

# A Century of Progress in Weed Control in Hardwood Seedbeds

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South, D.B. 2009. A century of progress in weed control in hardwood seedbeds. In: Dumroese, R.K.; Riley, L.E., tech. coords. 2009. National Proceedings: Forest and Conservation Nursery Associations—2008. Proc. RMRS-P-58. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station: 80–84. Online: [http://www.fs.fed.us/rm/pubs/rmrs\\_p058.html](http://www.fs.fed.us/rm/pubs/rmrs_p058.html).

**Abstract:** Weeds have existed in nurseries since before the time Bartram grew hardwoods during the 18th century. Hand weeding was the primary method of weed control during the first part of the 20th century. From 1931 to 1970, advances in chemistry increased the use of herbicides, and advances in engineering increased the reliance on machines for cultivation. Many managers now rely on chemical treatments, including methyl bromide, chloropicrin, and various selective herbicides. The last 3 decades of the 20th century saw an increase in regulation of chemicals due to health and environmental concerns. If soil fumigation becomes impractical due to governmental regulation, hand-weeding times in hardwood seedbeds will likely increase unless managers adapt to the change. Some managers will increase their use of sanitation practices and herbicides. Although a few herbicides are registered for use on hardwoods, many herbicides that may be used on food crops cannot be legally applied to hardwood seedbeds. In general, grasses can be effectively controlled with properly timed, selective herbicides. The germination of many small-seeded broadleaf weeds can be suppressed with pre-emergence herbicides. Several perennial weeds and various broadleaf weeds, however, are difficult to control with pre-emergence herbicides. For some difficult-to-control weeds, a few nursery managers use shielded herbicide sprayers to apply non-selective herbicides between drills.

**Keywords:** herbicides, fumigation, integrated pest management

## Introduction

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In 1908, Dr. Carl Schenck hosted a 3-day forestry meeting (26-28 November 1908) at Asheville, NC. The Battery Park Hotel was the headquarters for the meeting, and those in attendance included state foresters from New York and Massachusetts, a U.S. senator, and more than 80 other individuals. On 26 November, the tour included several pine and hardwood plantations. That evening, dinner was at the hotel. The next day, the group visited the Biltmore Nursery and greenhouses, the Biltmore Dairy, and an afforestation site on Coxehill. In the evening, there was a possum hunt with a barbecue and much rejoicing (Anonymous 1908). At one point during the meeting, Schenck said that “no tree do I hold more dear than the yellow poplar” (*Liriodendron tulipifera*).

A century later, history is repeated. Greg Pate and the North Carolina Division of Forest Resources hosted a 3-day meeting at the Crown Plaza Resort in Asheville on 22-26 July 2008. On 22 July, those in attendance visited a nursery and greenhouse at Crossnore, with an enjoyable barbecue lunch and a talk by the State Forester of North Carolina. The next day, the attendees visited the Biltmore estate and were given a forest history tour by Bill Alexander, Landscape and Forest Historian. The group visited what was once the old Biltmore Dairy, now America’s most visited winery, and most likely saw some of the same trees that were planted by Schenck and his students. Although there was no opportunity to hunt possums, participants were given a bottle of “possum water” as a gift.

Another common factor between now and 1908 involves managers growing hardwoods and controlling weeds. In fact, weeds have been a problem in hardwood nurseries for more than 200 years. In 1784, John Bartram was growing various species, including oaks (*Quercus* spp.), sweetgum (*Liquidambar styraciflua*), and yellow poplar. Today, nursery managers are fighting some of the same weed species that Bartram had in his nursery. Although hand weeding is still used, the number of tools available to combat weed competition has increased. This paper reviews some of the common practices that have been used to suppress weeds in hardwood seedbeds.

## 1891 to 1930

The Biltmore Nursery (Asheville) was established in 1889. By 1893, it contained more than 1.8 million tree seedlings. The nursery (which contained seedbeds, transplant beds, shadehouses, and greenhouses) was managed by Chauncy Beadle. He helped propagate more varieties of plants than Kew Gardens in London. Oak and white ash (*Fraxinus americana*) seedlings, and cottonwood (*Populus deltoides*) were sold to the public for US\$ 0.20 each, and plants were shipped in either boxes or bales (Alexander 2007). Unfortunately, it was situated adjacent to the Swannona River, and a flood destroyed the nursery and greenhouses in 1916.

Dr. Carl Schenck started the first forestry school in North America. To keep seedling costs low, his students established several “shifting” nurseries. A “shifting” nursery produces a few crops and is then abandoned. Dr. Schenck’s students used knives, forks, hoes, and special weeding wheels to weed seedbeds (fig. 1). Because the “shifting” nurseries were typically established on forest soil, they did not suffer from an excess of weeds that developed at stationary nurseries



**Figure 1.** A photo taken by Dr. Carl Schenck on 1 September 1909. (Photo courtesy of the Forest History Society, Durham, NC.) The two weeders are forestry students at the Biltmore Forestry School. The “stationary” nursery at the Biltmore Estate (managed by Chauncey Beadles) operated until it was destroyed by a flood in 1916. As part of their instruction, students at the Biltmore Forestry School operated several “shifting” nurseries. At least two of these temporary nurseries were already abandoned by 1908, one being an oak nursery. In his lecture on “remedies against fungi in nurseries,” Schenck (1909) mentioned “sterilized soil in nursery beds” and spraying with a fungicide including copper and lime.

like the Biltmore Nursery (Schenck 1907). Therefore, one method of weed control involved abandoning the nursery and shifting to a new, less weedy location. One “shifting” oak nursery established by Schenck was abandoned in 1905 (Anonymous 1908).

Seeds with good germination were sown in drills 12.5 to 25 cm (5 to 10 in) apart, and the rows made weeding easier (Schenck 1907). Mulch (moss, sawdust, straw, twigs, and so on) was placed between drills to keep weeds down. In contrast, when seeds were broadcast, Schenck employed high seedbed densities as a weed-control method. He said, “Weeding can be dispensed with in dense, broadcast seedbeds. In thinly stocked beds planted broadcast, it is most necessary and most difficult.” Seed broadcast was used for seeds of low germination, including birch (*Betula alba*), elm (*Ulmus americana*), beech (*Fagus grandifolia*), alder (*Alnus glutinosa*) and yellow poplar. Of course, weeds should be removed before they produce seeds (Meier 1897).

Horses were used to cultivate transplants, but soon machines were developed to assist in weeding seedbeds. At the Clearfield Nursery in Pennsylvania, a gasoline motor cultivator was developed for use in drill-sown beds (Dague 1925). This was a cheaper method than using hand weeders in broadcast beds. Schenck (1909) listed soil sterilization as a method to control soil fungi in nurseries, and Dague (1925) suggested weeds might be suppressed by steam sterilization of seedbeds.

At this time, some nurseries sold hardwood seedlings for US\$ 0.002 to 0.01 each (Tillotson 1916).

## 1931 to 1970

Before 1930, only a few forest nurseries were in operation, but the number increased after the establishment of the Civilian Conservation Corps in 1933. During that time, cheap labor was plentiful and mechanical weed control was discouraged (Augenstein 1949). However, when the availability of tractors increased and labor costs increased, many managers adopted mechanical weed control (McComb and Steavenson 1936). One nursery developed a gas-powered cultivator specifically for hardwoods that could be moved by either two workers or one tractor (Mony 1954).

During this 4-decade period, managers began to experiment with chemical weed control. In some places, nurseries applied ally alcohol to seedbeds to kill weed seeds before sowing. Mineral spirits were applied to guayule (*Parthenium argentatum*) and, due to its success with this plant, this herbicide was tested on both conifer and hardwood seedlings. Most hardwoods were injured by the treatment, but some managers found that sweetgum seedlings had some tolerance (Vande Linde 1973).

Soil fumigation with methyl bromide showed promising results, and the weed control reductions were great. Kopitke and Langford (1952) remarked, “Cottonwood, commonly acknowledged as a difficult crop to grow because the seedbeds must be kept moist during the germination period with a resultant high population of weeds, has been grown on methyl bromide treated soil with no hand weeding whatever.” Because mineral spirits were not used in most hardwood seedbeds, many managers quickly adopted the use of soil fumigation.

## 1971 to 2010

The next 4 decades saw an increase in chemical regulations. In 1972, Congress passed the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) to regulate the use and labeling of pesticides. As a result, most herbicides that were permitted for use on food were no longer permitted for use in hardwood seedbeds (if the label did not list ornamental, non-cropland, or nurseries). As a result, at some nurseries, managers had to rely on fumigation and hand weeding, because they could no longer legally apply the herbicides they had used on hardwoods in 1970. For example, simazine could be used on oaks in 1970, but not in 1973. It was only recently labeled for use on oak seedbeds using a state label (Wichman 2005). In general, EPA is not sympathetic to the plight of minor-use, non-food crops (Fennimore and Doohan 2008).

In 1983, several environmental groups sued the USDA Forest Service over the use of herbicides in the forest. As a result, a U.S. District Court Order temporarily banned the use of herbicides on National Forest lands in Washington and Oregon. The consequence of ceasing the use of herbicides in a nursery weed management program was documented by observing the effect on weed management costs at the USDA Forest Service J. Herbert Stone Nursery (Central Point, OR). Even with soil fumigation (that is, methyl bromide with 33% chloropicrin) and mechanical cultivation, hand-weeding costs in 1-year seedbeds after the ban were up to 5 times greater than the total weed management costs in 1983 (when herbicides were used). In addition, seed efficiency at the USDA Forest Service Wind River Nursery (Carson, WA) was reduced to the point where 25% more seeds were required to produce the same number of plantable seedlings. The herbicide ban was lifted in 1989, but “only when other methods are ineffective or will increase project costs unreasonably.”

In 1993, the Forest Stewardship Council (FSC) was established to promote responsible forest and plantation management. To earn FSC certification, plantation owners

should not obtain hardwood seedlings from nurseries that use certain herbicides. Nursery chemicals not permitted in FSC certified nurseries include: ally alcohol, methyl bromide, metam sodium, atrazine, diquat dibromide, fluziflop-butyl, hexazinone, isoxaben, MSMA, oryzalin, oxyfluorfen, simazine, pendimethalin, and trifluralin. In addition, managers of FSC plantations “shall make every effort to move away from chemical pesticides and fertilizers, including their use in nurseries.” As someone who supports the use of pesticides and urea in forest nurseries, I assume “every effort” really means “every effort.”

## Current Weed Management Practices

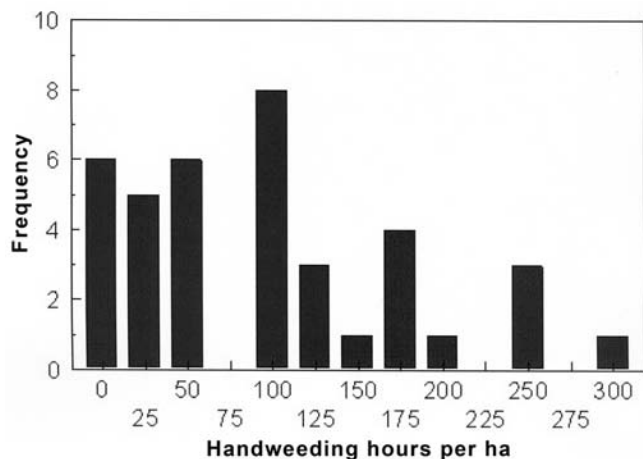
At the request of USDA Forest Service specialists with the Regeneration, Nurseries, and Genetics Resources (RNCR) group, Douglass Jacobs and Amy Ross-Davis (Purdue University, West Lafayette, IN) developed a hardwood nursery questionnaire. In 2006, 91 questionnaires were sent to nurseries in the eastern United States. From a return of 26 surveys, it was learned that 21 nurseries use soil fumigation, 20 nurseries use herbicides, 19 nurseries sow oak seeds in the fall, 25 use hand weeders, and 6 use mechanical cultivation.

One question that was asked: “What are the three (3) most troublesome pests (including weeds) with regard to hardwood seedling production?” Half (13) indicated that weeds were the number one pest. Of the remaining half (13), five said weeds were the second most troublesome pest, and four said weeds were their third most troublesome pest. Four managers did not list weeds among the top three pests (although one of these indicated his nursery required about 250 hours of hand weeding/ ha [100 hours/ac]). Several managers listed specific weeds as troublesome (table 1).

Questions were also asked about the amount of time required to mechanically weed or hand weed seedbeds. Some managers did not keep good records and could not answer this question, or answered “as needed.” Twenty managers included a number. The maximum amount of hand weeding time was 309 hours/ha [125 hours/ac], and one nursery

**Table 1.** Weeds mentioned by hardwood nursery managers in 2006.

Common name	Species	State
Barnyardgrass	<i>Echinochloa crus-galli</i>	Michigan
Hairy crabgrass	<i>Digitaria sanguinalis</i>	Wisconsin
Goosegrass	<i>Eleusine indica</i>	Arkansas
Sourgrass	<i>Digitaria insularis</i>	Alabama
Witchgrass	<i>Panicum capillare</i>	New Hampshire
Yellow nutsedge	<i>Cyperus rotundus</i>	Alabama, Iowa
Carpetweed	<i>Mollugo verticillata</i>	New Hampshire
Creeping charlie	<i>Glechoma hederacea</i>	Iowa
Chickweed	<i>Stellaria media</i>	Michigan
White clover	<i>Trifolium repens</i>	Minnesota, West Virginia
Dayflower	<i>Commelina communis</i>	Iowa
Eclipta	<i>Eclipta alba</i>	Oklahoma
Horseweed	<i>Conyza canadensis</i>	Michigan, Wisconsin
Redroot pigweed	<i>Amaranthus retroflexus</i>	Louisiana, New Hampshire
Common purslane	<i>Portulaca oleracea</i>	New Hampshire, Wisconsin
Spurge	<i>Chamaesyce maculata</i>	Alabama, New Hampshire, Wisconsin



**Figure 2.** Annual hand weeding required in hardwood seedbeds (data from a 2006 survey of hardwood nurseries). One nursery with no hand weeding employed sanitation practices, soil fumigation, and multiple applications of herbicides.

required no hand weeding (fig. 2). On average, hardwood seedbeds required 92 hours of hand weeding/ha (37 hours/ac). One nursery, that did not report any use of herbicides, employed 100 seasonal employees, while 6 nurseries employed less than 11 seasonal employees. There was no relationship between nursery production and number of seasonal employees. In fact, one nursery that produced 2.4 million hardwood seedlings and over 50 million pine seedlings employed only two seasonal workers.

The reliance on seasonal labor varies with nursery and with the cost of labor. In some cases, prison labor is used, and the cost of hand weeding may be relatively low. At some nurseries, the cost of contract labor is US\$ 20/hour, and the cost of 100 hours of hand weeding might exceed US\$ 2000/ha (US\$ 810/ac). Therefore, the use of herbicides depends, in part, on the cost of hand weeding. At some nurseries, herbicides are used and no hand weeding is required, while other managers rely on hand weeding and, except for soil fumigants, do not apply herbicides to hardwood seedbeds. Currently, hardwood nursery managers use a number of herbicides, including DCPA, fluzifop-butyl, glyphosate, isoxaben, napropamide, oryzalin, oxyfluorfen, paraquat, sethoxydim, simazine, pendimethalin, trifluralin. Although several granular herbicides are registered for use on hardwoods (South and Carey 2005), most managers of bareroot nurseries avoid their use due to the additional cost associated with granular herbicides.

When asked “Do you fumigate your soil?” five managers said, “No.” Of the 21 who fumigate, three used dazomet (300 to 350 kg ai/ha [270 to 310 lb ai/ac]) and two used sodium methylthiocarbamate (267 to 307 kg ai/ha [238 to 274 lb ai/ac]). The remaining treated either with methyl bromide+33% chloropicrin (392 kg ai/ha [350 lb ai/ac]) or with methyl bromide + 2% chloropicrin (336 kg ai/ha [300 lb ai/ac]). Dazomet was applied in September and sodium methylthiocarbamate was applied in August. Fumigation with methyl bromide and chloropicrin occurred either in the summer (6), fall (9), or spring (6). One advantage of methyl bromide and chloropicrin is that they can be used relatively close to fields containing seedlings. In some situations,

injury to adjacent crops has occurred when dazomet (or sodium methylthiocarbamate) was applied without a tarp (Scholtes 1989; Buzzo 2003). In addition, dazomet is not as effective as methyl bromide in controlling nutsedge (*Cyperus* spp.) (Carey 1995; Carey and South 1999; Fraedrich and Dwinell 2003).

Because hardwood seedbeds often contain either four or five drills, sometimes mechanical cultivation is used to control weeds once seedlings are tall enough to withstand some mechanical disturbance. Of the 21 managers, 6 indicated they used some “mechanical weeding.” The time required for this practice averaged 15 hours/ha/year (6 hours/ac/year), but one nursery required 37 hours/ha/year (15 hours/ac/year).

Efficient weed management systems for hardwoods involve a combination of methods that may include: sanitation (Wichman 1982, 2005), living mulch (Ensminger 2002; Hawkins 2005), soil fumigation, herbicides (South 1984; Rentz 1999; South and Carey 2005), and mechanical cultivation (Barham 1980; South 1988). Less efficient systems usually rely on just one or two methods of weed management and do not incorporate a “24/7” weed management program.

## Future Practices

No one is certain what the future will hold, but I will “go out on a limb” and predict that weeds will continue to exist in hardwood seedbeds (as long as bareroot nurseries exist). What might not last is the ability to effectively control weeds with chemicals. Perhaps advances in robotic technology will produce robots that will weed seedbeds mechanically (Fennimore and Doohan 2008). This would result in a loss of jobs, but would virtually eliminate problems associated with nursery workers waiting 3 days before reentering herbicide- or insecticide-treated fields.

A harder prediction involves how governmental regulations will affect the cost of hardwood weed control. Will governmental regulators ban the use of chemicals, or will they impose restrictions that make their use impractical? For example, recently imposed regulations by EPA will likely increase costs associated with use of both herbicides and fumigants. Buffer restrictions will reduce the potential fumigated area and will increase the cost of hardwood seedlings. In some cases, regulations and urban sprawl might result in the closing of some bareroot nurseries. Some may decide to convert to 100% container production, while others might be relocated to remote locations. In some cases, these changes will double seedling cost so a hardwood seedling might have a retail cost of US\$ 0.70 or more.

## Acknowledgments

The author wishes to thank Ron Overton (Area Regeneration Specialist with the USDA Forest Service) and George Hernandez (Southern Region Nursery Specialist with the USDA Forest Service) for their assistance with nursery selection, survey development, and follow-up contact with non-respondent nurseries. Douglass Jacobs and Amy Ross-Davis (Associate Professor and Post-Doctoral Research Scientist in the Department of Forestry and Natural Resources, Purdue University) for designing and conducting the survey. Thanks also goes to Edward Loewenstein (Assistant Professor in the

School of Forestry and Wildlife Sciences, Auburn University), Ken McNabb (Professor and Interim Special Assistant to the Provost, Auburn University), and Tom Landis (Consultant and Research Nursery Specialist) for assistance with survey development. Elizabeth Bowersock (Outreach Assistant with the Southern Forest Nursery Management Cooperative) assisted with obtaining nursery contact information and follow-up contact with non-respondent nursery managers. I especially thank the 26 hardwood nursery managers who were willing to take the time to answer the questionnaire.

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