DIPHENYLETHER HERBICIDES IN SOUTHERN PINE NURSERIES

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Abstract.-- Over the last decade, more than 16 diphenylether herbicides have been tested for use in forest nurseries in the southern United States. This family of herbicides can be divided into two main groups: (1) p-nitrodiphenylethers and (2) diphenylethers with no p-nitro substitution. The p-nitrodiphenylethers have herbicidal activity on both broadleaf weeds and annual grasses. Diphenylether herbicides that have activity only on grasses usually do not have a p-nitro substitution. Thus far, southern pines (loblolly, slash, longleaf, and shortleaf) have demonstrated good tolerance to postemergence applications of p-nitodiphenylethers and excellent tolerance to diphenylether herbicides having no p-nitro substitution. Both bifenox and oxyfluorfen (both p-nitrodiphenylethers) are commonly used at sowing however, under certain weather conditions, their use has resulted in a weakening of emerging seedlings. Currently, three diphenlyether herbicides are registered for use on southern pines; bifenox, oxyfluorfen, and fluazifop-butyl. Use of these diphenylether herbicides has gained favor with nursery managers in the southern United States.

Additional index words: Weed control, *Pinus taeda* L., *P. elliottii* Engelm. var. *elliottii*, *P. palustris* Mill., and *P. echinata* Mill.

Since 1970, researchers with the Nursery Cooperative at Auburn University have been assessing the suitability of several herbicides for use in southern pine nurseries. Various herbicides from the triazine, dinitroanaline, thiocarbamate, and substituted amide families have been tested and a few have shown promise for use in pine seedbeds. Prometryn (triazine family), trifluralin (dinitroanaline family), EPTC (thiocarbamate family), diphenamid and napropamide (substituted amide family) have all been tested and used operationally on southern pine seedbeds. However, problems have occurred with each of these herbicides. Injury has been observed with prometryn, trifluralin, and napropamide (prometryn can cause injury by inhibiting photosynthesis and trifluralin and napropamide can inhibit root growth). Poor weed control has resulted from use of diphenamid and EPTC (although EPTC can suppress growth of purple nutsedge *Cyperus rotundus* L. and yellow nutsedge *C. esculentus* L.).

However, a number of herbicides from the diphenlyether family (Table 1) have been tested on southern pine seedlings with acceptable results. Most of the major southern pines have demonstrated good tolerance to both preemergence and postemergence applications. As a result, diphenylether herbicides are currently used at most forest nurseries in the southern United States. This report summarizes the results of a decade of testing diphenylether herbicides in southern pine seedbeds.

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GROUPING OF DIPHENYLETHER HERBICIDES

Diphenlyether herbicides can be placed into various groups according to their chemical structure. The herbicidal activity of diphenylethers will depend on where radical substitutions are made on the benzene rings.

p-nitro- substitution

Diphenylether herbicides can be divided into two groups as determined by the substitution at the para (p-) position of the right benzene ring (Table 2). Diphenylethers having a nitro group at this position can be designated as p-nitrodiphenylethers. These herbicides usually have activity on both broadleaf weeds and annual grasses. Rapid disruption of cellular membranes is a mode of action of several p-nitrodiphenylethers (Gorske and Hopen 1978, Orr and Hess 1981).

Plants that are tolerant to p-nitrodiphenylethers might survive because they translocate less herbicide than susceptible species (Leather and Foy 1978, Rogers 1971, Walter *et al*. 1970). Another possible mechanism for selectivity may involve the amount of cuticular wax present at time of application. Pereira *et al*. (1971) worked with two cabbage cultivars which varied in tolerance from very susceptible to highly tolerant. Leaves of the susceptible cultivar had less wax per unit leaf surface and absorbed ^{14}C-nitrofen twice as fast as leaves of the tolerant cultivar. Plants of both cultivars grown in the shade had poor cuticle development and were more susceptible than plants grown in full sunlight. Rubbing the leaves with glass wool to remove the cuticle increased phytotoxicity and decreased selectivity. Leaf absorption of nitrofen was, apparently, restricted by the cuticle.

The thick cuticular wax layer present on pine needles could explain why pine seedlings are generally tolerant of p-nitrodiphenylethers. Only newly formed tissue is injured when young loblolly seedlings are treated with oxyfluorfen (South 1984). Under greenhouse conditions, it took approximately 2 weeks for loblolly pine cotyledons and primary needles to produce enough wax to prevent substantial injury from a postemergence application of oxyfluorfen.

To avoid contact injury caused by postemergence applications of p-nitrodiphenylethers, a formulation other than an emulsifiable concetrate should be used. A granular, wettable powder, or flowable formulation will cause less foliar injury. Although most p-nitrodiphenylethers are marketed as emulsifiable concentrates, bifenox is sold in a flowable formulation. This formulation of bifenox will cause little or no contact injury when applied postemergence to southern pine seedlings.

Most of the non-p-nitrodiphenylethers have activity only on grasses (one exception is chloroxuron which is also considered to be a substituted urea herbicide). In addition, diphenylether herbicides that have activity only on grasses usually have no substitution at the meta position on the right benzene ring and do not exibit rapid membrane disruption. Instead, it may take one to three weeks before symptoms are observed on grass species.

Ortho Substitution

P-nitrodiphenlyether herbicides can also be divided into two groups according to the ortho position of the left benzene ring (Matsunaka 1976). One of these groups requires light for phytotoxic activity while the other is phytotoxic even in the dark. The light-requiring group is characterized by having a substitution at the ortho position of the left benzene ring (Table 2). Herbicides 1-9 belong to the ortho-substituted group. The p-nitrodiphenylether group not requiring light for activity has no substitution at the ortho position of the left benzene ring (no herbicides in this group have been tested on southern pine seedbeds).

Since ortho-substituted p-nirtodiphenylether herbicides require light for activity, the timing of the herbicide application may be important when attempting to control certain weeds. Applications made at dusk or just after sunset may provide better herbicidal activity than daytime applications. If applied during the day, the herbicide will cause local injury to the leaf and will likely not be readily taken up by the plant. If applied in the dark, the ortho-substituted p-nitrodiphenylether herbicide will be nonphytotoxic and it is believed that more of the herbicide will be taken up by the weed. When light activates the herbicide the next day, the increased uptake will result in a better kill. For example, when nitrofen at 4 kg ai/ha was applied in oil at noon, growth of purple nutsedge was reduced by 25%. However, if the same treatment was applied 30 minutes after sunset, growth suppression was increased to 60% (William and Warren 1975).

Under certain conditions, the light activation of certain ortho-substituted p-nitrodiphenylether herbicides may be a disadvantage. Although bifenox and oxyfluorfen have been commonly used in nurseries throughout the South, their use at time of sowing has on occasion caused injury to loblolly pine seedlings (South and Mexal 1982). "White lesions" formed on the hypocotyl and some seedlings were weakened (it is likely that this type of injury may also occur with other p-nitrodiphenylethers). 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 percent.

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 (Gates 1972, Pollak and Crabtree 1976). They found that light intensity during emergence plays a significant role in the action of fluorodifen which causes lesions to form on hypocotyls of soybeans [_Glycine_ _max_ (L.) Merr. var. "Bragg"] and green beans (_Phaseolus_ _vulgaris_ L. 'Tendercrop'). Their studies indicated that low light intensities after a preemergence application of fluorodifen, followed by higher light intensities at the time of crop emergence, or shortly thereafter, increased the probability of crop injury.

p-chloro- and p-trifluoromethyl- substitutions

Diphenylether herbicides can also be placed into groups according to the substitution at the para position on the left benzene ring (Table 2). These diphenylethers can be designated as either p-chloro- or p-trifluoromethyl-. Older diphenylether herbicides tend to be from the p-chloro- group while most of the newer diphenylether herbicides are from the p-trifluoromethyl- group. Herbicides from the p-trifluoromethyl- group are usually about 3 to 9 times more phytotoxic than ones from the p-chloro- group. For this reason, herbicide rates needed for effective weed control are usually lower for herbicides in the p-trifluoromethyl- group.

P-NITRODIPHENYLETHERS

nitrofen

Nitrofen was tested in conifer nurseries as early as 1968 (Magnani 1968), but testing in the southern United States was not begun untill about 1974. At a nursery in Georgia, no injury was observed on slash pine seedlings with once or twice weekly applications (begining 19 July 1974) at 2.2 kg ai/ha per application (personal communication Frank Vande Linde). This herbicide regime was effective in killing grasses and flathead sedge (*Cyperus compressus* L.). Bland and Doggett (1977) compared weekly applications of nitrofen with weekly applications of mineral spirits at a loblolly pine nursery in North Carolina. They found nitrofen to be more effective than mineral spirits and cost approximately 50 percent less. In 1977, ten nurseries throughout the South tested weekly applications of nitrofen at 1.1 and 2.2 kg ai/ha per application (Gjerstad and South 1977). No injury was observed on loblolly, longleaf, or shortleaf pine. However, nitrofen is currently no longer marketed in the United States but is used at pine nurseries in other regions of the world.

bifenox

Bifenox was first tested in southern pine nurseries in 1974 (South *et al*. 1978). Since that time, over 70 experiments involving preemergence and/or postemergence applications of bifenox have been conducted throughout the southern United States. Bifenox is currently registered for use in loblolly, slash, longleaf, and shortleaf pine seedbeds.

When applied at time of sowing, bifenox provides good control of most broadleaf weeds but is not very effective on annual grasses and does not control nutsedge, rhizome bermudagrass [*Cynodon dactylon* (L.) Pers.], or sicklepod (*Cassia obtusifolia* L.). A preemergence application of 3.4 kg ai/ha usually provides 4 to 5 weeks of weed control (South *et al*. 1978). Bifenox does not leach and forms a chemical barrier which should not be broken. This herbicide can provide better weed control if applied before mulching. Since bifenox is weak on grasses, it is best used in combination with a herbicide effective for controlling grasses.

Although this herbicide has been commonly used 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 to the point where they lacked the vigor to lift the testa and cotyledons out of the soil. The occurrence of injury appears to be related to overcast weather during emergence (see discussion above). A few nurseries with very low weed populations have chosen to avoid this risk by not applying this treatment.

Bifenox can also be applied postemergence to the seedlings. 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. In the past, nursery managers usually would apply two or three postemergence applications of bifenox at 2.2 kg ai/ha per application. Nutsedge and bermudagrass are not controlled with postemergence applications.

The flowable formulation of bifenox is usually less phytotoxic to young pine seedlings than the emulsifiable concentrate (EC) 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.

fluorodifen

Fluorodifen was first tested on young pine seedlings at a nursery in Texas (Barr and Merkle 1976). Seedlings 32 days from sowing (ca. 3.8 cm tall) were treated with 3.4 kg ai/ha of fluorodifen. Soon after treatment 0.6 to 1.2 cm of water was applied by sprinkler irrigation. No foliar injury was observed with this treatment. However, a second application applied 57 days after sowing did cause needle burn. The injury was temporary and after two weeks seedlings had recovered to near normal.

This herbicide exibited good activity on broadleaf weeds like pigweed (*Amaranthus spp.*) and exibited some activity on goosegrass [*Eleusine indica* (L.) Gaertn.]. Fluorodifen is currently no longer marketed in the United States.

oxyfluorfen

Oxyfluorfen was first tested in southern pine nurseries in 1976 (South and Gjerstad 1980). Since that time, over 70 experiments involving preemergence and/or postemergence applications of oxyfluorfen have been conducted througout the southern United States. Oxyfluorfen is currently the most commonly used herbicide in southern forest nurseries and the EC formulation is registered for use in loblolly, slash, longleaf, and shortleaf pine seedbeds.

When applied at time of sowing, this herbicide can provide excellent control of many annual grasses and broadleaf weeds but does not kill nutsedge tubers or rhizome bermudagrass. A preemergence application of 0.6 kg ai/ha will usually provide 4 to 7 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 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. The occurrence of injury appears to be related to overcast weather during emergence (see discussion above). A few nurseries with very low weed populations have chosen to avoid this risk by not applying this treatment.

This herbicide also has postemergence activity and will control many small annual weeds. 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 which produces 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 used (at 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 5 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 0.14 kg ai/ha or lower have been safely applied to seedlings 2 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 1 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 1 week old than when 3 or 4 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 which inhibits weed emergence. However, when the chemical barrier is broken (due to heavy rains, irrigation, tractor tires, or handweeding) certain weeds like prostrate spurge (Euphorbia supina Raf.) and flathead sedge 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.

acifluorfen-sodium

This herbicide was tested on southern pine seedbeds at five nurseries in 1977 (South and Gjerstad 1983). A postemergence treatment of 0.3 to 0.6 kg ai/ha did not reduce seedling production of loblolly, slash, or longleaf pine. This herbicide was again tested in 1978 and 1979. At 12 nurseries, no seedling injury was observed on young seedlings treated with 1.1 kg ai/ha. However, injury was noted at one nursery where slash pine seedlings were treated only 30 days after sowing.

Although acifluorfen-sodium provided effective postemergence control of broadleaf weeds, it did not provide residual activity comparable to that of oxyfluorfen. For this reason (and because acifluorfen-sodium was more expensive than oxyfluorfen), this herbicide was dropped from further testing. Unlike most diphenylether herbicides, acifluorfen-sodium is very soluble in water because it is formulated as a salt.

acifluorfen-ethyl

Tests were conducted with this herbicide at five nurseries in 1980 (Gjerstad and South 1981a). A postemergence treatment of 0.125 to 0.25 kg ai/ha did not reduce loblolly pine seedling survival. This herbicide is currently not being marketed.

fomesafen

A preemergence treatment of fomesafen at 0.5 kg ai/ha was tested on southern pine seedbeds at eight nurseries in 1984. Seedling injury was observed on loblolly pine at one nursery. Data from this nursery suggest that fomesafen is more toxic to loblolly pine than oxyfluorfen. Preliminary results for 1985 indicate southern pine seedlings may be tolerant of postemergence applications of 0.25 kg ai/ha. This herbicide has good activity on several broadleaf weeds and has shown some activity on yellow nutsedge.

lactofen

Lactofen is being tested on southern pine seedbeds at nine nurseries in 1985. Preliminary results indicate no seedling injury with a postemergence treatment of 0.2 or 0.4 kg ai/ha. This herbicide has good activity on several broadleaf weeds.

PPG-1013

This herbicide is being tested on southern pine seedbeds at nine nurseries in 1985. Preliminary results indicate no seedling injury with a postemergence treatment of 0.15 kg ai/ha. However, slight tip necrosis has been observed at one nursery at a 0.3 kg ai/ha rate. This herbicide has good activity on several broadleaf weeds.

NON p-NITRODIPHENYLETHERS

diclofop-methyl

This herbicide was tested at seven southern nurseries in 1978 (Gjerstad and South 1978) and at nine nurseries in 1979 (Gjerstad and South 1980). An application of 2.0 kg ai/ha made just after sowing resulted in no observed injury to loblolly, slash, shortleaf, or longleaf pine. Postemergence treatments were also tested at six nurseries in 1979. No injury was observed at either the 2.0 or 4.0 kg ai/ha rate. Seedlings were as young as 1 month from sowing when treated.

This compound exhibits little or no phytotoxic effects on broadleaf weeds. Most annual monocots are controlled with preemergence applications of 2 kg ai/ha or with postemergence applications of 1 to 2 kg ai/ha when the monocots are in the one- to three-leaf stage of growth. This herbicide is currently not used for southern pines because it is not registered for use in nurseries and because it does not effectively control perennial grasses.

clofop-isobutyl

This compound was tested at six southern nurseries in 1976 (Gjerstad and South 1981b). A application of 0.9 or 1.8 kg ai/ha made just after sowing resulted in no observed injury to loblolly, slash, or shortleaf pine. This compound exhibits little or no phytotoxic effects on broadleaf weeds. Most annual monocots are controlled with preemergence applications of 2 kg ai/ha or with postemergence applications of 0.7 to 1.5 kg/ha when the monocots are in the one- to two-leaf stage of growth. This herbicide is currently not marketed.

RO 13-8895

This herbicide was tested on pine seedbeds at four nurseries in 1980 (South and Gjerstad 1982) Young loblolly pine seedlings were not injured when treated with a postemergence application of either 0.5 or 1.0 kg ai/ha. This systemic herbicide controls most annual and perennial grasses. It shows no activity on sedges or broadleaf weeds. This herbicide is currently not being marketed in the United States.

fluazifop-butyl

This herbicide was tested on southern pine seedbeds at 10 nurseries during 1982 and 1983 (South and Boyer 1983, South and Boyer 1984). Young loblolly, slash, and longleaf seedlings were not injured when treated with a postemergence application of either 0.3 or 0.6 kg ai/ha. This herbicide is currently registered for use on pines.

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 0.28 kg ai/ha (4 EC formulation) but bermudagrass may require a second application. When the new formulation (Fusilade 2000) becomes available lower rates will be recommended. An oil concentrate or surfactant is recommended for use with fluazifop.

difenopenten

Difenopenten was tested on pine seedbeds at one nursery in 1980 (South and Gjerstad 1982). Young loblolly pine seedlings were not injured when treated with a postemergence application of either 0.5 or 1.0 kg ai/ha. This systemic herbicide controls most annual and perennial grasses. It shows no activity on sedges or broadleaf weeds. This herbicide is currently not being marketed in the United States.

haloxyfop-methyl

This herbicide was tested on southern pine seedbeds at five nurseries in 1983 (South and Boyer 1984). No seedling injury was observed with postemergence treatments of either 0.3 or 0.6 kg ae/ha. This herbicide has activity only on grasses.

SUBSTITUTED UREA

chloroxuron

The substitution at the meta position on the right benzene ring for this herbicide is a urea compound. Therefore, chloroxuron is regarded as a substituted urea herbicide rather than a diphenylether (Matsunaka 1976). Chloroxuron was first tested on loblolly and slash pine in a greenhouse study in 1965 (Carter and Martin 1967). A preemergence treatment of 2.2 to 4.5 kg ai/ha did not reduce seedling survival. Chloroxuron was again tested in 1976 at a slash pine nursery (Gjerstad and South 1976). No seedling injury was observed on month old seedlings at either 2.2 or 4.5 kg ai/ha. However, weed control was not as effective as other diphenylether herbicides and therefore this herbicide was dropped from further testing.

CONCLUSIONS

Over 100 experiments conducted in southern forest nurseries have demonstrated that southern pine seedlings are generally tolerant of diphenylether herbicides. Southern pines are very tolerant of non-p-nitrodiphenylethers. Certain herbicides in this group can kill both annual and perennial grasses. Proper use of these herbicides has eliminated the need to handweed grasses.

Southern pines have also demonstrated good tolerance to p-nitrodiphenylethers. These herbicides can be used to suppress the growth of various broadleaf weeds. Postemergence applications of p-nitrodiphenylethers may cause slight burning on young pine tissues but this injury is usually cosmetic and seedlings quickly grow out of this condition. Preemergence applications of these herbicides may result in injury if seedling emergence occurs during overcast weather.

Although nitrofen and oxyfluorfen are currently used in pine seedbeds throughout the world, other diphenylether herbicides may be available for testing. Knowing how the chemical structure affects herbicidial activity may be helpful in selecting which diphenylethers to test.

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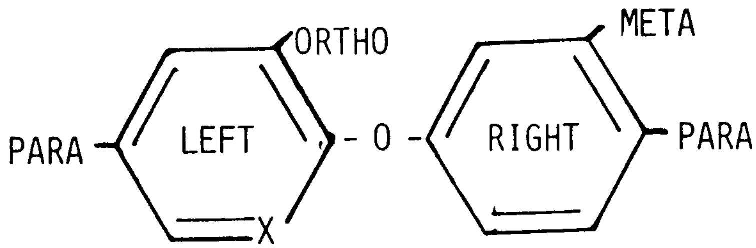
Table 1. Common, trade, and chemical names of diphenylether herbicides tested in southern pine seedbeds.

Common name	Formulation	Trade name	Chemical name
nitrofen	2 EC	TOK	2,4-dichlorophenyl-p-nitrophenyl ether
bifenox	4 F	Modown	methyl 5-(2,4-dichlorophenoxyl)-2-nitrobenzoate
fluorodifen	2.5 EC	Preforan	p-nitophenyl(a,a,a,-trifluoro-2-nitro-p-tolyl)ether
oxyfluorfen	1.6 EC	Goal	2-chloro-1-(3-ethoxy-4-nitrophenoxy)-4-(trifluoromethyl)benzene
acifluorfen-sodium	2 LC	Tackle Blazer	5-[2-chloro-4-(trifluoromethyl)phenoxy]-2-nitrobenzoic acid
acifluorfen-ethyl	2 EC	RH-8817	ethyl-5-[2-chloro-4-trifluoromethylphenoxy]-2 nitrobenzoate
lactofen	2 EC	Cobra	1-(carboethoxy)ethyl 5-[2-chloro-4-(trifluoromethyl)phenoxy]-2-nitrobenxoate
	.25 EC	PPG-1013	5-(2-chloro-4-trifluoromethylphenoxy)-2-nitroacetophenone oxime-O-acetic acid methyl ester
fomesafen	2 LC	Reflex	5-(2-chloro-4-trifluoromethylphenoxy]-N-(methylsulfonyl)-2-nitrobenzamide
diclofop-methyl	3 EC	Hoelon	methyl 2-[4-(2,4-dichlorophenoxy)phenoxy]propanoate
clofop-isobutyl	3 EC	Alopex	4-(4'-chlorophenoxy)-phenoxy-a-propionic-isobutylester
	3 EC	RO-13-8895	acetone-O-[D-2[p-[(a,a,a-trifluoro-p-tolyl)-oxy]phenoxy]propionyl]oxime
diphenopenten	4 EC	KK-80	ethyl 4-[4-[4-(trifluoromethyl)phenoxy]phenoxy]-2-pentenoate
fluazifop-butyl	4 EC	Fusilade	(±)-butyl 2-[4-[(5-(trifluoromethyl)-2-pyridinyl)oxy]phenoxy]-propanoate
haloxyfop-methyl	2 EC	Verdict	2-[4-[[3-chloro-5-(trifluoromethyl)-2-pyridinyl]oxy]phenoxy]propanoic acid
chloroxuron1/	50 WP	Tenoran	3-[p-(p-chlorophenoxy)phenyl]-1,1-dimethylurea

1/ Is often considered as a substituted phenylurea herbicide.

Table 2. Chemical structure of diphenylethers tested in southern forest nurseries.



Herbicide	Substitution at left benzene ring			Substitution at right benzene ring		Herbicidal[1/] activity
	para	ortho	X	para	meta	
1. nitrofen	Cl	Cl	C	NO_2		B + AG
2. bifenox	Cl	Cl	C	NO_2	$C_2H_3O_2$	B + AG
3. fluorodifen	CF_3	NO_2	C	NO_2		B + AG
4. oxyfluorfen	CF_3	Cl	C	NO_2	C_2H_5O	B + AG
5. acifluorfen-sodium	CF_3	Cl	C	NO_2	CO_2Na	B + AG
6. acifluorfen-ethyl	CF_3	Cl	C	NO_2	$C_3O_2H_5$	B + AG
7. fomesafen	CF_3	Cl	C	NO_2	$C_2H_4O_3NS$	B + AG
8. lactofen	CF_3	Cl	C	NO_2	$C_6H_9O_4$	B + AG
9. PPG-1013	CF_3	Cl	C	NO_2	$C_5H_8O_3N$	B + AG
10. diclofop-methyl	Cl	Cl	C	$C_4H_7O_3$		AG
11. clofop-isobutyl	Cl		C	$C_6H_{11}O_3$		AG
12. Ro 13-8895	CF_3		C	$C_6H_{10}O_3N$		AG + PG
13. difenopenten	CF_3		C	$C_7H_{11}O_3$		AG + PG
14. flusifop-butyl	CF_3		N	$C_7H_{13}O_3$		AG + PG
15. haloxyfop-methyl	CF_3	Cl	N	$C_4H_7O_4$		AG + PG
16. chloroxuron	Cl		C	$C_3H_7ON_2$		B + AG

1/ B= broadleaf weeds; AG= annual grasses; PG= perennial grasses.