conditions, it took approximately two weeks for the pine cotyledons and primary needles to produce enough wax to prevent substantial injury from a postemergence application of oxyfluorfen. The cuticular wax layer on many newly emerged weeds is often insufficient for preventing injury.

Morphological differences between the stage of development of the crop and weed species can also be utilized in providing herbicide selectivity. Certain herbicides can be applied after pine seedlings have emerged but prior to weed seed germination. At this state, a herbicide that has preemergence activity but no postemergence activity can be used. This technique can be used to apply granular herbicides such as oxadiazon.

Differences in germination habits could also help explain why pines are often tolerant to a preemergence application of oxyfluorfen. Oxyfluorfen is active primarily on shoots and usually does not reduce germination or root growth. Therefore, both pine seed and weed seed can germinate below the chemical barrier formed by a preemergence application of oxyfluorfen. A weed is usually killed when the emerging shoot comes in contact with the herbicide barrier. However, the shoot of a pine seedling is normally protected by the testa as it breaks through the chemical barrier. Usually, the shoot becomes exposed only after the seedling has emerged from the soil (although the shoot may be protected, under certain conditions, the pine hypocotyl can be injured by contact with soil treated with oxyfluorfen).

HERBICIDES APPLIED PRIOR TO SOWING AND SOIL INCORPORATED

Certain herbicides like trifluralin and EPTC are more volatile than other herbicides. When applying such volatile herbicides prior to sowing, it is important to incoroporate the herbicides into the soil immediately after application. This reduces loss of the herbicide through volatilization.

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Table 1. Savings in hand-weeding costs and mineral spirits usage at 30 of the 64 cooperative nurseries.

Nursery location		Ac	Hand-weeding time 1975	Hand-weeding time 1980–84	Savings in hand-weeding cost ($6/hr)	Mineral spirits used 1975	Mineral spirits used 1980–84	Savings in cost of mineral spirits ($1.25/gal.)	Approximate increase in herbicide costs	Savings in weed control costs[1]
			(hr/ac)		($)	(U.S. gal.)		($)	($)	($)
1	AL	42	57	24	8,316	518	900	(−478)	924	6,914
2	AL	43	126	18	27,864	1,500	1,500	-0-	946	26,918
3	AL	37	52	8	9,768	4,038	-0-	5,047	814	14,001
4	AL	20	67	30	4,440	1,650	-0-	2,062	440	6,062
5	AR	38	77	194	(−26,676)	16,000	-0-	20,000	836	(−7,512)
6	FL	42	100	114	(−3,528)	15,000	2,000	16,250	924	11,798
7	FL	27	54	15	6,318	5,500	3,500	2,500	594	8,224
8	FL	50	64	11	15,900	2,000	-0-	2,500	1,100	17,300
9	GA	60	460	100	129,600	18,000	6,500	14,375	1,320	142,655
10	GA	25	97	37	9,000	6,500	-0-	8,125	550	16,575
11	GA	33	10	18	(−1,584)	18,000	1,500	20,625	726	18,315
12	GA	63	3	4	(−378)	20,000	4,000	20,000	1,386	18,236
13	GA	17	186	17	17,238	6,500	-0-	8,125	374	24,989
14	KY	15	450	20	38,700	-0-	-0-	-0-	330	38,370
15	KY	15	680	30	58,500	-0-	-0-	-0-	330	58,170
16	LA	11	118	120	(−132)	3,140	-0-	3,925	242	3,551
17	LA	19	85	12	8,322	10,000	65	12,419	418	20,323
18	LA	57	72	70	684	12,000	-0-	15,000	1,254	14,430
19	MS	72	150	80	30,240	15,000	-0-	18,750	1,584	47,406
20	MS	54	530	20	165,240	13,800	-0-	17,250	1,188	181,302
21	NC	50	72	36	10,800	7,500	-0-	9,375	1,100	19,075
22	SC	14	422	25	33,348	1,250	-0-	1,562	308	34,602
23	SC	11	670	107	37,158	3,000	-0-	3,750	242	40,666
24	SC	44	88	20	17,952	12,000	-0-	15,000	968	31,984
25	TX	29	140	12	22,272	10,000	-0-	12,500	638	34,134
26	TX	25	230	34	29,400	6,650	-0-	8,312	550	37,162
27	TX	35	330	80	52,500	23,808	60	29,685	770	81,415
28	VA	55	154	1	50,490	12,000	-0-	15,000	1.210	64,280
29	VA	15	36	33	270	3,300	1,100	2,750	330	2,690
30	VA	10	143	95	2,880	200	-0-	250	220	2,910
Total		1,028	5,723	1,385	754,902	248,854	21,125	284,659	22,616	1,016,945
Average		34	191	46	25,163	8,295	704	9,489	754	33,898
										× 64
								Approximate savings for 64 nurseries		2,169,472

[1] Does not include savings in reduced fumigation.

Trifluralin (dinitroaniline family)

This herbicide (see Table 2 for chemical names) has been used at 1 lb ai/ac (1.1 kg ai/ha) to control grasses and small seeded broadleaf weeds at a few southern nurseries. However, trifluralin mechanically incorporated into the soil has injured pine roots in Georgia (Rowan 1978), Mississippi, and Texas. For this reason, trifluralin is not recommended as a presowing treatment.

EPTC (thiocarbamate family)

EPTC has been used at several nurseries that had problems with yellow nutsedge (*Cyperus esculentus* L.) or purple nutsedge (*Cyperus rotundus* L.). However, nutsedge is not killed by this herbicide but is only suppressed for four to six weeks. The emulsifiable concentrate (EC) formulation can be applied at 6.1 lb ai/ac (6.9 kg ai/ha). One reason EPTC is not popular in southern nurseries is that a two-week waiting period is recommended before seeding. At some nurseries, sowing too soon after treatment may result in injury to pine seedlings (Rowan 1959). Use of EPTC may be helpful when used as part of an integrated system for controlling nutsedge (South 1978).

HERBICIDES APPLIED PREEMERGENCE IMMEDIATELY AFTER SOWING

It is easier to control germinating broadleaf weed seeds with a preemergence herbicide application than to control established broadleaf weeds with a foliage-applied herbicide. Therefore, it is important to use an effective preemergence herbicide since the most critical period for weed control is during the first five to six weeks after sowing in the spring.

There are several times during the sowing process when herbicides can be applied: (1) after bed shaping and prior to sowing and mulching; (2) after sowing and prior to mulching; and (3) after mulching. In some years, applying the herbicide before mulching may increase weed control. In 1978, tests were established to compare weed control obtained from bifenox applied before and after mulching. At the Pinson Nursery in Tennessee, applying bifenox before mulching increased weed control from 40 to 64%, thereby reducing the hand-weeding requirement by 120 work-hours per ac (296 work-

Table 2. Common, trade, and chemical names of selected herbicides used in southern forest nurseries.

Common name	Trade name	Chemical name
bifenox	Modown	methyl 5-(2,4-dichlorophenoxyl)-2-nitrobenzoate
diphenamid	Enide	*N,N*-dimethyl-α-phenyl benzeneacetamide
EPTC	Eptam Genept	*S*-ethyl dipropyl carbamothioate
fluazifop-butyl	Fusilade	(±)-butyl 2-[4-[(5-(trifluoromethyl)-2-pyridinyl)oxy]phenoxyl-propanoate
glyphosate	Roundup	*N*-(phosphonomethyl)glycine
napropamide	Devrinol	*N,N*-diethyl-2-(1-naphthalenyloxy)propanamide
oxadiazon	Ronstar	3-[2,4-dichloro-5-(1-methylethoxy)phenyl]-5-(1,1-dimethylethyl)-1,3,4-oxadiazol-2-(*3H*)-o
oxyfluorfen	Goal	2-chloro-1-(3-ethoxy-4-nitrophenoxy)-4-(trifluoromethyl)benzene
prometryn	Caparol Prometryn	*N,N'*-bis(1-methylethyl)-6-(methylthio)-1,3,5-triazine-2,4-diamine
sethoxydim	Poast	2-[1-(ethoxyamino)-butyl]-5-[2-(ethylthio)propyl]-3-hydroxy-2-cyclohexene-1-one
trifluralin	Treflan	2,6-dinitro-*N,N*-dipropyl-4-(trifluoromethyl)benzenamide

hours per ha). At the Baucum Nursery in Arkansas, hand-weeding was reduced by 183 work-hours per ac (452 work-hours per ha) by applying the herbicide before mulching. There may be two reasons for the improvement in weed control. When the herbicide is applied prior to mulching, less herbicide will be absorbed by the mulch, and less herbicide will be washed off the seedbed with the mulch.

Oxyfluorfen (diphenylether family)

This herbicide can provide excellent control of many annual grasses and broadleaf weeds but does not kill nutsedge tubers or rhizome bermudagrass (*Cynodon dactylon* [L.] Pers.). The most frequently used rate is 0.5 lb ai/ac (0.6 kg ai/ha), which usually provides four to seven weeks of weed control (South and Gjerstad 1980). Since oxyfluorfen does not leach, it forms a thin chemical barrier to germinating weeds on the soil surface. If this chemical barrier is disturbed by tractor tires or other devices that cause soil disturbance, untreated soil will be exposed and weed growth can occur. This herbicide may provide better weed control when applied before mulching.

Although this herbicide is commonly used in the South at time of sowing, injury has been observed on loblolly pine at several nurseries (South and Mexal 1983). White lesions formed on hypocotyls, and some seedlings were weakened. However, seedlings with lesions often survived and grew normally. Seedlings that died were usually weakened and lacked the vigor to lift the testa and cotyledons out of the soil. Mortality at some nurseries ranged from 5 to 10%. The occurrence of injury appears to be related to overcast weather during emergence. The probability of injury is apparently increased when low light intensities (during seedling emergence) are followed by higher light intensities. A few nurseries with very low weed populations have chosen to avoid this risk by not applying this treatment.

Bifenox (diphenylether family)

Bifenox provides good control of most broadleaf weeds but is not very effective on annual grasses and does not control nutsedge, bermudagrass, or sicklepod (*Cassia obtusifolia* L.). A 3 lb ai/ac (3.4 kg ai/ha) rate usually provides four to five weeks of weed control (South et al. 1978). Bifenox does not leach and forms a chemical barrier that should not be broken. This herbicide can provide better weed control if applied before mulching.

Under certain weather conditions, bifenox can cause white lesions on newly emerged seedlings (South and Mexal 1983). Mortality at some nurseries has ranged from 5 to 10%. As with oxyfluorfen, the occurrence of injury appears to be related to overcast weather during emergence. At a few nurseries with very low weed populations, nursery managers have chosen to avoid this risk by not applying this treatment.

Napropamide (substituted amide family)

This herbicide provides excellent control of many annual grasses and has been used in combination with bifenox to increase the spectrum of weed control. A tank mix of napropamide at 1 lb ai/ac (1.1 kg ai/ha) with 3 lb ai/ac (3.4 kg ai/ha) of bifenox has been used at a number of nurseries with excellent results. However, napropamide has caused seedling injury at several nurseries that have low soil organic matter. Since napropamide will leach in soils and can inhibit pine root growth, it should not be used on soils having less than 1% organic matter and should be applied after mulching.

Diphenamid (substituted amide family)

Diphenamid applied at 4 lb ai/ac (4.5 kg ai/ha) provides fair to poor control of annual grasses. Because leaching of this material is increased with frequent irrigation during early seedling establishment, weed control lasts only a few weeks. Due to the availability of less expensive, more effective herbicides, diphenamid is no longer used in southern pine nurseries.

Prometryn (triazine family)

This herbicide can provide good control of several grasses and broadleaf weeds and has been used at a number of nurseries in the past. However, tolerance of pines to prometryn is marginal and millions of seedlings have been killed with this treatment. Germination is not affected,

once the seedlings are established, the roots absorb prometryn (which has leached into the root zone), and it is translocated to the needles. Photosynthesis is inhibited, resulting in the needles turning brown at the tips. Browning continues until the entire seedling is brown. On fine-textured soils, most pines are tolerant to prometryn at 1 lb ai/ac (1.1 kg ai/ha). However, this rate has caused injury on sandy soils with low organic matter. Because of its limited registration and the potential injury to seedlings, this herbicide has very limited use in the South.

HERBICIDES APPLIED POSTEMERGENCE TO THE PINE SEEDLINGS

Postemergence applications are made after the emergence of pine seedlings. There are two types of postemergence applications: (1) those made prior to weed emergence; and (2) those made after weed emergence. Herbicides that are soil-active and control germinating weed seeds should be applied prior to weed emergence. This type of application is preferred since it is much easier to control germinating weed seeds than to control established weeds. When making applications after weeds have emerged, a herbicide that has either contact or systemic activity should be used. In addition, the size of the emerged weeds should be small since most weeds become more tolerant to herbicides as size increases. Table 3 indicates the relative effectiveness of herbicides applied before and after weed emergence.

Oxyfluorfen (diphenylether family)

This herbicide has postemergence as well as preemergence activity. It will control most annual weeds but will not control nutsedge or bermudagrass. When emerged weeds are present, the efficacy of oxyfluorfen will be increased if a surfactant or crop-oil is used.

Needle burn (a browning of new needles around the terminal) can result from postemergence applications of oxyfluorfen. The injury is usually transitory, and seedlings quickly grow out of this condition. The injury normally occurs on young succulent tissue that is less than a week old (South 1984). Nitrogen applications can stimulate growth of pine seedlings that produced more succulent tissue. Therefore, to avoid injuring this succulent growth, oxyfluorfen should be applied prior to nitrogen applications.

Most nursery managers use either monthly or weekly applications of oxyfluorfen. With monthly applications, two or three postemergence applications per year are normally used at 0.5 lb ai/ac (0.6 kg ai/ha) per application). Because late germinating seedlings may be injured by this rate, the first postemergence application should be made at least five weeks after emergence begins. However, at some nurseries, this delay has caused weeds to become well established by the time the first postemergence application is made. For this reason, some nursery managers have obtained better weed control by applying lower rates of oxyfluorfen sooner after emergence is complete. Rates of 0.125 lb ai/ac (0.14 kg ai/ha) or lower have been safely applied to seedlings two weeks after emergence is complete.

One reason weekly applications of oxyfluorfen are more effective than monthly applications is due to better timing of the spray with the stage of weed development. With weekly applications, emerged weeds are small (often less than one week old) and they usually have not developed enough wax on the leaf surfaces to protect against contact herbicides like oxyfluorfen. Troublesome weeds like sicklepod are therefore easier to kill when one week old than when three or four weeks old.

To obtain the best possible weed control from oxyfluorfen, applications should be made prior to weed emergence. Oxyfluorfen does have good contact activity on small weeds, but best control is obtained by forming a chemical barrier that inhibits weed emergence However, when the chemical barrier is broken (due to heavy rains, irrigation, tractor tires, or hand-weeding) certain weeds like prostrate spurge (*Euphorbia supina* Raf.) and flathead sedge (*Cyprus compressus* L.) can emerge through "cracks" in the barrier. This provides another reason why weekly applications of low rates of oxyfluorfen can be more effective than higher rates on a monthly basis. With weekly applications, holes in the chemical barrier are replaced with a new layer on a more frequent basis.

Bifenox (diphenylether family)

Bifenox has both contact and preemergence activity on annual broadleaves. Control of annual grasses is weak, and nutsedge and bermudagrass are not controlled In the past, nursery managers usually used two or three postemergence applications of bifenox at 2 lb ai/ac (2.2 kg ai/ha) per application.

For optimum control, bifenox should be applied prior to weed germination. The flowable formulation of bifenox has some contact activity on small broadleaf weeds, but best control is obtained by inhibiting weed emergence When controlling emerged weeds, use of a surfactant or crop-oil will slightly increase contact activity on small weeds.

The flowable formulation of bifenox is less phytotoxic to young pine seedlings than the emulsifiable concentrate of oxyfluorfen Therefore, the chance of injury to late germinants will be less from an early postemergence application of the flowable formulation of bifenox than from the EC formulation of oxyfluorfen.

Prometryn (triazine family)

This herbicide has both postemergence and preemergence activity on several grasses and broadleaves. Since pines are not extremely tolerant to this herbicide, usually only one postemer-

Table 3. Estimated effectiveness of herbicides on selected troublesome weeds.

Time of application and herbicide	Formulation	Rate (lb ai/ac)	No. of applications	Surfactant type	Surfactant rate (vol./vol.)	Site of uptake	Mode of action	Estimated half-life of parent compound in soil (mo)	Injury on pines	Crabgrass	Bermudagrass	Flathead sedge	Yellow nutsedge	Purple nutsedge	Sicklepod	Smallflower morningglory	
INCORPORATED PRIOR TO SOWING																	
EPTC	7 EC	6.1	1	—[1]	—	root	?[2]	0.25	1[3]	G[4]	F	G	G	G	P–F	P–F	
Trifluralin	4 EC	0.5	1	—	—	root	ICD	1–2	1–3	G–E	P	P	N	N	N	P	
PREEMERGENCE TO SEEDLINGS																	
Bifenox	4 F	3	1	—	—	shoot	DCM	0.25–0.5	1–2	P	N	G	N	N	P	F	
Diphenamid	90 WP	4	1	—	—	root	?	1	1	F	N	N	N	N	N	N	
Napropamide	50 WP	1	1	—	—	root	?	2–3	1–3	E	P	G	P	P	P	P	
Oxyfluorfen	1.6 EC	0.5	1	—	—	shoot	DCM	1–1.5	1–2	G	P	G	N	N	P	F	
Trifluralin	4 EC	1	1	—	—	root	ICD	0.5–1	1–2	F	P	P	N	N	N	P	
POSTEMERGENCE TO SEEDLINGS AND PREEMERGENCE TO WEEDS																	
Bifenox	4 F	0.5	8–14	—	—	shoot	DCM	0.25–0.5	1	P	N	G	N	N	P	F	
Bifenox	4 F	2	2–3	—	—	shoot	DCM	0.25–0.5	1	P	N	G	N	N	P	F	
Diphenamid	90 WP	4	1	—	—	root	?	1	0	F	N	N	N	N	N	N	
Napropamide	50 WP	1	1	—	—	root	?	2–3	1	E	P	G	P	P	P	P	
Oxadiazon	2 G	1	1	—	—	shoot	DCM	?	1	E	P	E	P	P	P	G	
Oxyfluorfen	1.6 EC	0.125	8–14	—	—	shoot	DCM	1–1.5	1	G	P	G	N	N	P	F	
Oxyfluorfen	1.6 EC	0.5	2–3	—	—	shoot	DCM	1–1.5	1	G	P	G	N	N	P	F	
Prometryn	80 WP	1	1	—	—	root & shoot	PI	1–3	2	G	P	G	N	N	F	F	
Trifluralin	4 EC	1	1	—	—	root	ICD	0.5–1	0	F	P	P	N	N	N	P	
POSTEMERGENCE TO SEEDLINGS AND POSTEMERGENCE TO WEEDS																	
Bifenox	4 F	0.5	8–14	COS	0.25%	shoot	DCM	0.25–0.5	1	P	N	P	N	N	P	P	
Bifenox	4 F	2	2–3	COS	1%	shoot	DCM	0.25–0.5	1	P	N	P	N	N	P	P	
Fluazifop-butyl	4 EC	0.25	1–2	NI	0.25%	shoot	?	0.25	0	E	G	N	N	N	N	N	
Glyphosate	4 S	5	1–4	—	—	shoot	IAAS	0.02	4	E	E	E	G	E	E	E	E
Oxyfluorfen	1.6 EC	0.125	8–14	COS	0.25%	shoot	DCM	1–1.5	1	G	P	P	P	P	P	F	
Oxyfluorfen	1.6 EC	0.5	2–3	COS	1%	shoot	DCM	1–1.5	1	G	P	P	P	P	P	F	
Prometryn	80 WP	1	1	NI	0.5%	root & shoot	PI	1–3	2	G	P	G	N	N	F	F	P
Sethoxydim	1.5 EC	0.19	1–2	COS	1%	shoot	?	0.17–0.5	0	E	G	N	N	N	N	N	

[1] COS = Crop oil and nonionic surfactant blend; NI = Nonionic surfactant.
[2] ICD = Inhibits cell division; DCM = Disrupts cell membranes; PI = Photosynthetic inhibitor; IAAS = Inhibits amino acid synthesis.
[3] 0 = no apparent injury; 1 = slight injury; 2 = moderate injury; 3 = severe injury; 4 = Complete crop destruction
[4] E = Excellent Control; G = Good Control; F = Fair Control; P = Poor Control; N = No Control.

gence application of 1 lb ai/ac (1.1 kg ai/ha) should be used on seedlings at least six weeks after emergence is complete. Use of a surfactant can increase the activity of this herbicide. Several nurseries have reported injury with this herbicide, and thousands of pine seedlings have been killed with postemergence applications of prometryn. Injury symptoms are similar to those discussed for a preemergence application of prometryn. Because of a limited number of state registrations and potential injury to seedling production, use of this herbicide is limited in southern nurseries.

Trifluralin (dinitroaniline family)

Trifluralin has preemergence activity on several grasses and small seeded broadleaves, but it has no contact activity. This herbicide is safe for use on established pine seedlings (six weeks after emergence) at the 1 lb ai/ac (1.1 kg ai/ha) rate but should be applied prior to weed germination. Because trifluralin is a volatile compound, application should be made in the cooler part of the day and followed immediately with irrigation to incorporate the herbicide into the soil. Weed control using this method of application is often variable, and poor control can result. Because more effective herbicides are available, trifluralin is not presently used in southern pine nurseries.

Oxadiazon

The granular formulation of this herbicide has preemergence activity on many grasses and broadleaf weeds. The liquid formulation can cause injury to young pines and should not be used in southern nurseries. The granular formulation can provide excellent weed control, but because the cost is approximately five to ten times more than other effective herbicides, this product is not used in southern pine nurseries.

Glyphosate

Glyphosate is a systemic herbicide that will control troublesome perennial weeds such as nutsedge. It has no preemergence activity since it is inactivated with soil contact. Perennial weeds should be actively growing and have at least four to eight leaves when treated so translocation into the plant can occur. Very early treatment of pe-

rennial vegetation may result in less weed control. Better results have been obtained when treating perennials at or near full maturity. Annual weeds are controlled regardless of growth stage.

The primary use of glyphosate in southern nurseries has been with directed spot applications. This use has been effective in keeping perennial weeds such as nutsedge under control. Young southern pines are not tolerant to glyphosate and are normally killed when foliage is contacted by the herbicide. Because of toxicity to pines, glyphosate is not recommended for use as an over-the-top broadcast spray in forest nurseries.

Sethoxydim

Sethoxydim is a systemic herbicide that exhibits postemergence activity on most annual and perennial grasses. It is not active on broadleaf weeds or sedges. Symptoms include a slowing or stopping of growth (generally within two days), reddening of the foliage, and leaf tip burn. Subsequent burnback of the foliage occurs generally within three weeks. No seedling injury was observed with rates up to 0.89 lb ai/ac (1 kg ai/ha) (South and Gjerstad 1982). When used with a 1% solution of oil concentrate (containing 15–20% surfactant), this herbicide will control most small annual grasses at 0.19 lb ai/ac (0.21 kg ai/ha).

At a higher use rate, sethoxydim is effective in controlling perennial grasses such as bermudagrass. Because bermudagrass often grows in patches, spot applications with a 1% solution of sethoxydim may be appropriate. The spray coverage should be uniform and complete but not to the point of runoff. If regrowth occurs, a second application may be required.

Fluazifop-butyl

This systemic herbicide controls most annual and perennial grasses. It does not control sedges or broadleaf weeds. Killing the foliage and rhizomes takes several weeks, even though growth ceases soon after application. Annual grasses can be controlled at 0.25 lb ai/ac (0.28 kg ai/ha), but bermudagrass may require a second application. An oil concentrate or surfactant is usually recommended for use with fluazifop.

CONCLUSION

In the past, nursery managers often relied on fumigation with methyl bromide, applications of mineral spirits, and hand-weeding for weed control. However, use of herbicides registered with data provided by the Auburn University Southern Forest Nursery Management Cooperative has dramatically reduced costs of weed control. Without the use of herbicides, the total annual weed control costs for forest nurseries in the South could increase by more than two million dollars. □

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