# Weed Management in Southern Bareroot Hardwood Nurseries

8b

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## Outline



**Facing Page:** *Controlling nutsedge on fallow ground by treating emerged plants with glyphosate. (Photo by David South.)*

## Introduction

The hardwood nursery manager's primary objective is to produce morphologically improved stock as economically as possible. Morphologically improved hardwood seedlings have a minimum root-collar diameter of 10 millimeters (mm); are grown at low seedbed densities; have a higher probability of survival; have a higher root/weight ratio (root dry weight/seedling dry weight), often due to top-pruning; and have a greater root growth potential than smaller stock. Weeds can be a major obstacle to this goal since they compete with seedlings for light, water, and nutrients. In addition, handweeders often pull up seedlings while weeding, reducing revenue from seedling sales. In some cases, weed populations will stunt seedlings and will cause large variations in seedling size at lifting.

To maintain a relatively weed-free nursery, most hardwood nursery managers implement a comprehensive, year-round weed control program. In the past, some seedbeds required more than 3,800 hours of handweeding per hectare (Abrahamson 1987). Today, many managers use an integrated weed management (IWM) program (Walker and Buchanan 1982), which includes sanitation, soil fumigation, and herbicide applications to keep weed populations low and minimize handweeding. As a result, several hardwood nurseries now require less than 60 hours of handweeding per hectare.

## Weed Identification

To achieve good weed control, weed species must be accurately identified, especially when troublesome species are present. For example, some herbicides will suppress yellow nutsedge (*Cyperus esculentus* L.) but have little effect on purple nutsedge (*Cyperus rotundus* L.), even though the two species appear similar. Several online sites are available for identifying common weeds and extension weed specialists should be able to identify rare species. Table 8b.1 lists some of the more common weeds in southern nurseries, with their scientific names.

**Table 8b.1**—*Typical weed species in southern hardwood nurseries.*

| Common name | Scientific name |
|---|---|
| **Grasses** | |
| Bermudagrass | *Cynodon dactylon* (L.) Pers. |
| Crowfootgrass | *Daclyloctenium aegyptium* (L.) Ritcher |
| Hairy crabgrass | *Digitaria sanguianlis* (L.) Scop. |
| Sourgrass | *Digitaria insularis* (L.) Mez ex Ekman |
| Barnyardgrass | *Echinochioa crus-galli* (L.) Beauv. |
| Goosegrass | *Elusine indica* (L.) Gaertn. |
| **Sedges** | |
| Flathead sedge | *Cyperus compressus* L. |
| Yellow nutsedge | *Cyperus esculentus* L. |
| Common nut sedge | *Cyperus compressus* L. |
| **Broadleaves** | |
| Prostrate pigweed | *Amaranthus bitoides* S. Wats. |
| Redroot pigweed | *Ameranthus retrofelus* L. |
| Spiney amaranth | *Amaranthus spinosus* L. |
| Sicklepod | *Cassis obtusifolia* L. |
| Eclipta | *Eclipta alba* (L.) Hassk. |
| Dogfennel | *Euportorium capillifolium* (Lam.) Small |
| Spurge | *Chamaesyce maculata* (L.) Small |
| Tall morningglory | *Ipomoea purpurea* (L.) Roth |
| Carpetweed | *Mollugo verticillata* L. |
| White clover | *Trifolium repens* L. |

## Sanitation

Preventing weeds from going to seed in the nursery is an important sanitation practice, since weed populations in future years greatly depend upon the number of seed produced during the current season. If one yellow nutsedge plant is allowed to mature, it can produce more than 2,400 seeds. A mature purslane plant (*Portulaca oleracea* L.) can produce over 52,000 seeds, and a single redroot pigweed (*Ameranthus retrofelus* L.) can produce 117,000 seeds or more (Stevens 1932). The importance of preventing a single weed from maturing and producing seed in the nursery cannot be overemphasized. A severe infestation of nutsedge can quickly result from failure to control even a single plant. For example, one tuber of purple nutsedge produced 1,168 plants and 2,324 tubers after 6 months (Ishii et al. 1971). Weeds must be prevented from going to seed not only in the seedbeds, but also on the riserlines, fencerows, cover-crop areas, and fallow areas (Wichman 1982).

### Irrigation Water

Irrigation water can be a major source of introduced weeds when the water is from a lake, pond, or river. Screens installed at the intake pipe can help filter out large-seeded weeds. Although the screens may require frequent cleaning, it is easier to remove the weed seeds from the screens than to remove weeds from seedbeds. When irrigating from ponds, it is best to keep the pond edges free of weeds. When installing a new nursery, a deep well is preferred over surface water sources.

## Cover-Crop Seeds

Sowing weed seeds along with cover-crop seeds can be minimized by always using certified seed. At one nursery, the use of cheap, uncertified seed resulted in a large infestation of morning glory (*Ipomoea* spp.). Regulations require certified seed to be free of primary noxious weeds and to contain only small amounts of common weeds. The percentage of common weeds must be shown on the certification tag. It is best to buy seeds with the lowest percentage of common weeds.

## Machinery

Weed seeds, rhizomes, and tubers are easily introduced by machinery. Frequent washings reduce the amount of weeds introduced by soil carried on tillage equipment, tractors, and vehicle tires. Weed seeds are often spread by combines during the harvest of cover crops. For this reason, it is better to leave cover crops unharvested unless combines are carefully cleaned before and after use.

Some weeds spread slowly by vegetative means alone. For example, nutsedge would spread less than 3 meters (m) (10 feet [ft]) per year without help from nursery workers and their cultivation equipment (Klingman and Ashton 1975). For this reason, make a special effort to avoid spreading nutsedge. Map infested seedbeds in the summer to help identify areas in which to avoid soil movement (thus spreading nuts) in the winter after lifting. Lift nutsedge-free areas first to avoid spreading tubers to noninfested fields. Time taken to prevent mechanical dissemination of nutsedge tubers will be repaid several-fold in the ease of eliminating nutsedge from a nursery.

## Wind

Wind will constantly introduce weed seeds, but the impact may be reduced by planting windbreaks between the nursery and adjacent weed sources. Windbreaks will also help to protect the nursery from high winds that blow mulch off beds, blow plastic off fumigated soil, and cause excessive drying of the beds.

## Mulches

In the past, the use of straw mulches after sowing was a major source of introduced weeds (Bland 1973, Mullin 1965, South 1976). For example, pine straw mulch increased time spent on handweeding by 260 to 500 hours per hectare at some nurseries (Bland 1973, South 1976). The expense and introduction of weed seed has reduced use of straw mulches over time. Several managers were using pine straw in 1980 (Boyer and South 1984), but today few use it due to the expense. New bark or sawdust mulches are relatively weed free (Stringfield 2005), but old, stockpiled supplies are often contaminated with weed seed. Several hardwood managers apply weedfree soil stabilizers after sowing. Most of these managers will forgo using mulch, and therefore will apply additional irrigation.

***Figure 8b.1**—When nursery managers adopt an effective integrated weed management program, the amount of handweeding can be kept to a minimum. Handweeding is most effective when weeds are small, before they go to seed. Weeding takes less time when the soil is moist and the weed has a small root system. (Photo by David South.)*

## Organic Amendments

In some cases, using organic amendments will introduce weed seeds. In one nursery, rush (Juncus spp.) was introduced when an organic amendment was donated to the nursery. Yard litter and leaves collected by municipalities can contain many types of weed seeds. The value of these "free" amendments will depend on the increase in cost of subsequent weed control. Composting can help reduce the viability of many weed seeds, but some will likely remain viable.

# Handweeding

Frequent weeding can be an important IWM tool. Handweeding is best conducted when the soil is moist and weeds are small (fig. 8b.1). Weeding small plants has two advantages: the weeds are often removed before they go to seed, and the weeds are easier to remove when the roots are small. In many cases, the total weeding cost is less than if weeding is delayed until the weeds are large and hard to remove.

The use of seasonal labor varies with each nursery. When using contract labor, the cost of 100 hours of handweeding might exceed $4,900 per hectare. Therefore, the use of herbicides depends, in part, on the cost of handweeding. At some nurseries, herbicides are used and minimal handweeding is required, while other managers rely on handweeding and, except for soil fumigants, do not apply herbicides to hardwood seedbeds. With an effective IWM program, hardwood seedbeds may require less than 60 hours of handweeding per hectare (South 2009).

## Mechanical Cultivation

Mechanical cultivation for weed control between seedling rows is feasible when the spacing between rows is 30 cm (12 in) or wider (Barham 1980, Stanley 1970). Several types of seedbed and alleyway cultivators are available (Lowman et al. 1992). For example, a "brush-hoe" can be effective in reducing weeds in hardwood seedbeds (South 1988), although it has some drawbacks. To obtain a specified level of weed control requires a precise adjustment to ensure a proper working depth (Weber 1994). Weeds within the row remain uninjured. Any small error in alignment can damage hardwood seedling roots or shoots. In 2006, only 2 hardwood managers, out of 26, were using mechanical weed control between seedling rows (South 2009).

## Living Mulch

The "living mulch" concept was used by the Virginia Department of Forestry during the 1980s. Rye (*Secale cereale* L.) seed were drilled into the sections immediately before sowing hardwoods in the fall. The "living mulch" protected the fall-sown seedbeds from injury by wind, rain, and frost. This system was also effective for fall-sown hardwoods in Illinois and Indiana (Stauder 1994, Wichman 1994). Nursery managers in Georgia and Tennessee currently sow wheat (*Triticum aestivum* L.), rye, or oats (*Avena sativa* L.) on prepared beds before fall sowing acorns (Ensminger 2002). The living mulch is then sprayed with an herbicide in February, prior to emergence of oak seedlings. This system offers several advantages, including retarding weed growth.

## Fall Sowing

Fall-sown hardwoods, such as red oaks (*Quercus* spp.) and black walnut (*Juglans nigra* L.), typically have fewer weeds the following year than spring-sown crops. This reduction in weeds is due to application of herbicides sooner in the spring and the fact that fall-sown crops typically achieve full canopy closure and shade out weeds sooner than spring-sown crops (fig. 8b.2).

## Soil Fumigation

Effective soil fumigation with methyl bromide is a cornerstone of a successful IWM plan at many nurseries. Several

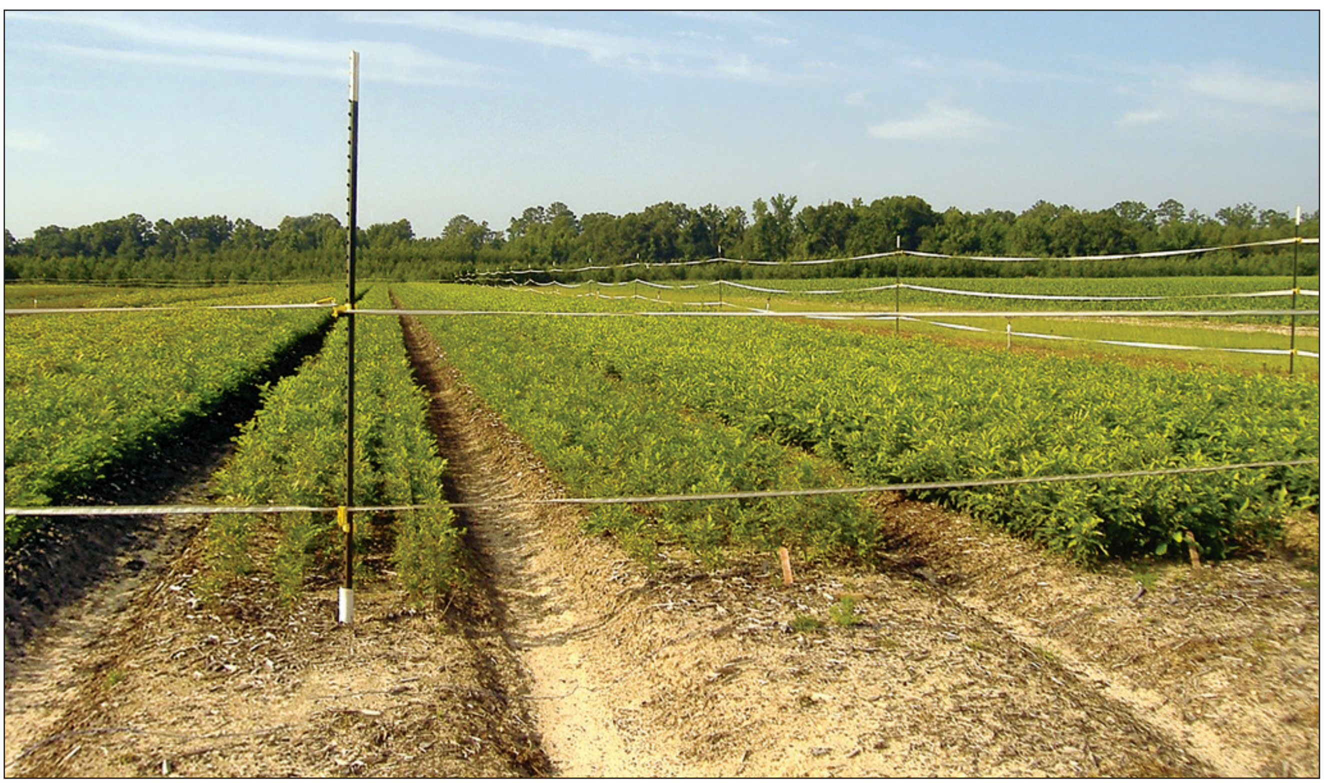

***Figure 8b.2**—Weed control is typically easier when hardwoods are sown in the fall or winter because the canopy closes sooner in the spring and the resulting shade reduces growth of various weed species. (Photo by David South.)*

nursery managers contend that soil fumigation is more important when growing hardwoods because, when compared with conifers, fewer effective, registered herbicides exist (Murray 2009). It is relatively easy to justify soil fumigation because it typically costs less than 6 percent of the wholesale value of the hardwood crop. For this reason, most managers in the South fumigate the soil prior to each hardwood seedling crop. Although dazomet is used in northern hardwood nurseries (Schroeder and Alspach 1995, Storandt 2002), hardwood managers in the South have traditionally relied on a combination of methyl bromide and chloropicrin to reduce weed, nematode, and fungi populations.

In the future, methyl bromide will continue to be produced by oceans, fires, and certain plants and fungi. It is possible, however, that production in the United States will decline due to regulations (Enebak et al. 2013). If this occurs, some managers will likely switch to alternative fumigants, such as chloropicrin and dazomet, that have relatively low efficacy on weeds. Although dazomet can control certain soilborne pests, it is not effective in controlling nutsedge (Carey 1995; Carey and South 1999; Fraedrich and Dwinell 2003). If the use of effective soil fumigants declines, nursery managers will need to increase herbicide use to control weeds in fallow fields or cover crops.

## Herbicide Use

The Weed Science Society of America (WSSA) sorts herbicides into 27 groups according to their chemical structure and activity. About one-third of these groups are used operationally in bareroot hardwood nurseries (table 8b.2). Herbicides in the cyclohexanedione family (WSSA group 1) and dinitroanaline family (WSSA group 3) are commonly used in hardwood seedbeds.

Herbicides can be grouped into selective (not generally harmful to hardwood seedlings) or nonselective (should not contact bark and foliage). Glyphosate is typically a nonselective herbicide (kills both weeds and hardwoods) while sethoxydim is a selective herbicide (kills only grasses) (South and Gjerstad 1982). It is important to know the specific crop/weed system involved. For example, the herbicide clopyralid is a selective herbicide for black walnut but it is nonselective when applied to black locust (*Robinia pseudoacacia* L.).

The terms preemergence or postemergence are used to describe when the herbicide is applied. For example, preemergence herbicides, such as napropamide, kill germinating weeds before they emerge through the soil surface. Some preemergence herbicides can be applied after emergence of the hardwood crop but before the emergence of the weed. Postemergence herbicides, on the other hand, are applied after the weeds emerge. When discussing herbicides, it is important to clarify if the application is to be made after the crop emerges and before the weeds emerge (e.g., pendimethalin, a preemergence herbicide) or after weeds emerge but before the hardwoods emerge (e.g., glyphosate, a postemergence herbicide).

### Herbicide Applications in Cover Crops

The number of mature weeds in this year's cover crop will determine the amount of weed seeds present in next year's seedbeds. Some cover crops grow quickly and shade out the soil, thus reducing germination and growth of weeds. These cover crops are preferred over those that are sown at low densities and allow light to reach the soil. In the South, most herbicides used in cover crops will have no effect on seedling growth the following year. This is especially true when the herbicide is applied before July 1. Check with nursery experts, however, to ensure that carryover from one season to the next will not be a problem. Some herbicide labels include information on the number of months required before sowing sensitive crops.

Cover-crop rotation provides an excellent opportunity to control weeds that are resistant to herbicides used in seedbeds. For example, if only diphenylether herbicides (WSSA group 14) were continually used on an area, resistant weed species such as prostrate spurge (*Euphorbia maculat*e L.) could rapidly increase. However, by using an herbicide from a different herbicide family in the cover-crop area, the spread of troublesome weeds could be checked. Recommendations for using herbicides in cover crops vary, depending on the region and weed species to be controlled. The local extension service can provide specific recommendations on herbicides and use rates. Some genetically modified cover crops have a glyphosate-resistant gene that some managers use as part of an IWM program to reduce nutsedge in cover crops.

### Herbicide Applications on Fallow Land

Weed control with herbicides is much easier on fallow ground (fig. 8b.3) than it is on hardwood seedling beds because: (1) a greater number of herbicides may be applied to fallow ground; (2) injury from drift is less likely; (3) multiple applications can be made; (4) timing of the application is not restricted to stage of hardwood growth; and (5) it is easier to see the weeds. For troublesome weeds like nutsedge, multiple applications of glyphosate on fallow ground is the preferred method to reduce the number of tubers in the soil (Fraedrich et al. 2003). At some nurseries, more glyphosate is used in fallow fields than is used in bareroot seedbeds (Juntunen 2001).

***Table 8b.2**—Common names and trade names of selected herbicides used in southern hardwood nurseries.*

| Common name | Product names | Comment | WSSA group | REI* hours |
|---|---|---|---|---|
| **Soil fumigant** | | | | |
| Chloropicrin | Various | Good nutsedge control | n/a | >120 |
| Dazomet | Basamid | Poor nutsedge control | 27 | >120 |
| Methyl bromide | Various | Excellent nutsedge control | n/a | >120 |
| **After sowing for oaks, walnut, hickory** | | | | |
| Oxyfluorfen | Goal, Galigan, Goaltender | Field-grown | 14 | 24 |
| **Very selective grass herbicides** | | | | |
| Clethodim | Clethodim, Select, Shadow | Grass control only | 1 | 24 |
| Fluazifop | Fusilade | Grass control only | 1 | 12 |
| Fluazifop | Segment, Sethoxydim | Grass control only | 1 | 12 |
| **Herbicides with some selectivity when applied over established hardwoods** | | | | |
| Dcpa | Dacthal | Found in groundwater | 3 | 12 |
| Dithiopyr | Dimension | Established plants only | 3 | 12 |
| Oryzalin | Surflan | May cause galls | 3 | 24 |
| Pendimethalin | Pendulum (Aquacap) | May cause galls | 3 | 24 |
| Prodiamine | Barricade, Resolute | May cause galls | 3 | 12 |
| Trifluralin | Trifluralin HF | Certain labels only | 3 | 12 |
| Clopyralid | Lontrel | Will injure legumes | 4 | 12 |
| Oxyfluorfen | Goaltender | Field-grown | 14 | 24 |
| S-metolachlor | Pennant | Active on sedge | 15 | 24 |
| Napropamide | Devrinol | Some grass control | 15 | 12 |
| **Granular herbicides – can be applied over transplanted stock** | | | | |
| Flumioxazin | Broadstar | Apply to dry leaves<br>Do not apply to bedding plants | 14 | 12 |
| Indaziflam | Marengo | Apply to dry leaves | 29 | 12 |
| Oxadiazon | Ronstar | Apply to dry leaves | 14 | 12 |
| Prodiamine | Barricade, Resolute | May cause galls | 3 | 12 |
| Oxyfluorfen + pendimethalin | OH2 | Apply to dry leaves | 14<br>3 | 24 |
| Dimethanamid + pendimethalin | Freehand | May cause galls | 15<br>3 | 24 |
| **Granular herbicides – cannot be applied to seedbeds due to label restrictions** | | | | |
| Dichlobenil | Casoron | 4 weeks after transplanting | 20 | 12 |
| Pronamide | Pronamide | Not for use on 1-0 stock | 3 | 24 |
| **Nonselective herbicides – applications must be directed away from seedlings** | | | | |
| Glyphosate | Roundup | Use shielded applicator | 9 | 4 |
| Pelargonic acid | Scythe | Use shielded applicator | 27 | 12 |
| Sulfosulfuron | Certainty | Avoid contact with leaves | 2 | 12 |

WSSA = Weed Science Society of America
*REI: Restricted-entry intervals for agricultural uses. Check the AGRICULTURAL USE REQUIREMENTS section of the label for required REI.

*Figure 8b.3—An effective way to control nutsedge on fallow ground is to treat emerged plants with glyphosate. Some managers treat nutsedge two or three times from June to September to reduce the population of tubers in the soil. (Photo by David South, 2012.)*

## Herbicide Applications on Riserlines and Fencerows

It is important to control weeds on riserlines and fencerows, not only to prevent weeds from producing seed, but also to reduce the cover available for small rodents. Some managers apply a tank mix of two or three preemergence herbicides to riserlines at the time of sowing to prevent weeds from maturing and going to seed. Other managers wait for weeds to develop and then apply a postemergence herbicide to kill emerged weeds. This type of application is often done with a shield designed to reduce drift to the hardwood crop (fig. 8b.4). Several types of shields can be used to reduce the potential of drift when applying herbicides to riserlines (Kees 2008). The number of herbicides that may be applied on riserlines is more than the number the U.S. Environmental Protection Agency (EPA) allows to be applied to tree seedlings. To reduce the risk of injury, managers should avoid applying herbicides that are very water soluble (which will move into adjacent seedbeds) or very persistent in the soil.

*Figure 8b.4—Controlling weeds adjacent to seedbeds is an important part of an integrated weed management program. Some managers prefer to apply preemergence herbicides to irrigation lines at time of sowing hardwoods, and others wait to treat emerged weeds with postemergence herbicides that have no soil activity. (Photo by Christine Makuck, USDA Forest Service, 2001.)*

## Herbicide Applications in Seedbeds

**At time of sowing.** Some hardwood nursery managers do not apply herbicides at time of sowing since they typically sow on recently fumigated fields. However, because fumigated soils can easily be contaminated with wind-blown seed, other managers apply herbicides at time of sowing (Jacob 2009, Murray 2009). Several preemergence herbicides can be applied at sowing to large-seeded species like oaks, black walnut, pecan (*Carya illinoinensis* L.), and hickory (*Carya* spp.). In contrast, only a few preemergence herbicides may be applied to small-seeded species like American sycamore (*Platanus occidentalis* L.). Managers who apply herbicides at time of sowing, in general, have less weeding times than those who rely solely on soil fumigants.

Oxyflurofen is labeled for use on field-grown deciduous trees and has been used operationally as a preemergence herbicide (applied just after sowing) on large-seeded hardwoods (Jacob 2009, Murray 2009). It should be applied before seeds germinate because contact with the herbicide can injure newly emerged tissues. Once oxyflurofen is applied to the soil, large-seeded hardwoods can usually penetrate the herbicide barrier without much damage.

**After the first true leaves have formed.** Herbicide selectivity is based on physiological or morphological differences between crop and weed. For example, a physiological difference between broadleaves and grasses is the basis of selectivity for clethodim, sethoxydim, and fluziflop-butyl. As a result, these postemergence herbicides typically do not cause injury to hardwoods after their first true leaves have formed. Preemergence herbicides (like prodiamine and pendimethalin) are active mainly on seed germination. These herbicides can also be applied once hardwood seedlings have germinated and have developed a few true leaves. The herbicide prodiamine is toxic to small hardwood seed such as sycamore if applied at time of seeding, but when applied after the seedlings are 5 centimeters (cm) (2 inches [in]) or taller, the chance of injury is greatly reduced. Although these herbicides will not control emerged weeds, they will help keep subsequent weed seed from germinating (South 1984a). Several nursery managers in the South successfully use this technique.

Some foliar-acting postemergence herbicides (like clopyralid) are selective and will affect the foliage of some weeds without harming certain hardwoods (Lawrie and Clay 1994; South 2000; Jacob 2009). Clopyralid, however, does have activity on legumes and therefore will injure eastern redbud (*Cercis canadensis* L.) and black locust. Injury has also been observed on black alder (*Alnus glutinosa* L.), hackberry (*Celtis occidentalis* L.), and dogwood (*Cornus florida* L.).

## Granular Herbicide Formulations

The WSSA defines granularas "a dry formulation consisting of discrete particles generally less than 10 $mm^3$ (.0006 $in^3$) and designed to be applied without a liquid carrier." Granular herbicides are often used in horticultural nurseries and a number of granular herbicides are labeled for use on hardwoods. However, the cost of using granular herbicides is greater than for liquid formulations. The per-hectare cost to treat with granular herbicides could exceed $300, which may be 8 to 10 times the cost of applying the same active ingredient sold as a liquid formulation.

An advantage of granular herbicides is that when hardwood leaves are dry, the granules drop to the ground and do not affect the foliage (fig. 8b.5). When applied to dry foliage, herbicide granules of oxyfluorfen and oxadiazon may be less phytotoxic to foliage than liquid formulations (which may contain inert ingredients such as naphthalene). In cases where granules are lodged in the foliage, a sufficient amount of irrigation soon after treatment will reduce the chance of phototoxicity. For this reason, a wide variety of species are listed on granular herbicide labels. Granules of flumioxazin, oxyfluorfen, or oxadiazon could cause some temporary necrosis if they are allowed to remain on leaves.

Granular herbicides are not applied at time of sowing, but are applied after the hardwoods have developed true leaves. Although effective weed control can be obtained with granular herbicides (Reeder et al. 1991), most nursery managers choose not to use granular formulations due to the added expense and because application is easier when herbicides are sprayed.

Managers should be aware that "water dispersible granules" (WDGs) do not fit the WSSA definition even though they are called "granules." Therefore, do not treat WDG formulations

***Figure 8b.5***—*Although granular herbicides are typically more expensive, they often are less phytotoxic than liquid formulations. Granular herbicides should be applied to dry foliage, which allows most of the granules to roll off the foliage. Those that remain lodged in the foliage could be shaken off by dragging a cloth or bar over the foliage. (Photo by David South, 2007.)*

as though they were true granular formulations. WDG formulations should be mixed with water and applied as a liquid spray. Carefully follow label directions when applying WDG formulations.

## Directed Herbicide Application Using Shields

One way to provide selectivity is to ensure the herbicide does not come in contact with the hardwood foliage. This can be done with careful directed applications by hand or by using shields when applying herbicides between drill rows (fig. 8b.6). To reduce the potential for injury, direct most foliar-active herbicides away from the crop and toward the weeds.

Some nursery managers apply glyphosate "as needed" to control troublesome perennial weeds between rows using shielded sprayers (South and Carey 2005, Stallard 2005, Windell 2006). Glyphosate is a foliar-applied, nonselective herbicide with no soil activity. Glyphosate is bound tightly to soil particles and is unlikely to move offsite. The relatively slow absorption of glyphosate into foliage causes efficacy to be reduced by rains within a couple of hours of application.

## Herbicide Injury

Although many factors can injure seedlings, herbicides are often the first to be blamed. For example, herbicides have been blamed for injury caused by fertilizer. To reduce chances of a misdiagnosis, nursery managers should leave a few untreated areas in the seedbeds (i.e., check plots). The size of the check plot can be relatively small. These check plots are not only useful for diagnosing herbicide injury (fig. 8b.7), but also provide a useful demonstration of what seedbeds would look like without the use of herbicides.

In some cases, herbicide injury will be minor and ephemeral. In fact, some herbicides might initially cause injury but eventually produce stock that is larger than untreated controls with no injury symptoms (Reeder et al. 1994). Therefore, most hardwood managers are more concerned with treatments that cause an "economic" injury to their crop than one that causes a "cosmetic" injury to leaves, especially when hardwoods drop their leaves before lifting.

Economic injury occurs when an herbicide treatment reduces crop value (e.g., when the number of shippable

**Figure 8b.6**—*This photograph shows an example of a shielded herbicide applicator designed for hardwood seedbeds. The advantage of this model is that it can be operated by one person. (Photo by David South, 2010.)*

**Figure 8b.7**—*Use of untreated check plots can help to properly identify herbicide injury. Seedlings on both seedbeds experienced sandblasting during a May storm. Seedlings on the bed on the left were injured by sand that carried an herbicide, while those on the right were blasted with soil that did not contain an herbicide. In this case, injury was temporary and seedlings were fully recovered by July. (Photo by David South, 2010.)*

seedlings produced per seedbed is reduced). The problem is determining which herbicides reduce seed germination prior to operational use. In some cases, herbicide trials are designed in such a manner that even a 50-percent reduction in crop value would not be classified as "significant" injury (Garrett et al. 1991, South 1992). The low power of these experimental designs is due primarily to the high level of variability in many hardwood seedbeds.

Herbicide injury can result when the label instructions or precautions are not followed. An improperly calibrated herbicide sprayer may result in decreased uniformity and increased risk of injury. Also, consult with nursery experts to learn the latest information on an herbicide. For example, some managers have observed injury to dogwood when a certain herbicide in WSSA group 1 was applied to newly emerged seedlings. These injuries occurred because one brand contained 65-percent solvent naphtha and 7-percent naphthalene (which can injure new foliage when applied under high temperatures). Consultation with an expert might have prevented injury if the product recommended contained low amounts of naphtha and naphthalene.

Hardwoods occasionally have been injured when environmental conditions are right and the herbicide "lifts-off" the soil within water vapor and then drifts over newly emerged hardwood seedlings (South 1984b), a process known as co-distillation. This type of injury may occur soon after seedbeds have been treated with oxyfluorfen on warm, sunny days. The injury is usually just cosmetic—the new leaves turn brown. Fortunately, the affected seedlings typically recover and grow normally.

The use of dinitroaniline herbicides (WSSA group 3) has injured certain hardwood species at a few nurseries (Derr and Salihu 1996, Hood and Klett 1992, South 1992, Warren and Skroch 1991). In some cases, herbicide galls formed on the stem near the groundline (Altland 2005, South 2009). For example, sugarberry (*Celtis laevigata* Willd.) was injured after prodiamine and pendimethalin (fig. 8b.8) were applied. A postemergence application (after both weed and crop emergence) of oryzalin has caused injury and stem breakage on American sycamore, river birch (*Betula nigra* L.), yellow poplar (*Liriodendron tulipifera* L.), redbud, elm (*Ulmus* spp.), buttonbush (*Cephalanthus* spp.), plum (*Prunus* spp.), and black willow (*Salix nigra* L.).

In some cases, herbicide injury occurs when an herbicide applied to fallow ground carries over to the next year. For example, injury occurred when certain herbicides in the imidazolinone family were used the previous year on fallow land. A number of factors determine the length of time that an herbicide remains biologically active in the soil. In the South, most herbicides in WSSA groups 1, 3, and 15 do not persist long enough to affect hardwoods sown the next year. In regions where soils are cooler (e.g., Saskatchewan), however, herbicide carryover is more likely. This difference is primarily because the rate of microbial decomposition is slower in Saskatchewan than in Alabama or Georgia.

***Figure 8b.8***—*Some hardwood species are more tolerant of herbicides than others. For example, sugarberry (*Celtis laevigata *Willd.) can be injured by certain dinitroanaline herbicides. (Photo by Chase Weatherby, ArborGen, 2008.)*

Herbicide injury will sometimes occur after a wind storm. For example, herbicide injury to sawtooth oak (*Quercus acutissima* L.), swamp chestnut oak (*Quercus michauxii* Nutt.), and persimmon (*Diospyros virginiana* L.) was noticed at 2 days after seedlings were sandblasted (Skidmore 1966) with high winds. The herbicide (in this case, oxyfluorfen), was carried with the soil and the abrasions allowed the herbicide to enter the stem and foliage. Although oak seedlings in check plots were also sandblasted (fig. 8b.7), they were not injured because the sand did not contain the herbicide. Use of a soil stabilizer would have reduced the amount of sandblasting and this would subsequently have reduced this type of injury.

In some situations, injury to adjacent seedbeds has occurred when dazomet or metham sodium was applied without a tarp (Buzzo 2003, Scholtes 1989, Starkey 2011). To reduce the potential for injury to adjacent crops, a plastic tarp is recommended when fumigating with these compounds. Some contractors now only use a plastic tarp when fumigating with metham sodium.

Purchase liquid fertilizers in returnable totes only from a reputable dealer. Reputable dealers either do not refill herbicide totes with fertilizer solutions or they ensure the totes are thoroughly cleaned before they are refilled. At one nursery, injury resulted when a fertilizer dealer did not thoroughly clean out a tote that had previously contained triclopyr.

## Economics

Some nursery managers base their weed management decisions on securing economic profits and on maintaining good reputations for producing high-quality nursery stock. Their justifications for using herbicides include keeping seed efficiency high (South 1987) and production costs low. Managers operating as nonprofit entities look to achieve target production goals within a given budget. Both types of operations can benefit by using an effective IWM program to reduce handweeding costs.

The easiest way to justify the use of herbicides is to compare the cost of treatment with the cost of handweeding. For example, at a nursery where hand labor costs $15 per hour, an herbicide application that costs $30 per nursery hectare would be justified if it reduced handweeding by 2 hours or more. Thus, when seedbeds require 100 hours of handweeding ($1,500 total) to remove small grasses, 10 applications of herbicides ($300) could reduce weed-control costs by as much as $1,200 (assuming the use of herbicides eliminated the need for handweeding the grass).

Another method to justify herbicide use is to determine how many seedlings are lost to weed competition and to handweeding. If a nursery loses $0.30 every time a seedling is inadvertently pulled up by a weeder, then saving 100 seedlings could justify an herbicide treatment that cost $30. Therefore, even in rare cases in which use of herbicides does not reduce the annual cost of weed control, their use could still be justified when seedling sales are increased. An examination of a hardwood nursery budget might reveal that herbicide treatments amount to less than 0.5 percent of the retail value of the crop (table 8b.3). Therefore, use of herbicides may be justified when seedling production is increased by just 0.5 percent. This would be equivalent to selling 502,500 seedlings instead of 500,000 seedlings per hectare.

## Conclusions

Because of the numerous species involved, a single herbicide regime (e.g., South 1992) is unlikely to be effective for all hardwood species. Weed species, hardwood species, soil types, and labor costs vary with the nursery; therefore, weed management regimes vary. The most effective IWM programs, however, include a rigorous sanitation program and judicious use of efficacious herbicides.

***Table 8b.3**—Example of weed management costs in hardwood nurseries. Data assumes 444,600 seedlings per hectare and a price of $0.30/seedling.*

| Weed management practice | Active ingredient kg/ha | $ Per thousand seedlings | Percentage of total crop value |
|---|---|---|---|
| Herbicides in seedbeds | 2.24 | $0.50 | 0.2% |
| Herbicides on fallow ground | – | $0.70 | 0.2% |
| Handweeding – $15 per hour | – | $2.08 | 0.7% |
| Soil fumigation | 392 | $17.22 | 5.7% |
| **Total** | | **$20.50** | **6.8%** |

kg/ha = kilograms per hectare.

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