Chapter 18
Weed Management in Forest Nurseries

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Abstract

Weeds often create problems for forest-nursery managers. Left unmanaged, weeds can drastically lower crop quality. Conversely, weed control at any cost can devastate a budget. Proper weed management requires careful development of an integrated program—not mere reaction to problems after they occur. Program components include planning, implementing, documenting, and evaluating results of both prevention and control operations. Factors to consider include crop and weed species, nursery environment, weather, control technology, personnel and equipment, environmental impacts, regulations, and safety of workers and the crop. Principles of program development are discussed: the biology of weeds, as well as physical, biological, and chemical methods of control, are described: and current practices in Northwest forest-tree nurseries are summarized. The need to test prospective techniques is emphasized: (1) small but thorough tests should be conducted before large-scale use of any treatments new to a particular nursery—a myriad of interacting factors make extrapolating results from one nursery to another unwise, and (2) results of tests or operational treatments should be carefully evaluated—subtle but critical damage to crop seedlings may escape notice in cursory examinations.

18.1 Introduction

A weed is any plant growing out of place—especially one that grows faster than crop plants. Weed invasion in nurseries is exacerbated by the common practices of leaving gaps of bare ground and growing single-species crops that do not utilize all of the site resources. Intensive soil management adds to the problem; for example, more intensive irrigation and fertilization almost always require more intensive weed management. Furthermore, most conifer seedlings grow slower than many weed species. Left unmanaged, nursery weeds can virtually destroy entire reforestation programs by greatly reducing crop yield and quality. At the other extreme, some control measures can be biologically effective but economically destructive because of high treatment costs. This chapter emphasizes the need for well-planned weed-management programs in nurseries and provides guidelines for establishing effective, environmentally safe, economical control programs.

18.2 Impact of Weeds on Crops

The primary impact of weeds is reduced crop yield resulting from competition for water, nutrients, light, and space. Weed species vary in their competitive ability, but they characteristically have fast-growing root systems that give them an early advantage in competing for water and nutrients. In addition, use of light and space by weeds can reduce photosynthesis and ultimate crop yield [23]. Weeds can also have an allelopathic effect on crop species—that is, they can harm crops through the production of chemical compounds that escape into the environment.

Other negative impacts of weeds are their potential for harboring insects or disease organisms; for slowing induction of dormancy and cold hardiness by reducing radiation and air movement, subsequently lowering plant moisture stress; and

In Duryea. Mary L., and Thomas D. Landis (eds.). 1984. Forest Nursery Manual: Production of Bareroot Seedlings. Martinus Nijhoff/Dr W. Junk Publishers. The Hague/Boston/Lancaster, for Forest Research Laboratory, Oregon State University. Corvallis. 386 p.

for making lifting and sorting procedures more damaging to seedlings and more expensive. Furthermore, weedy nurseries may have an adverse psychological impact on workers and customers, thus potentially reducing productivity and profits.

A national survey of forest-nursery practices conducted in 1974 [1] showed that weed control constituted a major production cost. Of 99 nurseries surveyed, more than 1/2 reported that the cost of weed control accounted for 10% or more of their costs; 1/3 reported about 25%; and % reported more than 50%.

18.3 Components of Weed-Management Programs

It is more efficient to anticipate problems than to react to them after they occur. Managing nursery weeds is no different. Weed management should be considered in terms of a complete, designed, integrated pest-management program consisting of four main components: education and planning, implementing, documenting, and evaluating.

18.3.1 Education and planning

Planning long before sowing is critical for developing a balanced attack that is efficient both by itself and when coordinated with other nursery operations. Advance planning permits the nursery manager to have supplies, equipment, and personnel on hand when needed; to have administrative details such as contracts, environmental assessments, and herbicide approvals or registrations' completed on time; and to pay adequate attention to safety and coordination.

The need to develop and continually update expertise should be considered in the education and planning phase. Creating and using a library should be part of the effort; many of the sources cited in this chapter—weed science textbooks; handbooks giving technical information on herbicides, pesticide use, and safety [30]; and plant identification guides—would be valuable references. Keeping up with periodical literature is important. *Tree Planters' Notes*, published by the U.S.D.A. Forest Service, and American Nurseryman, published by American Nurseryman Publishing Co., are good sources of weed-management information. Consultants can also provide expertise.

Proper identification of weeds by species and in all their stages of growth is an important part of education. Sources such as Hitchcock and Cronquist [16] and Dennis [13] are useful. Learning scientific names avoids the confusion of varied common names. Developing a nursery herbarium also could be beneficial for aiding later identification and training nursery workers. Once a species is identified, information gained from studying its life history and ecology can form the basis for prescribing prevention or control techniques.

During the education and planning phase, nursery managers should be alert to new technological developments, research information, and experiences of others.

18.3.2 Implementing

A sound weed-management program normally includes some aspect of each of the basic techniques: prevention or sanitation and control by physical, chemical, or biological means. Total dependence on a single method will seldom solve all of a nursery's weed problems.

First consideration should be given to preventing weeds from becoming established. Preventive measures tend to be safer and longer lasting than direct control [21]. Effective practices include preventing weeds from going to seed anywhere on nursery grounds; making sure that weed seeds are not carried into seedbeds by clothing, equipment, irrigation water, mulches, or soil amendments or along with transplants from other nurseries; and preventing spreading perennials from entering seedbeds from nonseedbed areas. Vegetative windbreaks can serve as barriers to windblown seed as long as the species used does not create insect or disease problems and does not shed seeds that are easily disseminated by wind.

Prevention by itself is only a partial answer, however. Some type of direct control is necessary in most situations. Interacting factors to consider are: (1) types and species of weeds and crop seedlings, (2) types of control that are feasible at a particular nursery, (3) operations that can serve multiple purposes, (4) costs, and (5) environmental impacts and other secondary effects of weed-control treatments [2]. Remember that the main objective of weed control is to grow more vigorous tree seedlings—not to kill weeds.

Control methods useful in nursery seedbeds may be classified as physical, biological, or chemical. Physical control includes mechanical cultivation, hand weeding, and mulching; biological control includes crop rotation and reliance on natural enemies; and chemical control includes use of inorganic and organic herbicides. Descriptions of the various control methods and how they relate to each other and to other nursery operations are detailed in later sections.

18.3.3 Documenting

Every weed-management program should include provisions for documenting all its pertinent aspects: recording ideas, decisions and their rationale, procedures, descriptions of conditions, and results. Documentation should be done continuously throughout the year—not from memory at the end of the season. Both biological and economic considerations should be included. Results should be measured, not estimated, and should include determinations of effects of treatments on crops as well as on weeds.

18.3.4 Evaluating

Documentation provides the information needed to evaluate decisions and results. Documentation and evaluation should be ongoing during the course of a program; but a final, end-of-season evaluation of all program aspects also should be conducted. Furthermore, a 3- to 5-year evaluation should be made to account for varying weather patterns and to look for long-term trends in such factors as weed population or increasing phytotoxicity to the crop due to prolonged use of a particular herbicide. Conclusions reached should then be considered in the planning phase for the next version of the program.

18.4 Weed Biology

Much of the material in this section is from Crafts [12], Klingman and Ashton [19], and Muzik [23], all of which are good sources of additional information on weed biology.

18.4.1 Types of weeds

Weeds are commonly classified as annual (winter or summer), biennial, or perennial. Annuals (those living less than 1 year) are generally the easiest but often the most expensive to control because of their abundance and rapid growth. Winter annuals germinate in the fall or early winter and produce seed early the next summer; summer annuals germinate in the spring and seed in the fall. Biennials (those living 1 to 2 years) consist of only a few species and are generally treated the same as annuals. Perennials may live indefinitely, and many reproduce by vegetative means as well as by seed; these are

[1]This chapter discusses pesticides. It does not contain recommendations for their use, nor does it imply that the uses discussed have been registered. All uses of pesticides must be registered by appropriate state and (or) federal agencies before pesticides are approved for application.

the hardest to control. In some cases, the same species may be in different categories in different parts of its range or under different growing conditions. Weed species found in Northwest nurseries are listed in Table 1 (OSU Nursery Survey; see chapter 1, this volume).

18.4.2 Seeds

Weeds are notorious producers of large quantities of seed. Single plants of some species produce thousands of seeds annually-some produce a million or more. A few species, for example, dandelion (*Taraxacum officinale* Weber), may set seed without having been pollinated.

Seeds are disseminated by wind, water, humans and other animals, and machinery and as impurities in straw or crop seed. Seeds of many species have special adaptations for wind dissemination; parachutelike structures, cottonlike coverings, and thin wings are common examples. Light seeds may drift in the air for miles. Most seeds will float, and some remain viable in water for 3 to 5 years; some have air-filled envelopes or corky structures as particular floating adaptations. Other species have hooks or other clinging structures on their seeds that aid their dissemination by humans and other animals. Many seeds remain viable even after passing through animal digestive tracts or being regurgitated by birds.

Seed longevity varies by species—from a few weeks to 1,000 years. Enough seeds remain viable when buried in soil that complete germination and destruction of residual weed seeds in crop fields may take several years of cultivation.

18.4.3 Vegetative reproduction

Most perennial weeds and a few annuals spread vegetatively as well as by seeds. These weeds, which include many grasses and broadleaves, cause some of the most serious competition problems and are often the most difficult to control.

Types of underground reproductive structures include rhizomes (underground stems), tubers, roots, corms, bulbs, and bulblets. Stolons (stems that grow on top of the soil) are another type. Most plants spread relatively slowly—less than 10 feet/year in many cases—if left alone; however, cultivation spreads plant pieces, and some vegetative parts root quickly in moist soil.

Many perennials root very deeply, especially in cultivated fields with deep soils lacking hardpans. Depth from which roots may regenerate is the important factor. For example, quackgrass [*Agropyron repens* (L.) Beauv.] does not regenerate from depths of more than 1 foot, but field bindweed (*Convolvulus arvensis* L.) can do so from a depth of 4 feet.

18.5 Methods of Control

18.5.1 Physical

18.5.1.1 Mechanical cultivation

Drill-sown seedbeds can be cultivated by tractor-drawn equipment when crop seedlings and weeds are small (see chapter 3, this volume). Cultivation should be shallow and careful, to avoid physical damage to the seedlings, which reduces growth and provides avenues for entrance of pathogenic fungi. In addition, splash erosion of cultivated soil can suffocate small seedlings or promote damping-off. The threat of injury to seedlings as they grow larger limits between-row cultivation to an early, partial component of weed-control programs unless spacing between rows is wider than the normal 6 inches in conifer seedbeds.

Table 1. Some common weeds found in Northwest forest nurseries[1] (OSU Nursery Survey).

Family	Species	Common names)	Life cycle
Equisetaceae	*Equisetum* spp.	Horsetails	Perennial
Gramineae	Many (not specified)	Grasses	Summer or winter annual or perennial
Cyperaceae	*Cyperus* spp.	Flatsedges, nutsedges	Perennial
Salicaceae	*Populus trichocarpa*	Black cottonwood	Perennial
	Salix spp.	Willows	Perennial
Polygonaceae	*Polygonum convolvulus*	Wild buckwheat	Summer annual
	P. persicaria	Black bindweed, ladysthumb, smartweed	Summer annual
Amaranthaceae	*Amaranthus* spp.	Pigweeds	Summer or winter annual
Portulacaceae	*Portulaea oleraceae*	Common purslane	Summer annual
Caryophyllaceae	*Spergula arvensis*	Corn spurry	Summer annual or biennial
	Spergularia rubra	Red sandspurry	Annual or perennial (rarely)
	Stellaria media	Common chickweed	Annual, biennial, or perennial
Cruciferae	*Brassica campestris*	Wild mustard	Winter annual or biennial
	Capsella bursa-pastoris	Shepherd's purse	Summer annual or biennial (rarely)
Leguminoseae	*Lupinus* spp.	Lupines	Annual or perennial
	Trifolium spp.	Clovers	Annual or perennial
	Vicia spp.	Vetches	Annual, biennial, or perennial
Geraniaceae	*Erodium cicutarium*	Common storksbill, redstem filaree	Winter annual or biennial
Onagraceae	*Epilobium angustifolium*	Fireweed	Perennial
Hippuridaceae	*Hippuris* spp.	Mare's tails	Perennial
Asclepiadaceae	*Asclepias* spp.	Milkweeds	Perennial
Convolvulaceae	*Cuscuta* spp.	Dodders	Summer annual
Solanaceae	*Solanum* spp.	Nightshades	Summer annual or perennial
Compositae	*Solidago occidentalis*	Western goldenrod	Perennial
	Senecio jacobaea	Tansy ragwort	Biennial or perennial
	S. vulgaris	Common groundsel	Annual or biennial
	Hypochoeris radicata	False dandelion, catsear	Perennial
	Taraxacum officinale	Common dandelion	Perennial
	Sonchus spp.	Sowthistles	Annual, biennial, or perennial

[1]Scientific and common names are from Hitchcock and Cronquist [16].

Approximately 1/2 the large forest-tree nurseries in the Northwest cultivate for weed control in pathways between seedbeds, and only about 1/4 use between-row cultivation, most on a limited basis, of 1+0 seedbeds (OSU Nursery Survey). Cultivation within seedbeds is more common in nurseries growing hardwood seedlings at wider spacings throughout the United States.

18.5.1.2 Hand weeding

Hand weeding has been the mainstay of forest-nursery weed-control programs. Done properly, it can be safe and effective. Its main drawback is the high labor cost. Currently, hand weeding is often used to supplement chemical methods—to remove weeds that were missed or resistant to herbicides or those in seedbeds of crop species that are particularly sensitive to registered chemicals. The technique is most useful for weeds that propagate by seed: those that spread vegetatively usually need repeated weeding because it is difficult to pull all of a plant's roots.

To be most effective, weeds should be removed before they go to seed, spread vegetatively, or become so large or numerous that they interfere with tree growth or damage trees when the weeds are pulled. Soil should be moist enough so that weeds pull readily without breaking underground. Some types of hand cultivators are helpful if weeds are too small or numerous to readily grasp by hand or when pulling by hand causes roots to break underground. Weeds should be carried off nursery beds and thrown away or composted.

All nurseries surveyed report some use of hand weeding (OSU Nursery Survey). Amounts reported vary from 1 to 80 person-hours/acre over an entire season, the variation resulting from differences in weed populations, management philosophies, and other practices. However, all nursery managers would like to reduce the need for hand weeding because of the high costs involved.

18.5.1.3 Mulching

Mulches have a variety of purposes: they protect soil from erosion, crusting, and puddling; reduce splash erosion and frost heaving; help retain soil moisture; minimize soil temperature fluctuations; and suppress weed growth (see chapter 9, this volume). Mulches control weeds by preventing light penetration to underlying weeds and (or) by imposing a thick, dry layer through which germinating weeds cannot grow. Hand weeding has been reduced by as much as 60 to 90% because of mulches [5], though a much smaller effect is more common.

Mulches are generally not used for weed control in Northwest nurseries, and we do not recommend their use for that purpose. They are not cost effective relative to other types of control. If mulches are used for other objectives at a nursery, however, then gains in weed control are a bonus, as long as mulches are free of weed seeds so that they do not add to weed-control problems.

18.5.2 Biological

18.5.2.1 Crop rotation

Periodically leaving ground fallow or using green manure or cover crops to improve soil conditions (see chapter 10, this volume) can be effective ways to reduce the populations of weed seeds. With either technique, residual seeds germinate and can be tilled under before the next crop is sown. Fallow areas can be cultivated as often as necessary to prevent germinated weeds from going to seed and to expose additional residual seeds to germination. Dense cover crops discourage invasion by weeds, but if weed control is a major objective, it is better to combine the fallow technique with irrigation to stimulate germination between tillings. Furthermore, weeds in cover crops may become a serious problem if ignored. A few nurseries in the Northwest gain some weed control using these techniques (OSU Nursery Survey).

18.5.2.2 Natural enemies

insects have generally been the most successful biological agents used in weed control [18]. They are usually host specific and slow acting, however—characteristics not suited to nurseries.

One biological agent—Chinese weeder geese—has shown promise at the U.S.D.A. Forest Service Wind River Nursery [14]. These geese, especially developed for use in rice paddies, are used in mint and cotton fields and in organic gardens in the United States. Dutton [14] reported that the geese at Wind River eat mainly seeds but also young plants of grasses and broadleaves such as sandspurry *(Spergularia* spp.) and dandelion. They seldom injure tree seedlings and can be used, if carefully watched, in 1+0 seedbeds after conifers are about 1 month old. Young geese are best. They are fenced in with 1-foot-high chicken wire in areas of 5 acres or less and are allowed to wander. They must be protected from predators, however, and are easier to replace each year than to keep over winter. Nursery personnel are pleased with the results of their trial and plan to increase the program.

18.5.3 Chemical

Herbicides-chemicals that suppress or kill plants—have been applied in forest-tree nurseries for many years. Materials used from the 1930s into the 1950s included inorganic compounds such as sulfuric acid, zinc sulfate, carbon disulfide, and sodium chlorate, as well as organic chemicals such as allyl alcohol, parachlorophenyl dimethylurea, methyl bromide, chloropicrin, and mineral spirits [33]. Except for the last three, the above have dropped from use as safer, more cost-effective, modern organic herbicides have been developed.

Because of the reliance being placed on herbicides, most of the remainder of this chapter is devoted to herbicide technology (see 18.6). The basics of the technology and use of herbicides in Northwest nurseries are described. In addition, safety to crops and effectiveness of the chemicals in controlling weeds are discussed.

18.6 Herbicides

18.6.1 Registration and use

Like other pesticides, herbicides are controlled by law. From the customer's standpoint, the product label is an important legal document. The label describes registered uses (those uses approved by the U.S. Environmental Protection Agency or a state agency); active ingredients and their concentrations and formulations; instructions for mixing and applying; guidelines for handling and storing the herbicide and for protecting the environment: and information on safety for humans and other animals.

A herbicide must be applied in one of several ways: (1) for the use pattern and site specified on the label, according to the directions and precautions stated; (2) for a proposed use pattern, on registered sites, after prudent interpretation of the label; or (3) under experimental permits issued by a state or the U.S. Environmental Protection Agency. In the last instance, the permit is usually issued to a manufacturer's representative, who gives general experimental guidance. The use of some pesticides, restricted because of the potential hazard to human health or environmental contamination, must be directly supervised by a certified applicator. Bohmont [9] presents a good summary of pesticide regulations.

Registrations of herbicides for forest-tree nurseries have historically been limited because of the small quantities applied and the chemical companies' potential for high liabilities in case of phytotoxicity to crop trees. Recognizing the potential benefits of herbicides, however, the U.S.D.A. Forest Service began programs to obtain experimental results to support federal and state registrations and to demonstrate the safety and effectiveness of promising herbicides to nursery managers. The first program started in 1970 when the Forest Service and Auburn University began the Cooperative Forest Nursery Weed Control Project for the 13-state area of the southeastern United States [15]. Between 1976 and 1980, a Western Nursery Herbicide Project was conducted with cooperators from state, federal, and private nurseries; the Forest Service; and the State University of New York. Syracuse [28]. Twenty-eight nurseries in 12 states were involved. In 1979, the Forest Service started an Eastern Nursery Herbicide Project in five states in cooperation with Purdue University and the State University of New York [17]; in 1981, this project was expanded to eight nurseries in three Great Lakes states.

All of these programs have similar objectives and methodologies, and information from one region often helps support that from others. More than 25 herbicide registrations for forest-tree nurseries have been obtained as a result of these studies [2, 22], and the number grows yearly. Although further improvements are needed, nursery managers now have a reasonable number of herbicides approved for production of conifer seedlings and a few for hardwood seedlings.

18.6.2 Characteristics

The material in this section is primarily from the textbooks of Klingman and Ashton [19] and Ashton and Crafts [8].

18.6.2.1 Action of herbicides on plants

Effects are determined by interactions among the herbicide, environmental conditions, and morphological and physiological characteristics of the plant. First, herbicides have to be absorbed through leaves, roots, stems, or seeds, depending on the characteristics of the particular chemical and how it is applied. Environmental conditions at the time of application affect the rate and amount of absorption. Instructions on the product label describe conditions under which the chemical can be effectively applied.

Some herbicides act on contact: the tissues that absorb the material are killed, but none of the herbicide is translocated to other parts of the plant. This type of chemical is useful for controlling small annual weeds, usually with no residual effect or danger of herbicide being absorbed by nontreated crop plants through the soil.

Noncontact herbicides translocate within the plant in much the same way as other solutes. Translocation is particularly important in controlling plants with underground reproductive structures. To apply an overdose of some herbicides can actually reduce herbicidal effect by damaging sprayed parts so much that disruption of tissues prevents translocation.

The phytotoxicity of most modern organic herbicides is caused by their disruption of plant metabolism. Biochemical reactions that may be affected are photosynthesis, respiration, carbohydrate metabolism, lipid metabolism, protein synthesis, and nucleic acid metabolism. The reaction disrupts plant growth and structure and is expressed as injury or death, depending upon the intensity of effect.

18.6.2.2 Selectivity

Selectivity refers to the differential effect of a particular herbicide on different crops. For example, a very selective chemical will retard or kill only a small group of plants at a particular stage of growth. A nonselective chemical is phytotoxic to all species. The product label of a given herbicide lists the plant species affected.

Selectivity involves interactions among the herbicide, plant, and environment. Herbicide factors include chemical structure, concentration and formulation used, and method of application (for example, broadcast vs. directed sprays). Plant factors include age, growth rate, morphology, physiology, and genetics of both weed and crop species. Main environmental factors are soil texture, amount of organic matter, rainfall or irrigation, and temperature. For example, water is necessary to activate soil-applied herbicides; high humidity usually makes foliage-applied herbicides more effective; high organic matter reduces effectiveness of most soil-applied chemicals; and some materials work better when air and soil temperatures are cool [34], whereas others kill weeds only at high temperatures.

One type of selectivity involves the interaction between leaching characteristics of a herbicide and rooting depth of a plant. For example, a deep-rooted plant is not affected by a chemical that stays near the soil surface, whereas shallow-rooted plants are killed.

18.6.2.3 Persistence in the soil

Herbicides vary in the length of time they remain active in the soil. Their persistence is important to the duration of weed control and to possible crop phytotoxicity, which might result from multiple applications of persistent chemicals. Potential environmental pollution is also a concern with persistent herbicides. Herbicides generally used in forest nurseries vary from those with little or no soil persistence (for example, glyphosate) to those providing full-season weed control (for example, napropamide).

Factors that affect persistence are microbial, chemical, and physical decomposition: adsorption on soil colloids; leaching; volatility; photodecomposition; and removal by plants when harvested [19]. It is important to know the general characteristics of persistence for each chemical used; the manufacturer and the *Herbicide Handbook* [38] are good sources of this information. More detailed information for a particular nursery requires conducting chemical analyses or biological assays (bioassays) with sensitive plant species. Anderson [7] and William [39] describe bioassay techniques that nursery managers can employ themselves.

18.6.2.4 Classification

Herbicides may be classified in a variety of ways—for example, by chemical type, mode of action, or time of application. Classification by chemical type is of minor interest to nursery managers-those wanting such information should consult previously mentioned textbooks. Classification by general type of action [9] may be more useful (Table 2). Classification by time of application in relation to the growing cycle of both weeds and crop may be exemplified by the following general scheme:

Preplant: Herbicides to be applied anytime *before* sowing seeds of crop species or transplanting crop seedlings.

Preemergence: Herbicides to be applied *after* sowing but *before* emergence of crop or weed seedlings.

Postemergence: Herbicides to be applied *after* emergence of crop or weed seedlings.

Because the terms "preemergence" and "postemergence" can relate to either crops or weeds [38], an alternate scheme may be less confusing:

Preseeding: Herbicides to be applied *before* sowing or transplanting crops.

Table 2. Classification of herbicides by type of action (adapted from [9]).

Where applied	Type of action	Selectivity
Foliage	Contact	Nonselective
	Contact	Selective
	Translocated	Nonselective
	Translocated	Selective
Soil	Short residual	Nonselective
	Short residual	Selective
	Long residual	Nonselective
	Long residual	Selective

Incorporation: Herbicides to be physically incorporated into soil *before* crop seeding.

Postseeding: Herbicides to be applied *after* sowing but *before* germination of crop seedlings.

Postgermination: Herbicides to be applied *after* germination of crop seedlings.

18.6.3 Types of treatments and their use

18.6.3.1 Fumigation

Fumigants are chemicals that volatilize, penetrating as gases into air spaces and films of water around soil particles. They are generally nonselective, making them useful in controlling pathogenic fungi, soil-inhabiting insects, and nematodes as well as weed seeds [27]. Their nonselectivity, however, makes fumigants detrimental to the beneficial mycorrhizal fungi and nitrogen-fixing and symbiotic bacteria in the soil [2, 36]. Fumigants are also very expensive. Considering the ready availability of effective postseeding and postgermination herbicides, the nonselectivity and high cost of fumigants make it difficult to justify their use primarily to eliminate weeds. If fumigation is necessary for other pests, then weed control early in the first season can be a bonus [10]; however, fumigants provide no residual control.

Two Northwest nurseries fumigate primarily to remove weeds; three fumigate both for weeds and for other pests (OSU Nursery Survey). The other nurseries in the northwestern United States use annual fumigation primarily for controlling pathogens. Nurseries in British Columbia normally fumigate former agricultural land during its establishment. (For further information about fumigation and its use in Northwest nurseries, see chapter 19, this volume.)

18.6.3.2 Mineral spirits

Sold under a variety of trade names, mineral spirits has been used for weed control in conifer nurseries since the 1940s. This herbicide, derived from naphthenic petroleum, contains 10 to 20% aromatic hydrocarbons. The following information on mineral spirits, unless specified otherwise, comes from Stoeckeler and Tones [33] and Wakeley [37].

Generally effective on a broad spectrum of weeds, mineral spirits is used most successfully after weeds germinate and when they are no more than 2 inches in height or breadth. Preemergence control of weeds is sometimes attained in late spring. However, earlier applications are probably ineffective because dormant weed seeds are resistant to the chemical.

Most hardwood species and larches *(Larix* spp.) are sensitive to mineral spirits at all stages of growth. Pines (*Pinus* spp.) are least sensitive, and Douglas-fir *[Pseudotsuga menziesii* (Mirb.) Franco], true firs *(Abies* spp.), spruces (*Picea* spp.), and junipers *(Juniperus* spp.) are usually resistant. *As* a general rule, mineral spirits applied to conifers before seedlings are 4 to 6 weeks old is likely to damage them, though applications prior to conifer germination do not appear harmful.

Mineral spirits has been nearly abandoned as a weed-control treatment in large forest nurseries in the United States for several reasons: (1) large, repeated doses, 25 to 100 gallons/acre 3 to 8 times/season, are necessary; (2) environmental regulations require a reduced percentage of aromatic hydrocarbons, the active ingredients for weed control; and (3) more effective, less costly herbicides are now available.

Nurseries in British Columbia report extensive use of mineral spirits (OSU Nursery Survey). These nurseries can still obtain material with high levels of aromatic hydrocarbons, and Canadian regulations prevent application of the newest herbicides. One nursery uses mineral spirits before germination of spruce and Douglas-fir and for 2+0 and 2+1 spruce beds. Three others use it as a postgermination herbicide, and one of the latter also applies it between rows of transplants to kill annual weeds. Application rates in all cases are approximately 50 gallons/acre.

18.6.3.3 Modern herbicides

Selective organic herbicides applied as low-pressure, liquid sprays are the most common and effective chemicals for nursery weed control. They are not a panacea, however: (1) one application at the recommended rate generally does not provide season-long control; (2) no single herbicide safe for crop seedlings will control all weed species; and (3) if one species or type of weed is controlled, another will likely take its place [21]. Given these herbicide characteristics, the best attack is usually to use combinations (though not necessarily mixtures) or to alternate them during a season.

Nomenclature.—Each product has three names: a chemical name that describes its makeup to an organic chemist [for example, 2-chloro-1,(3-ethoxy-4-nitrophenoxy)-4-(trifluoromethyl)benzene]; a common name accepted by one or more societies or standard-setting organizations that is usually a shortened, more easily remembered version of the chemical name (for example, oxyfluorfen); and a trade or product name given by the manufacturer (for example, Goal®).[2]

Formulations.—Herbicides are marketed in various physical forms to make application easier and (or) to make the chemical more effective. The following discussion is adapted from Newton and Knight [24], who give more detailed information about herbicide formulations.

Water-soluble liquids and powders need to be mixed when preparing a spray solution but do not settle out with time. They tend to bead on waxy foliage, so require a surfactant for efficient absorption. Wettable powders—typically, fine dusts mixed with inert materials and applied in water—are used for herbicides that have low water solubility. Flowable concentrates—very finely ground wettable powders in a liquid matrix—are easier to handle than powders. Wettable powders and flowable concentrates should be mechanically agitated during application. Oil-soluble liquids and emulsifiable concentrates are useful for penetrating waxy foliage. They may be mixed with water if emulsifiers are included in the formulation to disperse oil droplets in the water. Granular and pelleted herbicides are suitable for dry application to soil. Gaseous fumigants, another type of formulation, were mentioned earlier (see 18.6.3.1).

Application techniques.—Most nursery herbicides are applied by spraying small amounts of chemical diluted in water carrier at 20 to 60 lb pressure. Spraying, done properly, provides much more uniform application than does mechanically

[2] Mention of trade name or product does not imply endorsement by the U.S. Department of Agriculture.

spreading and incorporating granular or pelleted materials. Spray volumes of 20 to 50 gallons/acre are normally used, although 10 to 20 gallons/acre usually suffice for translocated materials. Instructions for specific compounds are found on product labels.

The nozzle is the key component of any spray system; its type and condition affect the uniformity and rate of application and the amount of drift. Nozzles are made in a variety of spray patterns. The most common type used for broadcast applications is a flat-fan spray with tapered edges and 30 to 50% overlap from adjacent nozzles. A cone-shaped spray is best for spot treatments, a flat-fan spray with even edges for band or strip spraying.

Nozzles are manufactured from a variety of materials, and choice depends largely on the type of chemical being sprayed. Some chemical formulations are corrosive; others, such as wettable powders, are abrasive. The *Herbicide Handbook* [38] lists use precautions for each specific herbicide. In any case, proper operation requires clean nozzles. Water and bristle brushes or wooden pegs should be used to clean nozzles instead of wire or knives, which might damage carefully milled edges. Filters or strainers, located on the intake of the spray tank, in the line, or as part of the nozzle, help keep nozzles clean. Coarse filters (50 mesh or larger) are usually needed for wettable powders.

The pressure of the spray affects nozzle output and spray pattern, so a pressure regulator is necessary. It is best to use the pressure recommended for a given nozzle. If application rates must be changed, use different size nozzles rather than changing the operating pressure.

Other main components of a spray system are a spray tank or reservoir, a pump, and plumbing designed for the pressures and materials to be used. Sprayers can be mounted on either a tractor or trailer (see chapter 3, this volume).

Most of the large forest-tree nurseries in the Northwest apply herbicides with tractor-mounted sprayers: of the nurseries surveyed (OSU Nursery Survey), 11 use tractors only (100- to 200-gallon capacity), four use trailer-mounted sprayers (150- to 500-gallon capacity), and five use both types. Several nurseries also reported using hand sprayers for spot treatments.

Mixing several herbicides together can be an efficient way to control different types of weeds simultaneously. For example, so-called tank mixes can do "double duty" when both grasses and broadleaf weeds are a problem, or when preemergence and postemergence weed control is needed at the same time. Although such mixes are legal unless specifically restricted on the label of one of the chemicals, it is best to use only herbicide combinations that are recommended on the labels to assure that the chemicals are compatible. Mixes should always be tested for any new use—even if a nursery manager has already tried the same chemicals separately. The combination could possibly change the phytotoxic characteristics of the separate chemicals, such as when oxyfluorfen or bifenox is combined with glyphosate [3]. Rates of application may be reduced if two chemicals are used together [21]. Experimenting with new mixes of separately registered herbicides is critical—there may be a chemical incompatibility that would clog equipment and reduce or eliminate weed control.

Granular materials can be spread like dry fertilizers. Some work better if mixed into the soil, to reduce volatility and to place the herbicide close to weed seeds. Instructions on the label concerning proper depth of incorporation and equipment should be followed closely for proper results. Also, if the soil is too wet or equipment is not operating at recommended speed, poor mixing may occur. Granular herbicides are more difficult and expensive to apply and are not any safer or more effective than preseeding broadcast sprays [31].

Bohmont [9] and Klingman and Ashton [19] give more information on application equipment and describe calibration techniques and formulas for calculating doses. Proper and careful calibration, mixing, and application play an important part in preventing adverse environmental impacts from herbicide treatments.

18.6.4 Herbicide use in Northwest nurseries

Each nursery surveyed (OSU Nursery Survey) relies on herbicides to some extent. Several managers stated they use herbicides with reluctance and only as a "last resort." Others have intensive programs that utilize three to five different chemicals for different weed problems or different species or age classes of crop seedlings. Including fumigants and mineral spirits, use of 14 different chemicals was reported (Table 3; OSU Nursery Survey). All of these nurseries also do some hand weeding.

Table 3. Herbicides used in Northwest forest-tree nurseries (OSU Nursery Survey).[1]

Common name[2]	Trade name[3]	No. of nurseries reporting use
Methyl bromide/chloropicrin	MBC-33®	16
Oxyfluorfen	Goal®	9
Bifenox	Modown®	8
Mineral spirits	Various	5
Napropamide	Devrinol®	4
Paraquat	Gramoxone® or Ortho Paraquat®	4
Diphenamid	Enide®	3
Hexazinone	Velpar®	3
Glyphosate	Roundup®	7
DCPA	Dacthal®	2
Propazine	Milogard®	2
Simazine	Princep®	2
Amitrole	Various	1
Atrazine	Various	1

[1]This listing does not imply any specific registration. Uses may have been experimental or operational in one or more of four states in the U.S. or in British Columbia.

[2]Listed in order of decreasing use.

[3]The use of a product name is for identification only and does not imply product endorsement.

Two of the most commonly applied chemicals, oxyfluorfen and bifenox, can control a wide spectrum of broadleaf weeds and grasses [38]. Oxyfluorfen, a contact herbicide effective both during preemergence and postemergence periods, has a very low translocation rate, impacting tops more than roots. It resists removal by rain, is strongly adsorbed on soil, has negligible leaching through soil, and is nonpersistent in the environment. Bifenox, an effective preemergence herbicide that also can be used postemergence when weeds are no more than 2 to 3 inches tall, has a low translocation rate, is rapidly absorbed by foliage, and is herbicidally active for 6 to 8 weeks. Not easily removed by rain, it is less affected by weather and by clay and organic matter in soil than most preemergence herbicides. Bifenox has negligible leaching through soil and is nonpersistent in the environment.

18.6.5 Herbicide effectiveness

Evidence is plentiful that herbicides can effectively reduce weed populations in nurseries and thereby lower costs of hand weeding. For example, in the Western Nursery Herbicide Project mentioned earlier (see 18.6.1), time spent hand weeding was reduced 39 to 98% in first-year seedbeds treated with one of three different herbicides, compared with nontreated seedbeds (Table 4). Abrahamson [2-4] reported average gross savings of $4,000 to $7,000/acre of seedbed over hand weeding alone.

These data also illustrate how the effectiveness of the same chemical at different nurseries or different chemicals at the

Table 4. Reductions in time spent hand weeding in first-year seedbeds treated with three herbicides (adapted from [26]).

Nursery, by state	Bifenox	DCPA	Napropamide
	~ ~ ~ ~ ~ ~ Percent reduction[1] ~ ~ ~ ~ ~ ~		
Oregon			
Aurora	47	40	88
Klamath Falls	98	93	47
Lava	86	43	57
Phipps	27	20	10
Stone	73	25	24
Average	66	44	45
Washington			
Greeley	58	43	63
Toledo	93	39	80
Webster	78	48	67
Wind River	93	98	91
Average	80	57	75

[1]Reduction in time spent hand weeding compared with time required for nontreated seedbeds.

same nursery can vary widely. Differences in weed populations, soil, weather, and procedures are important factors in this variation. Steward [31] and Abrahamson [3] have shown that postseeding treatments are usually more effective than post-germination applications for total-season weed control. Early-season weed control is important in forest nurseries because winter annuals have had several months to become established in seedbeds;. and prolific summer annuals have their main flush of germination in the spring.

Herbicides, even if used properly and cost effectively, do not provide 100% control. Some hand weeding or spot treatments will probably always be necessary for areas inadvertently skipped in application and for resistant weeds that should not be allowed to spread or go to seed. Actually, there is a secondary advantage to having a crew periodically go through nursery beds—they can spot problems with insects, diseases, and fertility, as well as weeds, that might otherwise go unnoticed. Furthermore, applying herbicides in doses heavy enough to eliminate all weeds increases the risk of crop damage [25].

18.6.6 Phytotoxicity to crop trees

It is senseless to use a herbicide in such a way that crop seedlings are damaged. Because herbicides are designed to be toxic to plants, the potential for crop damage is often high. Problems can result from improperly applying the chemical, applying too much chemical, or treating too frequently [21].

Phytotoxic effects can take many forms. Possible symptoms in crop seedlings include germination failure; needle chlorosis or burn; stem swelling or lesions; stunted or distorted growth of needles, shoots, roots, or the whole seedling; and mortality. Sometimes the damage is obvious (for example, heavy mortality or severe stunting); at other times, the effects are small losses in growth that can only be detected by careful analyses. In other cases, close observation is needed in the field. An example of the latter is the stem swelling on Douglas-fir and several other species west of the Cascade Mountains caused by DCPA [11]. Casual observers had attributed the swelling to heat damage, but careful workers—who compared the occurrence with seedlings in untreated seedbeds—found that the herbicide was the cause. On the other hand, nursery managers must also be careful not to mistakenly identify disease or nutrition problems as herbicide phytotoxicity just because a herbicide was used. Kozlowski and Sasaki [20] have a good discussion about the difficulties of assessing subtle phytotoxic effects.

One systematic approach to assessing damage to crop seedlings was developed by Anderson [6], who used the following rating scheme:

Rating	Description
10	No seedlings damaged.
7-9	Slight damage; seedlings will recover and achieve near-normal growth.
4-6	Moderate damage; few seedlings have died, but some show chemical effects and reduced growth.
1-3	Severe damage; many seedlings have died, and others are discolored and stunted.
0	All seedlings dead.

For consistency, the same individual should do all of the rating at a nursery. In addition, the person should briefly describe and record specific factors used to determine the ratings as an aid to later analyses. Table 5 is an example of damage ratings from a screening test in Northwest nurseries.

Systematic germination counts and seedling measurements such as height, stem caliper, and root weight, all supported by statistical analyses, are further steps that may reveal subtle phytotoxic effects.

The OSU Nursery Survey provided information on phytotoxicity, but there were too many unknown variables to draw conclusions about specific treatments. Some general observations are possible, however: (1) all the chemicals used at more than one nursery (Table 3), except methyl bromide/chloropicrin, were identified as phytotoxic in one or more instances; (2) hexazinone has caused the most severe, widespread problems; (3) oxyfluorfen and bifenox were often reported to cause needle burn or curl and sometimes were implicated in reduced germination or low-level seedling mortality; and (4) such symptoms as slight mortality, growth reduction or deformities, needle burn, chlorosis, and stem swelling (from DCPA) were reported for the other herbicides. Most of the burning seems to occur on new, active growth. Another subtle type of problem that has been reported in crops is that of herbicides predisposing Douglas-fir seedlings to diseases such as *Fusarium* top blight (see chapter 19, this volume).

Conifer species that seem most sensitive to herbicides include coast redwood [*Sequoia sempervirens (D.* Don) Endl.], lodgepole pine (*Pinus contorta* Dougl. ex Loud.), western hemlock [*Tsuga heterophylla (Raf*) Sarg.], and western larch (*Larix occidentalis* Nutt.) (OSU Nursery Survey; [3l]).

The effect on mycorrhizae is another type of phytotoxicity damage that must be considered. The importance of mycorrhizal development on most conifer nursery stock is becoming increasingly recognized (see chapter 20, this volume), and any practices that impede mycorrhizal formation should be discouraged. In a study at six western nurseries, neither bifenox, DCPA, nor napropamide significantly reduced the proportion of feeder roots colonized by mycorrhizal fungi or the number

Table 5. Effect of postseeding application of herbicides on conifer seedlings (adapted from [32]).

Herbicide	Dosage lb active ingredient/acre	Average damage rating[1] Douglas-fir	Lodgepole pine	Western hemlock
Nontreated	0	8.8	10	9.7
Bifenox	3	8.8	10	10
DCPA	10.5	8.2	10	3.7
Diphenamid	4	8.2	9.7	10
Napropamide	3	8.5	10	5.4
Hexazinone	0.5	8.3	1.7	4.7

[1]Based on scale developed by Anderson [6]: 0 means complete kill, 10 means no damage; see text.

of mycorrhizal types, compared to controls of 1+0 Douglas-fir and ponderosa pine seedlings [35]. In contrast, several of the herbicide-species combinations had greater numbers or types of mycorrhizae, compared with the controls. Trappe [35] showed that: (1) different herbicides or application rates can have different effects on mycorrhizae—thus nursery managers and scientists should assess this factor when monitoring herbicide effects; (2) more variation occurred between nurseries than between herbicide treatments: and (3) it may develop that some herbicide treatments will have mycorrhizal benefits that make them useful beyond just weed control.

18.6.7 Conducting screening tests

The safety and effectiveness of any herbicide should be tested at each nursery before operational use. Testing is urged because there is a strong possibility of differential results from varied interactions of different mixtures of tree and weed species, soil and climatic factors, and cultural practices at different nurseries. Furthermore, herbicides used at tree nurseries represent such a small market that nursery managers must often collect or arrange for collection of their own efficacy and phytotoxicity data for registration rather than depend on chemical companies.

Because research agencies spend relatively little time studying weed control in Northwest forest nurseries, much of the work falls to nursery managers. To assist in this process, a detailed plan has recently been published [29] describing the layout of a study, procedures for applying herbicides, and requirements for gathering and analyzing data on weed control and phytotoxicity; sample data forms are included. In addition, the basic plan may be used to conduct administrative studies of other types of weed-control practices.[3]

Several years of testing are advisable because of variations in effects caused by different weather. Tests should include "double doses" to evaluate the safety limits on crop seedlings and incorporate sound design procedures, such as leaving an untreated control and randomizing and replicating treatments to reduce bias (see chapter 28, this volume). Finally, close scrutiny for possible phytotoxicity is essential; subtle effects may go unnoticed without a combination of visual observations and measurements.

18.7 Recommendations

Weed management is an important component of a nursery manager's job. To be successful, it must be done with thoroughness and professionalism. In summary, we recommend that nurseries:

- Plan and implement an integrated weed-management program
- Gain expertise in weed science and be alert for new developments
- Document and evaluate conditions, treatments, and results on a thorough and continuous basis
- Test new prevention and control treatments and analyze them carefully for safety and cost effectiveness

References

1. Abbott. H. G., and S. D. Fitch. 1977. Forest nursery practices in the United States. J. Forestry 75:141-145.
2. Abrahamson, L. P. 1980. Pesticides in forest tree nurseries—primary and secondary effects. Pages 191-204 *in* Proc., North American forest tree nursery soils workshop (L. P. Abrahamson and D. H. Bickelhaupt, eds.). State Univ. New York, Coll. Environ. Sci. and Forestry, Syracuse.
3. Abrahamson, L. P. 1981. Herbicide trials for weed control in Great Plains forest tree nurseries. Pages 61-102 *in* Proc., 33rd Annual meeting of the Forestry Committee. Great Plains Agric. Council, Lubbock, Texas. Great Plains Agric. Council Publ. 102.
4. Abrahamson, L. P. 1983. Herbicides, an important component of the weed control program at Oklahoma State (Norman) Nursery. Pages 171-191 in Proc., 1982 Southern nurserymen's confs. Southeastern Area, State and Private Forestry, U.S.D.A. Forest Serv., Atlanta. Georgia.
5. Aldhous. J. R. 1972. Nursery practice. Her Majesty's Stationery Office, London. Forestry Commun. Bull. 43. 184 p.
6. Anderson, H. W. 1963. A system for evaluating effective weed control in forest nurseries. Tree Planters' Notes 61:19-23.
7. Anderson, H. W. 1970. A bioassay technique for measuring herbicide residuals in forest nursery soils. Tree Planters' Notes 21(2):1-5.
8. Ashton, F. M., and A. S. Crafts. 1973. Mode of action of herbicides. John Wiley and Sons, New York. 504 p.
9. Bohmont, B. L. 1981. The new pesticide user's guide. B & K Enterprises, Inc., Fort Collins, Colorado. Approx. 309 p.
10. Boyd, R. J. 1971. Effects of soil fumigation on production of conifer nursery stock at two Rocky Mountain nurseries. U.S.D.A. Forest Serv., Intermountain Forest and Range Exp. Sta., Ogden, Utah. Res. Pap. INT-91. 19 p.
11. Callan, N. W. 1980. Dacthal injury on Douglas-fir and true firs at the Medford Forest Nursery. Pages 23-24 in Proc., Intermountain Nurserymen's Association meeting, Aspen, Colorado, Aug. 13-16, 1979. U.S.D.A. Forest Serv., Mount Sopris Nursery, Carbondale, Colorado.
12. Crafts, A. S. 1975. Modern weed control. Univ. of California Press, Berkeley and Los Angeles. 440 p.
13. Dennis, L. J. 1980. Gilkey's weeds of the Pacific Northwest. Oregon State Univ. Press, Corvallis. 382 p.
14. Dutton, D. W. 1983. Chinese weeder geese, do they or do they not weed in the nursery? Pages 44-48 *in* Proc., 1982 Western Nurserymen's conf. Western Forestry Nursery Council, Southern Oregon Regional Services Institute. Southern Oregon State Coll., Ashland.
15. Gjerstad, D. H., D. B. South, C. W. Brewer, and W. D. Kelley. 1980. 1979-80 Annual report—Auburn University Forest Nursery Cooperative. Dep. of Forestry, Auburn Univ., Auburn, Alabama. 109 p.
16. Hitchcock, C. L., and A. Cronquist. 1973. Flora of the Pacific Northwest. Univ. of Washington Press, Seattle. 730 p.
17. Holt, H. A., and L. P. Abrahamson. 1980. Developing weed control programs for forest nurseries in central U.S. Page 52 *in* Abstracts—1980 meeting. Weed Sci. Society of America, Toronto, Canada, Feb. 5-7.
18. Huffaker, C. B. [1978?]. An overview of biological control, with particular commentary on biological weed control. Pages 3-12 *in* 1976 Proc.. IV International symp. on biological control of weeds (T. E. Freeman, ed.). Univ. of Florida, Gainesville. 299 p.
19. Klingman, G. C., and F. M. Ashton. 1975. Weed science: principles and practice. John Wiley and Sons. New York. 431 p.
20. Kozlowski, T. T., and S. Sasaki. 1968. Effects of direct contact of pine seeds or young seedlings with commercial formulations, active ingredients, or inert ingredients of triazine herbicides. Can. J. Plant Sci. 48:1-7.
21. Kuhns, L. J. 1982. How to control weeds—the basics and the herbicides. American Nurseryman 155(5):29-49.
22. Moon, B. L. 1982. Alliance for progress. Dow Industrial Vegetation Management 14(1):6-8.
23. Muzik, T. J. 1970. Weed biology and control. McGraw-Hill Book Co., New York. 273 p.
24. Newton, M., and F. B. Knight. 1981. Handbook of weed and insect control chemicals for forest resource managers. Timber Press. Beaverton, Oregon. 213 p.
25. Newton, M., J. Lemhouse, and R. K. Hermann. 1977. Chemical weed control in western conifer nursery beds—research and program development. *In* Proc., joint meeting, Western Forest Nursery Council and Intermountain Forest Nurserymen's Assoc., Richmond, B.C., Aug. 10-12, 1976. B. C. Forest Serv., Victoria. Not paginated.
26. Owston, P. W., and H. G. Weatherly. 1979. Semi-operational trials of three herbicides in Pacific Coast forest nurseries. U.S.D.A. Forest Serv., Forestry Sciences Lab., Corvallis, Oregon. Unpublished rep.

[3] Guidelines and forms for such tests are also available from the Horticulture Extension Office, Oregon State University, Corvallis.

27. Portman, R. W., and G. Santo. 1978. Soil fumigation manual. Washington State Univ. Ext. Serv., Pullman. Ext. Manual 4387. 12 p.
28. Ryker. R. A. 1980. Western nursery herbicide study—1979 update. Pages 1622 *in* Proc., Intermountain Nurserymen's Association meeting, Aspen, Colorado, Aug. 13-16, 1979. U.S.D.A. Forest Serv.. Mount Sopris Nursery, Carbondale, Colorado.
29. Sandquist. R. E., P. W. Owston, and S. E. McDonald. 1981. How to test herbicides at forest tree nurseries. U.S.D.A. Forest Serv., Pacific NW Forest and Range Exp. Sta., Portland, Oregon. Gen. Tech. Rep. PNW-127. 24 p.
30. Singer, J. 1980. Pesticide safety, guidelines for personnel protection. U.S. Forest Serv., Forest Insect and Disease Management, Methods Application Group, Davis, California. 45 p.
31. Steward [Stewart], R. E. 1977. Herbicides for weed control in western forest nurseries. Pages 78-89 in Proc., Western Society of Weed Sci., vol. 30.
32. Stewart, R. E., P. W. Owston, and H. G. Weatherly. 1979. Evaluation of six herbicides for weed control in Pacific Coast forest nurseries. Pages B-127 to B-133 *in* Conf. and workshop proc., Western Forest Nursery Council and Intermountain Nurserymen's Assoc. (R. W. Gustafson, ed.). Eureka, California, Aug. 7-11, 1978. U.S.D.A. Forest Serv.. Pacific SW Region, San Francisco, California. 288 p.
33. Stoeckeler,J. H., and G. W. tones. 1957. Forest nursery practice in the Lake States. U.S.D.A. Forest Serv., Washington, D.C. Agric. Handb. 110. 124 p.
34. Ticknor, R. L: 1981. Weed control in nurseries and ornamental plantings. Ornamentals Northwest 5(4):5-8.
35. Trappe, J. M. 1983. Effects of the herbicides bifenox, DCPA, and napropamide on mycorrhiza development of ponderosa pine and Douglas-fir seedlings in six western nurseries. Forest Sci. 29:464-468.
36. Trappe, J. M., and R. F. Strand. 1969. Mycorrhizal deficiency in a Douglas-fir Region nursery. Forest Sci. 15(4):381-389.
37. Wakeley. P. C. 1954. Planting the southern pines. U.S.D.A. Forest Serv., Washington, D.C. Agric. Monograph 18. 233 p.
38. Weed Science Society of America. 1983. Herbicide handbook. 5th ed. Weed Sci. Society of America. Champaign, Illinois. 515 p.
39. William. R. D. (compiler). 1983. Oregon weed control handbook. Oregon State Univ. Ext. Serv., Corvallis. 184 p.