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Chemical Weed Control in Southern Hardwood Nurseries

David B. South

ABSTRACT. In the past, hardwood nurserymen often relied on fumigation with methyl bromide for weed control. Today, however, herbicides can provide cost-effective control of grasses and most annual broadleaf weeds in hardwood seedbeds. New herbicides like sethoxidim can be used to control annual and perennial grasses while germination of many broadleaf weeds can be inhibited by oryzalin, oxadiazon, or napropamide. Resistant weeds can be controlled by directed applications of glyphosate. Use of these herbicides reduces the need for fumigation, which often lowers the population of beneficial endomycorrhizal fungi. Fumigation may still be required when controlling high populations of nutsedge or when pathogens are a problem. Although use of chemicals can make control of weeds easier, the nurseryman should not rely entirely on fumigation or herbicides for weed control. If left alone to reproduce, populations of resistant weeds can quickly increase. The nurseryman should therefore adhere strictly to a comprehensive year-round weed control program that prevents introduction, reproduction, and spread of weeds. Even with these efforts, several years may be required to deplete the reservoir of weed seeds in the soil. The nurseryman who is successful will be able to produce more uniform, higher-quality seedlings at a lower cost.

In order to maintain a relatively weed-free nursery, a nurseryman must follow a comprehensive year-round weed control program. A successful program will include various methods of weed control directed toward the disruption of the weeds' reproductive cycle. Good sanitation practices aimed at preventing the introduction and reproduction of weeds are essential to a successful program (Wichman 1982) and are especially important for hardwood nurseries. Other methods of weed control include mechanical cultivation, handweeding, crop competition, crop rotation, biological control, use of fire, and use of chemicals. Several of these methods may be necessary to provide optimum weed control. Although this paper deals primarily with chemical control, a successful program will not rely exclusively on chemicals.

Weed populations in hardwood seedbeds are often higher than in pine (*Pinus* spp.) seedbeds because of higher alkalinity, moisture, and fertilization used for growing hardwood seedlings. It usually requires from 12 to 494 man-hours/ha (5 to 200 man-hours/A) to handweed pine seedbeds that have neither been fumigated nor treated with herbicides. However, handweeding nontreated hardwood seedbeds often requires from 494 to 10,870 man-hours/ha (200 to 4,400 man-hours/A).

Table 1. Chemical identification of selected products used for weed control in forest nurseries.

Common name	Formulation	Trade name	Chemical name
bifenox	4F	Modown	methyl 5-(2,4-diclorophenoxyl)-2-nitrobenzoate
DCPA	75WP	Dacthal	dimethyl tetrachloroterphthalate
dichlobenil	4G	Norosac	2,6-dichlorobenzonitrile
diphenamid	50WP	Enide	*N*,*N*-dimethyl-2,2-diphenylacetamide
EPTC	7EC, 2.3G, 5G	Eptam	*S*-ethyl dipropylthiocarbamate
fluazifop	4EC	Fusilade	butyl 2-[4-[5(trifluoromethyl-2-pyridinyloxy)] phenoxy]propanoate
glyphosate	4S	Roundup	*N*-(phosphonomethyl)glycine
methyl bromide	98%	Brom-O-Gas 2%,	bromomethane
+ chloropicrin	2%	Dowfume MC-2	trichloronitromethane
methyl bromide	67%	Dowfume MC-33	bromomethane
+ chloropicrin	33%		trichloronitromethane
methyl bromide	67%	Terr-O-Gas 67%	bromomethane
+ chloropicrin	31.8%		trichloronitromethane
napropamide	50WP	Devrinol	2-(α-naphthoxy),*N*,*N*-diethylpropionamide
oryzalin	75WP	Surflan	3,5-dinitro-N^4,N^4-dipropylsufanilamide
oxadiazon	2G	Ronstar	2-tert-butyl-4(2,4-dichloro-5-isopropoxyphenyl)-Δ^2-1,3,4-oxadiazolin-5-one
oxyfluorfen	2EC	Goal	2-chloro-1-(3-ethoxy-4-nitrophenoxy)-4-(trifluoromethyl) benzene
sethoxydim	1.53EC	Poast	2-[1-(ethoxyamino)-butyl]-5-[2-(ethylthio)-propyl]-3-hydroxy-2-cyclohexene-1-one
trifluralin	4EC, 5G	Treflan	α,α,α-trifluoro-2,6-dintro-*N*,*N*-dipropyl-*p*-toluidine

SOIL FUMIGATION

Because of a lack of registered herbicides, nurserymen have often used methyl bromide fumigation to control weeds in their hardwood seedbeds. However, for methyl bromide (see Table 1 for chemical names) to provide effective weed control, exacting soil conditions must be met. The soil should be fine and loose with no lumps or clods. Soil temperatures should be above 16C (60F). Soil moisture should be moderate (slightly below field capacity), since moisture content of weed seeds must be high for good control.

It should be remembered that methyl bromide has no residual activity. Weeds will grow vigorously on fumigated soil if the area is contaminated by weed seed in straw mulches, nonfumigated soil, or by wind-carried seed. In addition, methyl bromide will not control certain weeds, such as morning-glory (*Ipomoea* spp.) or sicklepod (*Cassia obtusifolia* L.). In fact, germination of these weeds is often increased after methyl bromide fumigation. Table 2 indicates the relative effectiveness of methyl bromide and selected herbicides on controlling certain troublesome weeds.

Four studies were conducted in hardwood seedbeds from 1977 to 1982 to compare weed control obtained from methyl bromide fumigation with that obtained from herbicides. Herbicides provided better weed control than fumigation in three of the studies (Table 3). In all cases, the best weed control was obtained with a combination of herbicides and fumigation. However, the addi-

Table 2. Estimated effectiveness of variances of weed control treatments on selected troublesome weeds.

Treatment	*Crabgrass*	*Bermudagrass*	*Flathead sedge*	*Yellow nutsedge*	*Purple nutsedge*	*Sicklepod*	*Morning-glory*	*Prostrate spurge*
Fumigation								
methyl bromide	P–G[1]	E	P	E	E	N	N	E
Preplant incorporated								
trifluralin	G–E	P	P	N	N	N	P	N
EPTC	G	F	G	G	G	P–F	P–F	P
Preemergence to seedlings								
DCPA	F	N	N	N	N	N	N	N
diphenamid	F	P	N	N	N	N	N	N
trifluralin	F	P	P	N	N	N	P	N
oryzalin	G–E	P	P	N	P	N	P	N
Postemergence to seedlings and preemergence to weeds								
DCPA	F	N	N	N	N	N	N	N
napropamide	E	P	G	P	P	P	P	F
trifluralin	F	P	P	N	N	N	P	N
oryzalin	G–E	P	P	N	P	N	P	N
oxadiazon	E	P	E	P	P	P	G	?
dichlorobenil	G	F	G	P	P	P	P	?
Postemergence to the weeds								
glyphosate	E	E	E	G	E	E	E	E
sethoxidim	E	G	N	N	N	N	N	N
fluazifop	E	G	N	N	N	N	N	N

[1] *E = Excellent Control*, *G = Good Control*, *F = Fair Control*, *P = Poor Control*, *N = No Control*

Table 3. The effect of herbicides and methyl bromide in hardwood seedbeds on total handweeding times.

Nursery location	Fumigant and rate	Preemergence treatment and rate	First postemergence treatment and rate	Second postemergence treatment and rate	Methyl bromide + herbicides	Herbicides	Methyl bromide	Control
	... kg ai/ha (lb ai/A) ...				... Handweeding time in hr/ha (hr/A) ...			
Atmore, AL	MC-2 504 (450)	Trifluralin 1.1 (1)	Napropamide 1.7 (1.5)	None	230 (93)a[1]	257 (104)a	551 (223)a	494 (200)a
Natchez, MS	MC-2 596 (532)	EPTC 2G 7.8 (7)	None	None	355 (144)a	500 (202)a	1272 (515)a	2408 (975)b
Pinson, TN	MC-2 392 (350)	Trifluralin 1.1 (1)	Napropamide 1.7 (1.5)	None	183 (74)a	618 (250)b	427 (173)ab	1379 (558)c
Capron, VA	MC-2 392 (350)	Trifluralin 1.1 (1)	Oryzalin 1.1 (1)	Oryzalin 1.1 (1)	59 (24)a	141 (57)b	193 (78)c	437 (177)d

[1] *Within any row, any two means followed by the same letter do not differ significantly at the 5-percent level as judged by Duncan's New Multiple Range Test.*

tional cost of fumigation exceeded any additional savings in handweeding (when comparing present contract price for fumigation at $2,420/ha ($980/A) and handweeding cost at $5/hour). When compared with herbicides alone, the additional reduction in handweeding resulting from fumigation at the four nurseries was 27, 57, 145, and 435 man-hours/ha (11, 23, 58, and 176 man-hours/A). The cost of fumigation was uneconomical for controlling annual grasses and broadleaves. However, methyl bromide can be justified when controlling high populations of nutsedge or when pathogens are a problem.

When fumigating to control perennial weeds such as yellow nutsedge (*Cyperus esculentus* L.) and purple nutsedge (*Cyperus rotundus* L.), only methyl bromide with 2-percent chloropicrin should be used. With this formulation, up to 497 kg ai/ha (444 lb. ai/A) of methyl bromide may be legally applied. The methyl bromide formulation with 32-percent chloropicrin should not be used, since only 300 kg ai/ha (268 lb. ai/A) of methyl bromide can be legally applied (along with 143 kg ai/ha (128 lb. ai/A) of chloropicrin). The increased methyl bromide rate allowed with the 2-percent formulation provides more effective nutsedge control.

Effective control of nutsedge can be obtained by fumigating in the fall or spring when proper soil conditions exist. However, there are many more days in the fall when conditions are proper than in the spring. Due to frequent spring rains, some nursery managers have fumigated when soil conditions were too wet while others have had to forgo fumigation altogether. Waiting for proper soil conditions in the spring can delay sowing. For these reasons, fall fumigation is recommended when controlling nutsedge with methyl bromide.

One disadvantage of fumigation (especially with formulations which contain more than 2-percent chloropicrin) is that the population of beneficial endomycorrhizal fungi can be reduced (Bryan and Kormanik 1977, Barham 1978, Riffle 1980). Herbicides, on the other hand, have not been reported to seriously affect endomycorrhizal formation when applied at normal use rates (Altman and Campbell 1977, South et al. 1980, South 1981, Pope and Holt 1981).

MULCH FUMIGATION

Mulches suspected of containing weed seed should be fumigated prior to use in hardwood nurseries. Some mulches are relatively free of weed seed. However, pine straw and wheat straw mulch usually contain many weed seed. These mulches can greatly increase handweeding times (Mullin 1965, Bland 1973, South 1976). The pine straw mulched sycamore (*Platanus occidentalis* L.) and sweetgum (*Liquidambar styraciflua* L.) seedbeds required 484 more man-hours/ha (200 man-hours/A) of handweeding than nonmulched plots (South 1976).

Methyl bromide with 2-percent chloropicrin should be used for fumigation of straw mulches. The straw should be thoroughly soaked with water several days before treatment. After soaking, the bales should be piled and covered with a gasproof cover and the edges sealed in a similar manner, as recommended for soil. The labeled rate for mulch fumigation is 0.7 kg (1.5 lb.) per six bales. Minimum exposure time is 48 hours. Mulch should be aerated for 24 hours before use. A few nurseries in the South routinely fumigate pine straw mulch.

HERBICIDES

In order to control weeds in hardwood seedbeds without injuring seedlings, the herbicide application must be selective. Selectivity can be based on physiological and/or morphological differences between crop and weeds. For example, the basic physiological difference between broadleaves and grasses may comprise the basis of selective herbicide activity. In general, herbicides which are toxic to broadleaf weeds will usually be injurious to hardwoods (*i.e.* bifenox, oxyfluorfen). Herbicides which control mainly grasses will usually be relatively safe on hardwoods (*i.e.* diphenamid, trifluralin, sethoxydim).

Morphological differences between the seed of the crop and weed species can also be utilized in providing herbicide selectivity. Large seeded species such as oak (*Quercus* spp.) and walnut (*Juglans nigra* L.) can tolerate herbicides that would be toxic to small weed species. The same herbicides, however, may be too toxic to use on the smaller seeded sycamore or sweetgum. Because of the extremely small embryo of sycamore, this species is among the most sensitive of hardwoods grown in southern nurseries. Consequently, many herbicides will inhibit the germination of this species.

The best use of selectivity due to morphological differences is after the tree seed have germinated but prior to germination of the remaining weed seed. At this stage, a herbicide that has good preemergence activity and no postemergence activity can be used. This technique has been successfully used to apply herbicides such as trifluralin. The herbicide would be toxic to hardwood seed such as sycamore if applied at time of seeding, but when applied after hardwood germination, the chance of injury is reduced. Even herbicides that are very active on broadleaves can be applied in this manner if there is no contact activity and no translocation from the roots to the leaves. The use of granular formulations of herbicides can greatly reduce the chance of injury by keeping the herbicide off the hardwood foliage.

HERBICIDES APPLIED PREPLANT AND SOIL INCORPORATED PRIOR TO SOWING

When applying volatile preplant herbicides, incorporate the herbicides immediately after application to prevent loss of the herbicide through volatilization.

Trifluralin (dinitroaniline family)

This herbicide has been used to control grasses and small seeded broadleaf weeds at the Coastal Nursery in South Carolina. When 1.1 kg ai/ha (1 lb. ai/A) of trifluralin was incorporated before planting, no injury to sycamore, sweetgum, green ash (*Fraxinus pennsylvanica* Marsh.), or oaks was observed. However, this treatment can inhibit hardwood root development and can severely decrease sycamore germination. Because variations in climate and soils can affect root injury, this treatment should be thoroughly tested at each nursery prior to use. Large seeded hardwood species may prove to be more tolerant than small seeded species.

EPTC (thiocarbamate family)

This herbicide was used at the Columbia Nursery in Louisiana to control nutsedge and bermudagrass [*Cynodon dactylon* (L.) Pers.]. Early season control of several annual grasses and broadleaf weeds was achieved, but control of nutsedge and bermudagrass was limited since growth was only suppressed from four to six weeks. Sycamore, sweetgum, green ash, oak, walnut, black gum (*Nyssa sylvatica* Marsh.), pecan [*Carya illinoensis* (Wangenh.) K. Koch], and cottonwood (*Populus deltoides* Bartr.) were not injured when 7.8 kg ai/ha (7 lb. ai/A) of EPTC were incorporated at least 14 days prior to seeding. Because of a lack of registration, use of this herbicide has been very limited in hardwood seedbeds. EPTC is registered for use before transplanting oak, maple (*Acer* spp.), and dogwood (*Cornus florida* L.) seedlings.

HERBICIDES APPLIED PREEMERGENCE IMMEDIATELY AFTER SOWING

In forest nurseries, it is much easier to control germinating broadleaf seeds with a preemergence herbicide than to control established broadleaf weeds with a contact herbicide. It is important to use a preemergence herbicide since the most critical period for weed control is during the first five to six weeks of seedling establishment. Unfortunately, most preemergence herbicides used on hardwood seedbeds are effective in controlling grasses but usually provide poor control of broadleaf weeds.

DCPA (phthalic acid family)

This herbicide was tested in southern hardwood seedbeds in the late 1960s (Peevy 1968). Control was limited to annual grasses with little or no control of broadleaf weeds at the 11.8 kg ai/ha (10.5 lb. ai/A) rate. It has been shown to be safe on a number of hardwood species (Carter and Martin 1967), but control lasts only a few weeks. Due to being relatively ineffective as well as being expensive, DCPA is no longer used in southern hardwood nurseries.

Diphenamid (acid amide family)

When applied at 4.5 kg ai/ha (4 lb. ai/A), only poor to fair weed control of annual grasses is achieved. Excessive leaching can occur with frequent irrigation which reduces the duration of control to only a few weeks. This herbicide is registered in the United States for use on black walnut seedbeds and on new plantings of several deciduous trees. In England, diphenamid may also be used in seedbeds of maple, oak, and beech (*Fagus sylvatica* L.).

Trifluralin (dinitroaniline family)

A preemergence application of trifluralin has been evaluated at a number of hardwood nurseries (Auburn University 1978). After seeding and mulching, 1.1 kg ai/ha (1 lb. ai/A) was applied and immediately irrigated to reduce loss through volatilization. No injury was observed on sweetgum, green ash, oak, or autumn olive (*Elaeagnus umbellata* Thunb.). However, a reduction in sycamore germination has been observed at several nurseries. Incorporating trifluralin with irrigation provides poorer weed control than mechanical incorporation, but risk of root injury is lessened.

HERBICIDES APPLIED POSTEMERGENCE TO THE SEEDLINGS AND PREEMERGENCE TO THE WEEDS

Most herbicides that have contact activity on broadleaf weeds will also injure young hardwoods. Therefore, most herbicides applied broadcast on young hardwood seedlings usually have preemergence activity on grasses and broadleaved weeds.

DCPA (phthalic acid family)

This herbicide only controls some annual grasses, but weed control from it is limited to only a few weeks. DCPA at 11.8 kg ai/ha (10.5 lb. ai/A) will not control established weeds. Therefore, areas to be treated should be handweeded or cultivated to remove existing weeds. Because of the availability of more effective and less expensive herbicides, DCPA is seldom used in southern nurseries.

Napropamide (substituted amide family)

This herbicide provides good control of many grasses and has been tested as a follow-up application on seedlings that were treated with preemergence application of trifluralin. One month after the trifluralin application, when germination was complete and seedlings were showing their true leaves, the existing weeds were removed by handweeding. Napropamide at 1.7 kg ai/ha (1.5 lb. ai/A) was then applied to the seedbeds and was washed off the foliage with irrigation. Only the wettable powder formulation should be used. Weed control from this herbicide program ranged from 35 to 88 percent (Auburn University 1978). Injury with this treatment has occurred and the stand and height of green ash have been reduced. Higher rates of napropamide have stunted sycamore and sweetgum seedlings (Auburn University 1979). This product is presently registered for use on field-grown maple, ash, walnut, and cottonwood.

Trifluralin (dinitroaniline family)

This herbicide has preemergence activity on several grasses and small-seeded broadleaves, but it has no contact activity. It is safe for use on established hardwoods and has been used successfully at the Coastal Nursery in South Carolina for a number of years. The rate used varied from 0.6 to 1.1 kg ai/ha (0.5 to 1 lb. ai/A). Since trifluralin does not control established weeds, it must be applied prior to weed germination. Because trifluralin is volatile, application should be made in the cooler part of the day with irrigation following immediately to incorporate the herbicide into the soil. Weed control using this method of application is often variable and poor control can result.

Oryzalin (dinitroaniline family)

This herbicide has excellent preemergence activity on several grasses and small-seeded broadleaves, but it has no contact activity. Oryzalin will not control established weeds. Therefore, seedbeds should be handweeded or cultivated to remove existing weeds prior to treatment. In tests conducted in Mississippi and Virginia, sycamore, green ash, and sweetgum have not been injured with application of 0.6 to 1.1 kg ai/ha (0.5 to 1 lb. ai/A). Presently, this herbicide is registered for use on several woody species including sweetgum and oak.

Oxadiazon

The granular formulation of this herbicide has provided excellent preemergence activity on many grasses and broadleaf weeds. This herbicide has been successfully used at the Columbia Nursery in Louisiana and at the Hammermill Nursery in Alabama. At the Hammermill Nursery, excellent weed control was obtained by applying 1.1 kg ai/ha (1 lb. ai/A) per month for a total of three applications. The first application was applied when seedlings were approximately one month old. To avoid foliar burn, application should be made when leaves are absolutely dry. Irrigation should be applied to wash any residue from the leaf surfaces. This herbicide has caused injury to one-month-old sweetgum and sycamore when applied at 2.2 kg ai/ha (2 lb. ai/A) (Auburn University 1979). The label states that established field-grown seedlings of ash, maple, and dogwood may be treated with 2.2 to 4.5 kg ai/ha (2 to 4 lb. ai/A). Although this herbicide can provide excellent weed control, its use in hardwood nurseries has been limited.

Dichlorobenil (benzonitrile family)

The granular formulation of this herbicide has preemergence activity on many grasses and broadleaf weeds. Removal of annual weeds by handweeding or cultivation should be made prior to herbicide application. In tests conducted in Alabama, young seedlings of sycamore, yellow-poplar (*Liriodendron tulipifera* L.), and oak were treated with 4.5, 9.0, and 15.7 kg ai/ha (4, 8, and 14 lb. ai/A). No injury was observed at the low rate, but the higher rates did cause injury to yellow-poplar and oak (Carter and Martin 1967), However, the label prohibits the use of this product on seedbeds or on transplants less than four weeks after planting. Because of the limited production of transplant stock as well as the high cost of this product, this herbicide is not used in southern hardwood nurseries.

HERBICIDES APPLIED POSTEMERGENCE TO THE WEEDS

Glyphosate

Glyphosate is a systemic herbicide that can control troublesome perennial weeds such as nutsedge and bermudagrass. It has little or no preemergence activity since it is adsorbed or decomposes with soil contact. Perennial weeds should have at least four to eight leaves when treated, so sufficient translocation to the root system can occur. Very early treatment of perennial vegetation may reduce the weed control. Better results have been obtained when treating perennials at or near maturity. Annual weeds are controlled regardless of growth stage.

The primary use of glyphosate in southern nurseries has been with directed applications. This use has been effective in keeping perennial weeds such as nutsedge under control. Young hardwoods are not tolerant of glyphosate and are normally killed when foliage is contacted by the herbicide. Shielded applicators such as the "Stonville Wiper" (Chandler and Filer 1980) and "Ashe Spot Applicator" can be used in hardwood seedbeds to prevent contacting the foliage. A 2-percent solution is often used for spot applications of glyphosate.

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 generally occurs within three weeks. This herbicide has been tested on yellow poplar, black walnut, sweetgum, sycamore, green ash, and oak. No injury was observed with rates up to 1 kg ai/ha (0.89 lb. ai/A) (South and Gjerstad 1982). When used with a 1-percent solution of oil concentrate (containing 15–20 percent surfactant), this herbicide will control most small annual grasses at 0.21 kg ai/ha (0.19 lb. ai/A). Although a 1-percent solution of the oil concentrate is usually nonphytotoxic, its use could result in necrosis on young succulent hardwood leaves under certain conditions in the summer. For this reason, it may be safer to use a higher rate of sethoxydim (*i.e.* 0.3 kg ai/ha or 0.27 lb. ai/A) along with a nonionic surfactant. Use of sethoxydim without the oil has reportedly resulted in leaf necrosis on certain varieties. The nurseryman should always treat small areas first to determine if sethoxydim can be used safely prior to use.

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-percent solution of sethoxydim may be appropriate. The spray coverage should be uniform and complete but not to the point of run off. If regrowth occurs, a second application may be required. This product is registered for use on several species, including oak, maple, and dogwood.

Fluazifop

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. This herbicide has been tested on several woody ornamentals with good crop tolerance (Gilliam et al. 1982). Annual grasses can be controlled at 0.28 kg ai/ha (0.25 lb. ai/A) but bermudagrass may require a second application. A nonionic surfactant is recommended for use with fluazifop. As of March 1983, this product has had limited testing in hardwood seedbeds. This product is labeled for use on several hardwood species.

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Distribution of Gum Spots by Causal Agent in Black Cherry and Effects On Log and Tree Quality

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ABSTRACT. Gum spots were studied in 116 black cherry (Prunus serotina Ehrh.) *trees in West Virginia. Bark beetles are the major cause of gum spots in both black cherry poletimber and sawtimber trees. Approximately 90 percent of all gum spots in the bole sections are caused by bark beetles. Cambium miners cause few gum spots in the lower 6 m of the trees and virtually none in the quality zone. Bark beetle-caused gum spots are grade defects in both veneer and factory grade sawlogs. Cambium miner-caused gum spots cause little degrade in veneer logs and none in factory grade 1 and 2 sawlogs.*

Black cherry is the largest of the native cherry trees. It is the only species of its genus that provides lumber for commerce. The wood is used extensively for fine furniture and prefinished paneling. The botonical range of black cherry extends throughout the eastern deciduous forests. However, the area of commercial importance is largely limited to western New York, western Pennsylvania, and north central West Virginia. These three