Weed Control in US
NURSERY WEED CONTROL IN THE USA - PRACTICE AND PROBLEMS

DAVID B. SOUTH
Auburn University Southern Forest Nursery Management Cooperative
School of Forestry and Alabama Agricultural Experiment Station
Auburn University, Alabama 36849-5418, USA

ABSTRACT
In southern pine seedbeds, weed control relies on the use of diphenylether herbicides (oxyfluorfen, lactofen) and selective grass herbicides (sethoxydim and fluzifop-p-butyl). A number of nurseries use a polymer to stabilize the soil after sowing. This helps keep the herbicide barrier intact and extends the preemergence activity. Weekly postemergence applications of low rates are common and have proven more effective on weeds than monthly applications at higher rates. A few nurseries tank-mix liquid nutrients along with postemergence applications of oxyfluorfen. This eliminates the need for extra tractor trips to apply granular fertilisers and, in some areas, reduces the cost of fertilisation. The median handweeding time for southern pine nurseries is now 25 hours/ha/yr.

INTRODUCTION
In 1991, more than 1.6 billion seedlings were produced in tree nurseries in the United States (US) (Mangold *et al.* 1992). Of this number, 69% were produced in 13 southern states. In comparison, approximately 14% were produced in the Pacific Northwest (Washington and Oregon). Pine seedlings produced in the southern states are almost exclusively 1+0 stock while both container and bare-root stock (2+0, 1+1 and 2+1) are used in the Pacific Northwest. Weed management practices discussed in this paper pertain mainly to 1+0 seedlings of *Pinus taeda* L. and *Pinus elliottii* Engelm. Herbicides for hardwood seedbeds are discussed elsewhere (South 1984; South 1992a).

WEED MANAGEMENT PRACTICES
Weed management practices in pine nurseries have evolved dramatically since the turn of the century. Prior to 1947, weed populations were high and the time required to handweed often exceeded 3,000 hr/ha/yr (Figure 1). Now, with the use of effective herbicides, handweeding times at many nurseries are less than 25 hr/ha/yr (South 1992b).

Seed efficiency (number of plantable seedlings produced per viable seed sown) without the use of fumigation and herbicides was often less than 50% (e.g. Sutherland and Adams 1965). Low seed efficiency resulted not only from a loss of young seedlings during the handweeding process, but also because of losses due to fungal diseases, nematodes, white grubs, birds and insects. Rodents would often eat seed while hiding under the protective cover of weeds.

FIG.1-Handweeding times in nurseries as related to introduction of chemical weed control.

Fumigation and Mineral Spirits

Weed management systems in southern pine nurseries changed dramatically after World War II. Handweeding was greatly reduced by the wide-scale adoption of mineral spirits (with xylene as the active ingredient) as a selective herbicide and the use of methyl bromide fumigation. Although both methods were introduced to conifer nurseries about the same time, the less expensive treatment (mineral spirits) quickly gained favour with nursery managers. As a result, seed efficiency at many nurseries improved to about 65%.

By 1975, most nursery managers (73%) in the southern US were fumigating with methyl bromide and applying mineral spirits to control weeds. Average handweeding time for these nurseries was 380 hr/ha. Nurseries operated by state and federal governments tended to fumigate less frequently and averaged 545 weeding hr/ha. Industry nurseries fumigated on a frequent basis and averaged 182 weeding hr/ha. Although these chemicals were very helpful in reducing the level of weed populations, there still was a need for more efficient weed control.

Research by the Auburn University Southern Forest Nursery Management Cooperative determined that pines were tolerant of many diphenylether herbicides (South 1988). These herbicides (Table 1) were usually more effective and less expensive than mineral spirits. Although most diphenylether herbicides are very resistant to leaching, a few are water soluble when formulated as a salt (fomesafen; acifluorfen-sodium). With the use of herbicides and fumigation, seed efficiency can often be greater than 80%.

Diphenylether herbicides

In 1979, oxyfluorfen was registered for both preemergence and postemergence applications. It was initially believed that a preemergence application of 0.5 kg a.i./ha followed by three monthly applications (at the same rate per application) would be sufficient to provide season-long management of weeds (South and Gjerstad 1980). However, one manager noticed control of yellow nutsedge (*Cyperus esculentus* L.), purple nutsedge (*Cyperus rotundus* L.) and flathead sedge (*Cyperus compressus* L.) was less when using oxyfluorfen than when compared to weekly applications of nitrofen. Therefore, tests were conducted to compare weekly postemergence applications with monthly applications (Blake and South 1987). Weekly applications proved more effective on certain weeds than monthly applications (Table 2). The increase in weed suppression is attributable to two factors. First, weekly applications ensure that newly germinated weeds are treated before they have sufficient time to produce a thick epicuticular wax. Several weed species are more susceptible when they are 1 week old than when they are 2 weeks old (Wichert *et al.* 1992). Second, holes in the chemical barrier may result when irrigation, heavy rainfall, or tractor tires disturb the soil surface. Weed seed can germinate and emerge in these holes without having to contact the herbicide. With weekly applications, the chemical barrier is "repaired" and therefore the number of weeds that escape contact with the barrier is decreased. This appears especially important for species like prostrate spurge (*Euphorbia humistrata* Engelm. ex Gray), spotted spurge (*Euphorbia maculata* L.) and flathead sedge. Although the cost of application increases, the annual use of herbicide used does not increase. Therefore, efficiency of herbicide use is increased with light frequent applications. Many nursery managers in the South now use frequent applications of low rates of diphenylether herbicides (South 1992a).

In 1988, lactofen was registered for use on southern pine nurseries (South 1988). This herbicide has more activity on certain broadleaf weeds than oxyfluorfen (Table 2). However, it is less effective on certain grasses and sedges. Since newly emerged southern pines have demonstrated slightly more tolerance to lactofen than to oxyfluorfen, a number of nursery managers use lactofen for the first and second postemergence applications.

TABLE 2 - Effect of monthly and weekly applications of diphenylether herbicides on numbers of *Euphorbia* spp. and *Eclipta alba* per plot (223 m2)*.

		oxyfluorfen		lactofen		fomesafen	
weed	location	monthly	weekly	monthly	weekly	monthly	weekly
Euphorbia	Alabama	481331	05817				
	Arkansas	402036	125420				
	S. Carolina	16 121	054 1				
Eclipta	Alabama	166 0	0 0 0 1				
	Arkansas	3632 0	5 4335				

* Three monthly postemergence applications (560 g a.i./ha/application) compared with twelve weekly applications (140 g a.i./ha/application).

The sodium salt of fomesafen is currently registered in the state of Georgia as a preemergence application on pine seedbeds. Unlike most diphenylether herbicides fomesafen is formulated as a salt and therefore it will leach into the soil. At nurseries with silt loam soils, germinating pines have been injured with a preemergence application of 0.5 kg a.i./ha. This type of injury has not been observed on sandy soils in Georgia where the herbicide apparently is leached away from germinating seeds by frequent irrigation. Foliar injury has been observed on newly emerged pine seedlings when a surfactant or crop-oil was used with a postemergence application.

Grass Herbicides

Prior to the introduction of selective grass herbicides, annual and perennial grasses were very troublesome. However, since sethoxydim and fluzifop-p-butyl are now registered, the need to handweed grasses has been eliminated. Troublesome weeds now include a few broadleaf weeds [sicklepod (*Cassia obtusifolia*), morningglory (*Ipomea* spp.), spurges (*Euphorbia* spp.)] and sedges. The selective nature of grass herbicides allows nursery managers to apply these materials even during germination (injury could result when using a crop-oil adjuvant). One advantage of these herbicides is that they work best after grasses have emerged. This allows the nursery manager to apply the herbicide only when and where needed. Spot applications are often used to avoid wasting herbicide. With the use of sethoxydim, the median weeding time in southern pine nurseries is 25 hr/ha/yr. In 1980 (when sethoxydim was not used) the median weeding time was 62 hr/ha/yr (South 1986).

Soil Stabilisation

Polymeric soil stabilisation in pine seedbeds was first reported in Australia (Haines 1970). Use in the US increased after the Weyerhaeuser Company began using it to increase seed efficiency (Carlson *et al.* 1987). A solution of 1 part glue and 10 parts water (5,200 l/ha) is applied after

sowing. As it dries, it forms a thin protective crust. The crust reduces erosion due to wind, rain, and irrigation. Although the cost can be NZ $1,000/ha, it often increases seed efficiency enough to pay for treatment.

Several nursery managers have reported that preemergence weed control with oxyfluorfen is improved when using a soil stabiliser. This treatment helps keep the herbicide barrier intact and extends the preemergence activity. This can be important since postemergence applications (oxyfluorfen or lactofen) are delayed for about 6 weeks until enough epicuticular wax has developed to protect the epicotyl and young needles from injury. Similar results have been reported at the Owhata Nursery where propazine is used preemergence (Brown 1991).

Surfactants

For postemergence applications, many nursery managers use a crop-oil/surfactant blend (83% oil and 17% surfactant). This increases the phytotoxicity of oxyfluorfen to weeds while slightly increasing injury to pine needles. For this reason, the crop-oil is often not used for the first two postemergence applications. Use of the crop-oil is usually delayed until the pines are 8 to 10 weeks old. At this age, burning of the young needles is usually cosmetic and growth of the seedlings appears unaffected. Some managers are beginning to use the new silicone surfactants. These new compounds greatly reduce the surface tension and have the potential to increase selectivity.

Herbicide/Fertiliser Tank-mix

At a few nurseries, a liquid fertiliser is applied in a tank-mix along with weekly applications of oxyfluorfen. The herbicide/fertiliser solution is applied using the spraying equipment normally used for herbicides. This "weed and feed" program has an advantage since no additional trips are required to apply fertiliser. Liquid applications can be made irrespective of whether seedlings are dry or wet. In some cases, the cost of fertiliser is less in liquid form. The uniformity of fertiliser application appears to be better than with granular fertiliser.

At the Garland Gray Nursery in Virginia, the liquid fertiliser is diluted with water (50:50 ratio), the oxyfluorfen (140 g a.i./ha) is added, and the mixture is sprayed at 470 l/ha. No crop-oil or surfactant is used. The first four weekly applications of fertiliser are applied using 10-1-4 +(2.5% sulphur). This equates to applying 28 kg N/ha/application. The next 6 or 7 applications use a 14-0-8 +(4% sulphur) formulation (39 kg N/ha/application). Irrigation is applied immediately after each application. The nitrogen source is about half urea and half ammonium nitrate (a small amount is from ammonium thiosulphate).

At the Andrews Nursery in Florida, 28 l of the liquid fertiliser [30-0-0 +(2.5% sulphur)] is mixed with 132 l of water, oxyfluorfen (112 g a.i./ha) and micronutrients (2.3 l of Helena's ZFM PLUS). This solution is applied at 163 l/ha and equates to applying 11 kg N/ha/application. If the crop looks slightly chlorotic, the rate is increased to 15 to 19 kg N/ha. An application is made every week from June (when seedlings are 6 weeks old) until late August. A crop-oil/surfactant blend is not used since it burns the seedlings if combined with the tank/mix. An ammonium nitrate/urea source is used since urea is less phytotoxic than ammonium nitrate (Coker 1991).

Foliar fertilisation is not the objective of using this method. The main reasons for using this technique are to: (1) eliminate additional tractor-trips for fertiliser applications; (2) take advantage of a less expensive source of nitrogen; (3) increase uniformity of fertiliser application; (4) provide a more continuous supply of fertilisers; and (5) possibly increase nutrient use efficiency.

PROBLEMS

Weed Control at Forest Service Nurseries

The use of herbicides can become a political issue as evidenced by the US District Court Order that temporarily banned the use of herbicides on National Forest lands in Washington and Oregon. The consequences of ceasing the use of herbicides in a nursery weed management program can be documented by observing the effect on weed management costs at the J. Herbert Stone Nursery (Figure 2). Even with soil fumigation (methyl bromide with 33% chloropicrin) and mechanical cultivation, handweeding costs in one-year-old seedbeds after the ban were up to five times greater than the total weed management costs in 1983 (when herbicides were used). In addition, seed efficiency at the Wind-River Nursery was reduced to the point where 25% more seed was required to produce the same number of plantable seedlings. In contrast, seed efficiency can often be greater than 80% with the use of effective herbicides and methyl bromide fumigation (South 1990). Ceasing the use of herbicides in bare-root nurseries not only increases the cost of seedling production, but when seed is in short supply, it can also reduce the number of seedlings available for reforestation.

FIG.2-Weed control costs for 2+0 seedlings at the J. Herbert Stone Nursery. Cost of methyl bromide fumigation (NZ $5,600/ha) is not included. Herbicides were not used after 1983. Black bar represents costs for 1+0 stock.

The cost of seedling production at US Forest Service nurseries is usually higher than for comparable sized private nurseries or company nurseries (2+0 seedlings can cost NZ $338 per thousand). One reason is that Forest Service managers must operate under a different set of rules. For example, private nursery managers can select from any pesticide approved for use in nurseries by the Environmental Protection Agency (EPA). However, due to governmental regulations, only a few of these pesticides may be used at Forest Service nurseries. A pesticide background statement (USDA Forest Service 1987) must be financed and completed before a Forest Service manager can use an EPA approved pesticide. This limits the number of effective pesticides that may be used in Forest Service nurseries. For example, an old herbicide chlorthal (which can leach into the groundwater) may be used because it has a background statement, but the new herbicide lactofen (which is highly resistant to leaching) may not be used because it does not yet have a background statement. Due to additional red-tape, lack of a profit incentive, and pressure from anti-pesticide groups, several Forest Service managers use a minimal amount of herbicides. They want to show the public that they are serious about not utilizing chemical herbicides in the environment unless they are absolutely required to get the job done. For weed control, they rely mainly on soil fumigation (which costs NZ $6 per thousand seedlings), mechanical cultivation and handweeding. As a result, per hectare weed control costs at Forest Service nurseries are usually among the highest in the US. The handweeding cost per thousand 2+0 seedlings can exceed NZ $13.

Groundwater Concerns

Throughout the world, there is growing concern over nitrate and pesticide contamination of groundwater. In Canada, the Ministry of Environment will soon require that runoff from the nursery be contained on-site. Some container nurseries have installed systems to collect all run-off water for re-use. In the US and in Europe, water-soluble herbicides have leached into the groundwater. As a result, atrazine was banned in Germany. In Denmark, it can be used only once in three years (and then, no more than 750 g a.i./ha). In Finland, atrazine was the only herbicide approved for use in seedbeds in 1990. However, it has now been withdrawn by the chemical company.

Herbicides commonly used in southern pine nurseries include oxyfluorfen, lactofen, glyphosate, and fluazifop-p-butyl. The leaching potential for these herbicides is extremely low (Hornsby 1992). Herbicides that do have a high potential for leaching include atrazine, diphenamid, chlorthal (DCPA), hexazinone, propazine, simazine and fomesafen (sodium salt). Of these, atrazine, chlorthal and simazine have been detected in US groundwater (US EPA 1990). It is ironic that some governments (e.g. Canada, Finland, United Kingdom) have permitted tree nurseries to use atrazine or chlorthal or simazine but not oxyfluorfen (which is highly resistant to leaching). Fortunately, oxyfluorfen is legal for use in nurseries in a number of countries such as the US, South Africa, New Zealand, and Chile. In order to promote good public relations, nursery managers should cease using pesticides that are likely to leach into groundwater and should (where legal) switch to water-insoluble herbicides.

Ozone Concerns

Although methyl bromide does not contaminate groundwater, there is concern that it can act to deplete the ozone layer. Despite a lack of reliable data on either the half-life of methyl bromide in the atmosphere or the relative amounts of man-made vs. natural sources, some organizations would like the artificial production of methyl bromide to cease by the year 2000. If this fumigant is removed from the market, then use of fumigants such as 100% chloropicrin and dazomet may increase. These alternatives are more expensive (when used with a plastic tarp) and are not as effective on nutsedge. When used without a plastic tarp, dazomet is not as effective on pests as methyl bromide. If methyl bromide is banned, some managers may decide to control nutsedge tubers with water-soluble herbicides like fomesafen. There is little doubt that use of more soil-persistent pesticides would increase if methyl bromide is withdrawn from the market.

Nutsedge

Nutsedge occurs at many nurseries and can be difficult to control. When applied under optimum soil conditions (usually in the fall), methyl bromide fumigation can be very effective in reducing high populations. Directed applications of glyphosate (either applied by hand or using a wick) are sometimes used to control nutsedge. Unfortunately, there are only a few herbicides that are both effective and selective in controlling nutsedge. Selective herbicides include fomesafen, sulfometuron, perfluidone and metalochlor (granular formulation). Fomesafen has demonstrated good preemergence and some postemergence activity against yellow nutsedge. It leaches into the soil and directly affects tubers. Depending on soil texture, sulfometuron-methyl can be effective at rates as low as 18 g a.i./ha. A little known benefit of treating with this compound is that the

percentage of ectomycorrhizae can be increased (South 1987). A granular formulation of metalochlor has shown promise in controlling patches of nutsedge but this material can inhibit growth of pine seedlings. Unfortunately, perfluidone is no longer available in the US and although sulfometuron is registered for use in pine plantations, it is not registered for use on pine seedbeds.

Multileadered Seedlings

The application of mineral spirits was common in 1975 but the oil embargo caused a rapid increase in price. As the use of mineral spirits decreased, nursery managers around the world began to observe an increase in multileadered seedlings (Ray and Vanner 1988; South 1991). Some managers thought the increase was due to applying newer herbicides. However, at most nurseries the damage is caused by mirids feeding on young seedlings. In the northern hemisphere, *Lygus* spp. are causing problems while *Taylorilygus pallidulus* (Blanchard) has been found in pine nurseries in both hemispheres (South *et al.* 1993). Although *Lygus* (Wise 1977) and *Eurystylopsis harmandi* Poppius occur in New Zealand, it has not yet been proven that feeding by these mirids will injure *P. radiata*.

REFERENCES

BLAKE,J.I.;SOUTH,D.B. 1987: The efficacy of monthly vs. weekly applications of oxyfluorfen in southern forest tree seedling nurseries. *Proceedings of the 40th Annual Meeting of the Southern Weed Science Society*: 180.

BROWN,W. 1991: The cost of chemical weed control in *Pinus radiata:* a study of three central north island New Zealand Nurseries. Pp.52-55. *in* Menzies,M.I.;Parrot,G.E.;Whitehouse,L.J. (Ed.) "Efficiency of Stand Establishment Operations: Proceedings of an International Conference held at the Forest Research Institute, Rotorua, New Zealand, 11-15 September 1989". *New Zealand Ministry of Forestry, FRI Bulletin No. 156.*

CARLSON,W.C.;ANTHONY,J.G.;PLYER,R.P. 1987: Polymeric nursery bed stabilization to reduce seed losses in forest nurseries. *Southern Journal of Applied Forestry 11(3)*:116-119.

COKER,A. 1991: Foliar urea uptake effect on nitrogen distribution in *Pinus radiata* seedlings. Pp.287-292. *in* Menzies,M.I.;Parrot,G.E.; Whitehouse,L.J. (Ed.) "Efficiency of Stand Establishment Operations: Proceedings of an International Conference held at the Forest Research Institute, Rotorua, New Zealand, 11-15 September 1989". *New Zealand Ministry of Forestry, FRI Bulletin No. 156.*

HAINES,M.W. 1970: Soil consolidation in forest nurseries with Curasol AC. *Australian Forest Research 5(1)*:25-28.

HORNSBY,A.G. 1992: Site-specific pesticide recommendations: the final step in environmental impact prevention. *Weed Technology 6*:736-742.

MANGOLD,R.D.;MOULTON,R.J.;SNELLGROVE,J.D. 1992: Tree planting in the United States 1991. USDA Forest Service. 14 p.

RAY,J.W.;VANNER,A.L. 1988: Reducing the frequency of seedling malformations in *Pinus radiata* nurseries by the application of insecticides. *New Zealand Journal of Forest Science 18*:280-286.

SOUTH,D.B. 1984: Chemical weed control in southern hardood nurseries. *Southern Journal of Applied Forestry 8(1)*:16-22.

SOUTH,D.B. 1986: Herbicides for southern pine seedbeds. *Southern Journal of Applied Forestry 10(3)*:152-157.

SOUTH,D.B. 1987: Sulfometuron-methyl increased ectomycorrhizae at two loblolly pine nurseries in Arkansas. *Proceedings of the 40th Annual Meeting of the Southern Weed Science Society*: 181.

SOUTH,D.B. 1988: Diphenylether herbicides used on southern pine seedlings in the United States. *Aspects of Applied Biology 16*:215-222.

SOUTH,D.B. 1990: Nursery seed efficiency can affect gains from tree improvement. *Proceedings of the Southern Forest Nursery Association:* 46-53.

SOUTH,D.B. 1991: Lygus bugs: a worldwide problem in conifer nurseries. Pp. 215-222. *in* Proceedings of the 1st IUFRO Workshop on Diseases and Insects in Forest Nurseries. Forestry Canada, Information Report BC-X-331.

SOUTH,D.B. 1992a: Prodiamine: a herbicide for pine and hardwood nurseries. *Southern Journal of Applied Forestry 16*:142-146.

SOUTH,D.B. 1992b: Weed control costs using methyl bromide and herbicides for southern pine nurseries. *Proceedings of the 37th Southern Nurserymen's Association Research Conference:* 288-291.

SOUTH,D.B.;GJERSTAD,D.H. 1980: Oxyfluorfen: an effective herbicide for southern pine nurseries. *Southern Journal of Applied Forestry 4(1)*:36-39.

SOUTH,D.B.;ZWOLINSKI,J.B.;BRYAN,H.W. 1993: *Taylorilygus pallidulus* (Blanchard) - a potential pest of pine seedlings. *Tree Planters' Notes (In Press).*

SUTHERLAND,J.R.;ADAMS,R.E. 1965: Stand, growth, and nitrogen content of red pine seedlings following chemical treatment of the soil to control disease. *Tree Planters' Notes 73*:7.

USDA FOREST SERVICE. 1987: Pesticide Background Statement, Volume III. Nursery Pesticides. Agriculture Handbook No. 670.

US ENVIRONMENTAL PROTECTION AGENCY. 1990: National pesticide Survey: Summary results of EPA's national survey of pesticides in drinking water wells. Office of Water/Office of pesticides and toxic substances.

WICHERT,R.A.;BOZA,R.;TALBERT,R.E.;OLIVER,L.R. 1992: Temperature and relative humidity effects on diphenylether herbicides. *Weed Technology* 6:19-24.

WISE,K.A.J. 1977: A synonymic checklist of the Hexapoda of the New Zealand sub-region: the smaller orders. Bulletin of the Auckland Institute and Museum. 176 pp.