CHAPTER 15.—WEED CONTROL

By: David South, Assistant Professor
School of Forestry
Auburn University
Auburn, AL

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

WEED COMPETITION

The nursery manager's primary objective is to produce first-class planting stock as economically as possible. At many nurseries, however, weeds are a major obstacle to this goal. Weeds compete with seedlings for light, water and nutrients, and reduce seedbed densities. Certain weeds such as bermudagrass can reduce the number of plantable seedlings by 66 percent (South, Gjerstad, and White 1978). Weed competition also causes seedling top and root stunting in various degrees, and results in large variations in seedling size at lifting.

Minimizing weed competition can reduce or possibly eliminate time and cost involved in seedling culling. Uniform seedling size aids in ease of field planting and increases survival. In heavy weed infestations, hand-weeders pull up considerable numbers of seedlings with the weeds, resulting in lower densities. Hence, weedy nurseries not only have the added expense of hand labor, but also produce seedlings of lower quality and require more acres to reach production goals.

MAJOR WEEDS IN SOUTHERN FOREST NURSERIES

Weed species must be identified for good weed control. Several good manuals are available for identifying weeds (USDA 1970; WSSA 1979; Auburn University 1975; Wilkinson and Jaques 1972; Radford, Ahles and Bell 1968). Some of the more common weeds in southern nurseries, with their scientific names, are listed in table 15-1. Terms are defined in appendix 15-1.

Troublesome Weeds

The most troublesome weeds that occur in southern forest nurseries are listed by nursery in table 15-2. Large crabgrass is the most common annual grass on the list. This species responds quickly to nitrogen fertilization and can grow to a large size in just a few days. The seed of this species is easily windblown and, therefore, is continually being introduced into the nursery.

Table 15-1. — Weed species in southeastern forest nurseries (1979).

COMMON NAME	SCIENTIFIC NAME
GRASSES	
broadleaf signalgrass	Brachiaria platyphylla (Griseb.) Nash
bermudagrass	Cynodon dactylon (L.) Pers.
crowfootgrass	Daclyloctenium aegyptium (L.) Richter
large crabgrass	Digitaria sanguinalis (L.). Scop.
barnyardgrass	Echinochloa crus-galli (L.) Beauv.
goosegrass	Elusine indica (L.) Gaertn.
annual bluegrass	Poa annua (L.)
smutgrass	Sporobolus poiretii (Roem & Schult.) Hitchc.
SEDGES	
Flathead sedge	Cyperus compressus L.
yellow nutsedge	Cyperus esculentus L.
purple nutsedge	Cyperus rotundus L.
BROADLEAVES	
prostrate pigweed	Amaranthus bitoides S. Wats.
redroot pigweed	Ameranthus retrofelus L.
spiney amaranth	Amaranthus spinosus L.
common ragweed	Ambrosia artemisiifolia L.
indigo	Baptisia tinctoria (L.) R. Br.
hoary cress	Cardaria draba (L.) Desv.
sicklepod	Cassia obtusifolia L.
lambsquarters	Chenopodium album L.
Florida beggerweed	Desmodium tortuosum (SW.) DC
yerba de-tago	Eclipta alba (L.) Hassk.
dogfennel	Eupatorium capillifolium (Lam.) Small
prostrate spurge	Euphorbia supina Raf.
cudweed	Gnaphalium sp.
tall morningglory	Ipomoea purpurea (L.) Roth
carpetweed	Mollugo verticillata L.
Pennsylvania smartweed	Polygonum pensylvanicum L.
common purslane	Portulaca oleracea L.
air fern	Portulaca pilosa L.
Florida pusley	Richardia scabra L.
black willow	Salix nigra Marsh
dandelion	Taraxacum officinale Weber
verbena *	Verbena rigida Sprengel.
cockelbur	Xanthium pensylvanicum Wallr.

* a common name used by nurserymen, not a WSSA accepted common name.

Bermudagrass is the most troublesome perennial grass in forest nurseries. Competition from this species can severely reduce seedling production (South, Gjerstad and White 1978). Bermudagrass usually grows well on fertile, irrigated nursery soils.

Morningglories and sicklepod are probably the most troublesome broadleaf weeds. Because the seeds are stratified during the fumigation process, the population of these weeds usually increases after fumigation with methyl bromide. At one nursery, the morningglory population increased thirteen fold after methyl bromide fumigation (South and Gjerstad 1980).

Overall, nutsedge is the most troublesome weed in forest nurseries. This weed is present in most southern nurseries and is considered troublesome in over half. Because a single, purple nutsedge plant can produce 1,300 tubers in 20 weeks (Hauser 1962), its population can rapidly multiply. For this reason, fumigation without persistant removal of escaped nutsedge plants has never been successful in eliminating nutsedge. See Chapter 18, section on "Pesticide Safety" before using pesticides.

Weed control techniques used in the nursery will vary depending upon the weed species present. For example, at the Westvaco Nursery, where annual grasses are the

primary problem, herbicides provide adequate weed control. However, fumigation, sanitation, and cultural practices are needed in addition to herbicides to control perennail weeds such as nutsedge at the Baucum Nursery in Arkansas.

HERBICIDE SELECTIVITY

Herbicides may be classified as selective or nonselective (adapted from Walker 1976). A selective herbicide is one that is more toxic to one plant than another. Selective herbicides are of primary importance in seedling production. Selectivity is based on many factors, the most important of which are: morphological, physiological, absorption, and translocation differences between plants.

Morphological Differences.—Refers to differences in plant size, shape, habit of growth, leaf shape and size, stages of growth, waxy or hairy leaves. The location of growing points and roots, etc., may dictate the degree of contact or absorption, or both, of a herbicide.

Physiological Differences.—Refers to differences in the internal chemistry of different plants, making them able or unable to tolerate various chemical substances. For example, corn has an enzyme system that breaks down atrazine into a harmless chemical. Many other plants cannot do this and are killed by atrazine.

Absorption Differences.—Refers to differences between plants that permit greater or less absorption of the chemical. Herbicides may be absorbed primarily via two routes: the leaves and roots. Some plants have waxy leaves, others do not. The location of plant root systems with respect to herbicide placement influences herbicide uptake.

Translocation Differences.—Translocation of herbicides may occur through *phloem* (tissues which transport carbohydrates from plant leaves), *xylem* (water and plant nutrient-conducting tissue) and through spaces between cells. Movement of herbicides may take place from one of these systems to another much the same as other solutes move within the plants.

In addition to plant differences, other factors may determine how selective a chemical is. In reality, few herbicides are completely selective. Most herbicides are nonselective to a greater or lesser degree. The degree of selectivity may be altered by: (1) time of application, (2) rate of application, and (3) site of application.

HERBICIDE FORMULATIONS AND SPRAY MIXTURES

Herbicides are not sold as pure chemicals, but as formulations with various additives. Such formulations permit more uniform application. Herbicides are formulated to be applied as sprays or granules (adapted from Walker 1976). Common and trade names of herbicides are listed in table 15-3.

Sprays

Solution.—A homogeneous mixture of two or more substances. The components of a solution cannot be separated by mechanical means.

Emulsion.—One liquid dispersed in another liquid, each maintaining its original identity. An *emulsifying agent* is a material often added to formulations to facilitate formation of emulsions. Oil-soluble herbicides are often formulated for mixture with water as an emulsion. An emulsifiable concentrate (EC) is a product that, when mixed with water, forms a sprayable emulsion.

Wettable Powders.—Finely ground, solid particles that can be suspended or dispersed in a carrier such as water and be sprayed. Most suspensions of wettable powders require agitation to prevent the powder from settling.

Granules

Granular herbicides are usually chemicals mixed with a carrier such as sand, vermiculite, etc.

Dusts

Dusts are popular formulations for insecticides and fungicides, but because of drift hazards, herbicides are not usually formulated to be applied as dusts.

EQUIPMENT

Boom Sprayers

These sprayers consist of a tank, a pump, and booms with plumbing, pressure regulator, and nozzles. A number of sprayers are available (Lowman and McLaren 1976). Those most suited for herbicide use are the low to medium volume sprayers that can apply up to 60 gallons per acre, under a pressure of 20 to 40 pounds per square inch. The spray nozzles are usually spaced 20 inches apart on the boom and are of a flat spray type. Cone-type nozzles are not often used for applying herbicides.

Many nursery personnel use the 8004 Teejet^{R} nozzles at a height approximately 18 inches from the surface of the bed. When traveling at 3 miles per hour and at a pressure of 30 pounds per square inch, the sprayer should be applying about 39 gallons per acre. The boom length can range from 18 to 60 feet, and tank sizes from 50 to 600 gallons. Those sprayers designed to be supported entirely by the three-point hitch are very maneuverable and are well suited for nursery use. The sprayer must be equipped to provide adequate agitation.

Table 15-2. — Troublesome weeds in southern forest nurseries (1979).

	Grasses				Broadleaves					Perennials	
Nursery	Crabgrass	Goosegrass	Crowfootgrass	Others	Morningglory	Sicklepod	Purslane	Carpetweed	Others	Nutsedge	Bermudagrass
ALABAMA											
Hauss	3						2		1-PS		
Miller	1			3-BG							2
Stauffer	3					2				1	
Champion	3					2				1	
Hammermill				3-PS	1	2					
Kimberly Clark	3						2			1	
Tennessee River					1				2-CB		
Weyerhaeuser	3				1					2	
ARKANSAS											
Baucum		1		2-BG						3	
Bluff City	1		2						3-PS		
Weyerhaeuser	1			3-BG				2			
FLORDIA											
Andrews	2				3				1-PS		
Munson	2	3								1	
Buckeye									1-CB,2-SC,3-FP		
Container	2					1					
Gilman	1						2		3-FB		
St. Joe	3					1			2-FP		
St. Regis									1-FB,2-CW,3-I		
GEORGIA											
Morgan	3					1				2	
Page-Walker					2	1				3	
Bowaters									2-RW,3-CB	1	
Brunswick	2									1	
Continental	3								1-RW,2-AF		
Great Southern					2	1				3	
ITT Rayonier				1-FS		3			2-DF		
Union Camp	3								2-DF	1	
KENTUCKY											
Kentucky Dam	1								3-BW	2	
LOUISIANA											
Beauregard	3									2	1
Columbia								3		2	1
Continental	1		2						3-RP		
MISSISSIPPI											
Ashe			3							2	1
Mt. Olive		2		3-BS						1	
Waynesboro		1								2	3
Winona			3			2				1	
International Paper									2-V,3-BW		1

(Continued)

Table 15-2. — Troublesome weeds in southern forest nurseries (1979).

	Grasses				Broadleaves					Perennials	
Nursery	Crabgrass	Goosegrass	Crowfootgrass	Others	Morningglory	Sicklepod	Purslane	Carpetweed	Others	Nutsedge	Bermudagrass
NORTH CAROLINA											
Claridge	2						1		3-DF		
Edwards	1									2	3
Linville				2-SG				3	1-DL		
Federal				1-FS					2-Y,3-L		
Weyerhaeuser	1			2-FS						3	
OKLAHOMA											
Norman				1-AB					2-PP,3-SA		
Weyerhaeuser	1				2					3	
SOUTH CAROLINA											
Coastal	3								1-CW	2	
Piedmont							3		1-SW,2-PS		
Ridge	1								2-FP,3-PW		
Tilghman	1								2-PS		
Champion	2								3-CB	1	
Westvaco	2	1	3								
TENNESSEE											
Pinson	2									1	3
TEXAS											
Indian Mound									1-RW,2-H,3-Y		
Champion	1	2							3-DF		
St. Regis	3									2	1
Temple-Eastex			2							1	
VIRGINIA											
Augusta							1	2	3-DL		
New Kent		1					2			3	
Continental	2				3					1	
Union Camp	1				3			2			

1 = most troublesome weed 2 = second most troublesome weed 3 = third most troublesome weed

AB = annual bluegrass
AF = air fern
BG = barnyardgrass
BS = broadleaf signalgrass
BW = black willow
CB = cockelbur
CW = cudweed
DF = dogfennel
DL = dandelion
FB = Florida beggarweed
FP = Florida pusley
FS = Flathead sedge
H = hoary cress
I = indigo
L = lambsquarters
PP = prostrate pigweed
PS = prostrate spurge
RP = redroot pigweed
RW = ragweed
SA = spiny amaranth
SC = showy crotalaria
SG = smutgrass
SW = smartweed
V = verbena
Y = yerba de-tago

Table 15-3.—Relative toxicity of herbicides to mammals. (Adapted from Walker, 1976)

Based on actue oral LD_{50} Values for Adult White Rat With Technical Material

Common Name or Designation	Some Common Trade Names	LD_{50} mg./Kg.	Toxicity* Rating	Dermal Response Rating**
Sodium aresenite	Atlas A, Triox	10	2	1,2
Methyl bromide	Various brands	17 ppm (air)	2	2
Kerosene	Various brands	-	2-3	-
Paraquat	Paraquat	157	3	2
Gasoline	Various brands	-	3	2
Aromatic solvents	Various brands	-	3	-
2,4,5-T	Various brands	300	3	4
Copper sulfate	Various brands	300	3	-
Silvex	Kuron, Weedone-tp	500	4	4
2,4-D	Various brands	500	4	4
DMTT	Mylone	500	4	4
Petroleum solvents	Various brands	-	4	1
DSMA	Sodar, Ansar, Methar	600	4	5
Perfluidone	Destun	633	4	5
MSMA	Weed-E-Rad, Ansar	700	4	-
ASPRIN	(For comparison)	750	4	5
SMDC	Vapam	820	4	3
Diphenamid	Enide	960	4	5
Cacodylic acid	Ansar 560,120	1000	4	-
Alachlor	Lasso	1200	4	3
Linuron	Lorox	1500	4	-
EPTC	Eptam	1630	4	-
Vernolate	Vernam	1780	4	-
Nitrofen	Tok E-25	2630	4	-
Metalachlor	Duel	2780	4	4
DCPA	Dacthal	3000	4	5
Atrazine	Aatrex	3080	4	5
TABLE SALT	(For comparison)	3320	4	5
Diuron	Karmex	3400	4	4
Trifluralin	Treflan	3700	4	5
Chloroxuron	Tenoran, Norex	3700	4	5
Prometryne	Caparol	3750	4	-
Butylate	Sutan	3997	4	3
Dichlobenil	Casoron	4250	4	4
Glyphosate	Roundup	4320	4	4
Simazine	Princep, Aquazine	5000	5	5
Napropamide	Devrinol	5000	5	4
Oxyfluorfen	Goal	5000	5	4
Propazine	Milogard	5000	5	-
Terbacil	Sinbar	5000	5	5
Bromacil	Hyvar X	5200	5	4
Fenuron	Dybar	6400	5	4
Bifenox	Modown	6400	5	4
Siduron	Tupersan	7500	5	4
Oxadiazon	Ronstar	8000	5	4
Picloram	Tordon	8200	5	-
Dalapon	Dowpon, Basfapon	9300	5	4
Benefin	Balan	10000	5	-
Oryzalin	Surflan	10000	5	5

*Numerical toxicity rating is based on a modification of the classification of pesticides in the Federal Insecticide, Fungicide, and Rhodenticide Act and from "Clincal Toxicology of Commercial Products" by Gleason, M.N., Gosselin, R.E., and Hodge. H.D. Williams and Wilkins Co., Baltimore, M.D., 1957.

Toxicity Rating	Class	LD_{50}* (Mg./Kg.)	Probably Lethal Dose for 150 lb. man
1	Extremely toxic	Less than 5	A taste (less than 7 drops)
2	Very toxic	5 to 49	7 drops to 1 teasp.
3	Moderate toxic	50 to 499	1 teasp. to 1 oz.
4	Slightly toxic	500 to 4,999	1 oz. to 1 pint (1 lb.)
5	Almost Nontoxic	5,000 to 14,999	1 pint to 1 quart
6	Nontoxic	15,000 and above	More than 1 quart

** Numerical rating is based on the following classification:

1. Absorbed and poisonous
2. Causes burns and blisters
3. Moderately irritating
4. Mildly irritating
5. Nonirritating

[1]Adapted from Walker (1976).

[2]Paraquat is extremely toxic when inhaled.

Directed Applicators

When applying nonselective herbicides, care must be taken to not contact the seedlings. Directed herbicide applicators have been used in both pine and hardwood seedbeds. A rope wick applicator has been used to apply glyphosate to weeds that are taller than the pines. For smaller weeds, shielded applicators are used. At the Ashe Nursery in Mississippi, a multi-row, tractor-mounted spot applicator has been used for applying glyphosate between the drills of pine seedlings to control nutsedge and bermudagrass. See figure 15-1. In hardwood seedbeds, the Stoneville wiper has been used at Stoneville, Miss. this applicator uses shielded carpet strips which are saturated with glyphosate and are dragged over weeds between the drills (Chandler and Filer 1980).

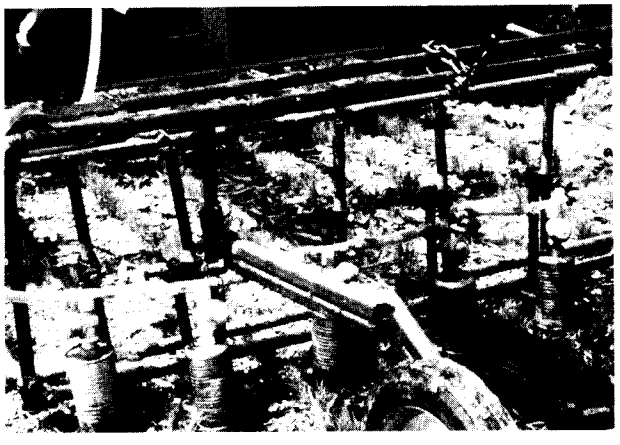

Figure 15-1.—Shielded applicator developed at the Ashe Nursery

Spot Applicators

There are four main types of hand applicators which are used primarily for spot treatments. Backpack sprayers hold from 2 to 4 gallons and are pressurized by pumping while spraying. Hand-held sprayers hold 1 to 2 gallons and are available in several styles (Lowman and McLaren 1976). (See figure 15-2). The squirt bottle, which is sometimes adapted from household cleaning bottles, usually holds less than ½ gallon. The "hockey stick" or sponge on a stick are inexpensive, nonpressurized applicators and are used to wipe the herbicide directly on the target weeds. All of these applicators can be used in seedbeds to treat weeds that have escaped or are resistant to the normal broadcast treatments.

Granular Applicators

Fertilizer spreaders that provide a uniform, broadcast application to the seedbeds can also be used for applying granular herbicides. Tractor-mounted, cyclone spreaders should not be used because they may distribute the granules unevenly. Several styles of granular applicators are available (Lowman and McLaren 1976).

Figure 15-2.—Spot treatment with backpack sprayer

Spray Preparation and Dilution

Herbicides must be properly diluted to be applied correctly. Herbicides are not formulated as pure chemicals. Recommendations are sometimes given in rate of active ingredient (ai) per acre. The following formulae may be used to calculate the amount of commercial product needed when the rate of active ingredient per acre is known (adapted from Walker 1976).

Solids.—Wettable powders, etc.

$$\frac{\text{Rate of active ingredient/acre}}{\text{percent active ingredient}} \times 100 = \text{Rate of commercial product per acre}$$

Example: If 2 pounds of active herbicide are recommended per acre and the herbicide is available as an 80-percent wettable powder, the amount of product per acre would be calculated as follows:

$$\frac{2 \text{ (lb. ai/acre)}}{80 \text{ (\% ai)}} \times 100 = 2.5 \text{ pounds of product per acre.}$$

Liquids.—EC, soluble liquids, etc.

$$\frac{\text{Rate of active ingredient/acre}}{\text{Pounds active ingredient per gallon}} = \text{Gallons of product per acre}$$

Example: If 2 pounds of active herbicide are recommended per acre and the herbicide is available as a 4-pounds per gallon EC, the amount of product per acre would be calculated as follows:

$$\frac{\text{2 lb. ai/acre}}{\text{4 lbs ai/gal}} = \text{1/2 gallon product per acre}$$

Band Rate.—Herbicide recommendations are commonly given on a broadcast basis. To convert broadcast rate to band rate, use the following formula:

$$\frac{\text{Band width}}{\text{Row width}} \times \text{Broadcast rate/acre} = \text{Band rate per acre of crop}$$

Example: If a herbicide is recommended to be applied at the rate of 2.5 pounds of 80-percent WP per acre on a broadcast basis and a grower desires to spray only a 20-inch band on 40-inch rows, the rate of product per acre would be determined as follows:

$$\frac{\text{20-inch band}}{\text{40-inch rows}} \times \text{2.5 lb. 80\% WP/acre} = \text{1.25 pounds 80-percent WP per acre of crop.}$$

Once the rate of commercial product per acre needed has been calculated, that amount should be added to the amount of water or other carrier being applied per acre. Determine the rate of carrier per acre by calibrating the sprayer before each use.

Calibration

Proper calibration of spraying equipment is a most important task often neglected in forest nurseries. Boom sprayers should be calibrated before each spray season and should be checked before each spraying. Improper calibration can result in a failure to obtain proper weed control because of insufficient herbicide application or, worse, death of seedlings because too much herbicide was used. Methods used by nursery workers to calibrate sprayers vary widely. Some calibrate equipment to within a tenth of a pound per acre, while others adjust the tractor speed while spraying until it "comes out about right."

There are many correct methods for calibrating a sprayer, but most are rather complicated. A relatively simple method is commonly called the Hundred-foot Method (Mayfield 1974). The method will work, assuming a broadcast application is used with nozzles on a 20-inch spacing. Follow these seven steps:

1. In the field, measure off 204 feet.
2. Clock the number of seconds it takes to drive the spray rig 204 feet in the gear and at the throttle setting used for spraying. Make several runs over the distance and average the time it takes. Mark the throttle setting you used.
3. With the rig standing still, engage the pump, set the throttle at the spraying position, and set the sprayer pressure. Catch the output from each nozzle for the number of seconds it took to cover the measured distance. Measure the output from several nozzles and find the average in ounces.
4. The number of ounces caught per nozzle equals the gallons of spray mixture that will be applied per acre.
5. Divide the capacity of your tank by the gallons that will be applied per acre to find the number of acres you can treat per tank of spray.
6. Multiply the recommended rate per acre for the chemical used by the number of acres treated per tank of spray.
7. To prepare the spray, fill the tank more than half full with water and pour in the right amount of chemical while the pump is running. Then finish filling the tank. When using wettable powders, make a slurry in a separate container and then add the slurry to the half-filled tank.

When calibrating a single-nozzle hand sprayer, the following method can be used. Mark off an area 5 by 20 feet (100 square feet). Fill the sprayer with water and spray the 100-square-foot area using the same speed and pressure that will be used for spraying weeds. Refill the sprayer, measuring accurately the amount of water to refill the original level. The following calculations convert the amount of water used per 100 square feet to the number of gallons used per acre.

Nozzle discharge per 100 square feet	Equivalent discharge per acre
(*ounces*)	(*gallons*)
8	27
16	55
24	82
32	109

Cleaning Sprayers

Spray equipment used to apply herbicides should always be cleaned *immediately* after each use. It is difficult to remove all traces of phenoxy (i.e., 2,4-D) compounds from sprayers, especially if the tank is rusty or if spray mixtures are left in the tank for extended periods. Because of these problems, phenoxy herbicides should *not* be used

in nursery sprayers. Suggested procedures for cleaning herbicides from spray equipment are:

Liquid Herbicides

A. Flush the entire spraying system with a detergent solution until all traces of color disappear.
B. Flush with clean water.

Wettable Powder Herbicides

A. Clean the sprayer immediately after use by flushing the entire system with clean water.
B. Remove sprayer nozzles and clean residues from screens.
C. Rinse the system with a detergent solution, followed by clean water. Replace the nozzles.
D. The herbicide label may suggest special cleaning procedures. If so, follow these recommendations.

PERSISTENCE OF HERBICIDES IN THE SOIL

The length of time that a herbicide remains in the soil is extremely important as it relates to the length of time that weed control can be expected. In addition, residual toxicity is important because of possible injury to succeeding, sensitive crops. Seven factors that affect the persistence of a herbicide in the soil are discussed below (adapted from Walker 1976).

Microbial Decomposition.—Microorganisms in the soil are able to use herbicides as sources of energy (food) and decompose the chemical or alter its structure to make it herbicidally inactive.

Chemical Decomposition.—Some herbicides disappear partly because of decomposition by chemical processes in the soil such as oxidation and hydrolysis.

Adsorption.—Some herbicides are readily adsorbed by mineral (clays) and organic colloids (organic matter) and rendered unavailable or made slowly available for plant uptake.

Leaching.—Movement of water through the soil can remove herbicides from surface layers or reduce the concentration in upper soil layers. Generally, the more water-soluble a chemical is, the easier it leaches.

Volatility.—Herbicides may evaporate and be lost to the air as a gas. The effectiveness of highly volatile herbicides is rapidly lost if they are not incorporated into the soil.

Photodecomposition.—A few herbicides are decomposed by light. If such a chemical remains on the surface of a soil for an extended period of time, it will decompose.

Rate.—High rates of application generally last longer than low rates.

POTENTIAL HERBICIDE PROBLEMS

The best general advice that can be given for the safe use of herbicides is to read and heed all instructions, precautions and restrictions on the product label. A tremendous amount of research, time, effort and money goes into obtaining information for a product label. Before the Environmental Protection Agency (EPA) will grant a label or register a herbicide for a specific use, conclusive data must be available demonstrating the product's effectiveness in controlling listed weeds, safety to the user and crop, and safety in the environment. Therefore, it is important that herbicides be used according to the label.

Failure to use herbicides according to the label may result in: *poor weed control; crop injury; soil residue problems; injury to nearby crops or plants; injury to livestock, wildlife and fish; and injury to humans.* Some of the potential problems that may occur as a result of herbicide misuse are discussed in the seven following sections (adapted from Walker 1976).

Poor Weed Control

Most of the important herbicides used in seedling production are selective, which means the herbicides will control some plants but not others. Therefore, unless the herbicides is *selected* on the *basis of the weeds it will control* and unless it is applied at the *right rate, right time* and in the *proper manner* poor weed control can be expected. For example, it would be foolish to suggest that a nursery manager use bifenox for a rhizome bermudagrass problem in pines or that he or she apply glyphosate preemergence to control crabgrass in hardwoods. Always select the herbicide on the basis of the weed and crop plants.

Seedling Injury

Injury to seedlings can be caused by a number of reasons. Fertilizers, insects, diseases, winds, nutrient deficiencies, nematodes, and abnormal weather conditions can cause stunting or injury, but it is usually herbicides which are the first to be blamed. For this reason, check plots should always be used. Leave at least a 50-foot length of bed untreated for every 4 acres. Place the untreated area in the middle of the treated section and flag it off. By using check plots, you can easily determine if a seedling abnormality is herbicide-related. The following are some common practices that can result in seedling injury:

1. Selection and use of a herbicide not labeled for the crop. (Example: bifenox on sycamore).
2. Sprayer contaminated with 2,4-D-type herbicides. Sprayers contaminated with 2,4-D or related phenoxy herbicides should not be used to apply chemicals to

the foliage or susceptible crops. Minute amounts of 2,4-D may cause serious injury to nursery crops.

3. Herbicide spray mixtures left over from spraying one crop or noncropland were left in the tank and used on susceptible crops. Leftover sprays should not be used on a crop for which that herbicide is not recommended or labeled. Sprayers should always be drained and cleaned immediately after use. If small amounts of some herbicides are left in the spray tank, serious injury can occur to a susceptible crop.
4. Sowing crops on land treated with a herbicide injurious to that crop.
5. Excessive herbicide rates. The margin of selectivity between the weeds and crop plants for a given herbicide is often small. Therefore, it is essential that correct rates not be exceeded. Some frequent causes of excessive herbicide rates are:
   A. Intentional use of high rates as a result of the philosophy if a little is good a lot is better.
   B. Improper sprayer calibration, poor agitation, poorly maintained sprayers.
   C. Using the wrong rate of herbicide for a specific soil type.
6. Improper method and time of application often result in seedling injury:
   A. Incorporation of a herbicide that should be applied to the surface of the soil. Example: incorporation of trifluralin in pine seedbeds.
   B. Application of herbicides at growth stages when the crop is particularly sensitive to the herbicide. Example: Oxyflurofen application just after nitrogen top-dressing.
7. Injury to crops may also be caused by herbicide drift or movement of herbicides from another area by washing (See figure 15-3). This is discussed in more detail in the following section.

Injury to Nearby Crops or Plants

Injury to nearby crops and plants may occur as result of spray drift, vapor drift, washing of herbicides into untreated areas, or leaching, as discussed in the four following sections.

Spray drift.—Drift hazards are greatest with herbicides that affect plant leaves. These include growth-regulator herbicides and contact herbicides such as paraquat, petroleum oils, and dinitros. Spray drift is caused by spray that has been atomized into a mist by high pressure and a small nozzle opening. Winds blowing toward susceptible plants increase the likelihood of injury from spray drift. To prevent spray drift use low pressure (10 to 30 psi for ground sprayers) and a nozzle with a large orifice, which gives a coarse spray. Do not spray if the wind is blowing toward nearby susceptible crops. Do not spray if the wind is greater than 7 miles per hour.

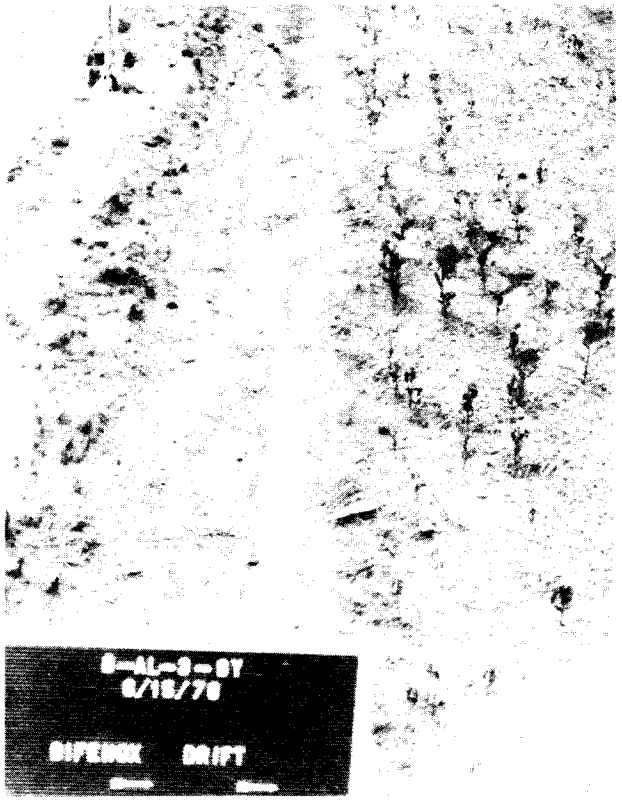

Figure 15-3.—Seedling injury from Bifenox drift

Vapor Drift.—Injury from vapor drift results when herbicides volatilize or form vapors. The vapors are moved by wind or air currents and can be carried considerable distances to injure susceptible crops.

Cleaning Spraying Equipment.—This work presents a hazard on slopes, bare ground, and pavements. The herbicide may be carried by surface runoff to valuable plants downslope. Do not drain or flush equipment where herbicides may flow onto desirable plants.

Leaching.—Chemicals may move downward through the soil. If the herbicides are readily absorbed by roots, plants whose roots extend under the treated area are likely to be injured. Herbicides such as hexazinone used for weed control in non-crop land must be used carefully around trees and shrubs because they may leach into the soil and be taken up by the roots of the desirable plants (See Figure 15-4). Do not drain or flush equipment where leaching to the roots of desirable plants may occur. Avoid treating such areas with soil sterilants.

Soil Residue Problems

Most of the herbicides used in crop production in the South do not persist from one year to the next in quantities high enough to injure susceptible crops, when used at the proper rates. Herbicide carryover from one year to the next is most often the result of excessive rates.

Some herbicides will persist from a spring or summer application in high enough amounts to injure crops planted in the fall of the same year. Late-summer herbicide applications are most likely the cause of this problem. Before fall seeding an area where a herbicide has been used in the spring or summer, read the herbicide label carefully to check for restrictions against such a use.

Figure 15-4.—Velpar damage (foliar burn on one side of the crown).

Livestock Poisoning

The chief dangers of direct livestock poisoning are from consumption of herbicide remnants in open containers and from contaminated water. Livestock should be restricted from such areas.

Adverse Effects on Wildlife and Fish

Most herbicides pose little danger to wildlife. Some, such as the organic arsenicals and dinitrophenols, however can poison animals. Most injury results from overdoses, spillage, and improper disposal.

To avoid injury to fish, do not drain or flush spray equipment where the chemicals can wash into fish ponds or streams.

Safety to Humans

Most herbicides have a low acute oral toxicity, but some are highly toxic to humans. Paraquat and sodium arsenite are very toxic and have been placed on the restricted-use list. Some herbicides are irritating and potentially dangerous, but are not hazardous if used properly and if the recommended precautions are observed. Toxicity ratings are given in table 15-3 for the commonly used herbicides. The following are general precautions that should be observed to ensure safety to humans.

1. Read the label on each container before using the contents. Follow instructions; heed all cautions and warnings. Store in closed, well-labeled containers out of reach of children and pets, and where the herbicides cannot contaminate food or water. Never store or place herbicides in unlabeled containers.
2. Avoid inhaling vapors, dusts, or spray mists. Use a respirator when specified on the container label. Poisoning is more likely to occur from concentrated materials than from diluted sprays.
3. Avoid repeated or prolonged contact of herbicides with the skin. Some individuals are hypersensitive to certain chemicals and must be especially careful to avoid allergic reactions.
4. Wash hands and face thoroughly with soap and water after each use of a herbicide. Do not eat, drink or smoke until you have washed your hands and face. Wear synthetic rubber gloves, and goggles where label instructions specify.
5. Avoid spilling herbicide concentrate on your skin, and keep it out of your eyes, nose, and mouth. If you spill any on your skin, wash it off immediately with soap and water. If you spill it on your clothing, launder the clothing before wearing it again.
6. Handle flammable chemicals with care to avoid ignition from friction, sparks, or contact with combustible materials. Several nurseries have had fires in which EC-formulated herbicides caught fire. These examples emphasize why herbicides should be kept in a separate storage building.
7. Avoid contaminating potable water supplies with herbicides.
8. Dispose of empty containers and surplus herbicide mixtures by burial at least 18 inches deep in a level, isolated area that will not contaminate water supplies, in an approved landfill, or according to specific instructions on the herbicide label. See Chapter 18 and check with local pesticide control officials for up-to-date information on proper disposal for your area.

CHEMICAL CONTROL OF WEEDS IN PINE SEEDBEDS

Fumigants and herbicides are two different groups of chemicals that control weeds in pine nurseries.

Fumigants Used

A number of soil fumigants have been used in forest nurseries (table 15-4). However, only a few are used routinely in southern pine nurseries. A 1975 survey of nurseries in the South showed that 39 used methyl bromide, 7 used Vorlex, 2 used Telone-C, 2 used a D-D mixture, and 1 used Vapam. Of these, only methyl bromide and Vapam provided any degree of weed control. See figure 15-5.

Fumigating for Annual Weeds

In general, fumigation should not be used to control annual weeds in southern nurseries. Fumigants such as Telone, D-D mixtures, and Vorlex should not be used because of insufficient weed control. Fumigants such as methyl bromide that do provide control of annuals are too expensive when compared with effective herbicides. In addition to costing about one-tenth as much as methyl bromide, herbicides are easier and safer to apply and provide at least as effective control of annual weeds.

For methyl bromide to provide effective weed control, exacting soil conditions must be met. The soil should be fine and loose with no lumps or clods. Soil temperature at the 4-inch depth should be above 60 °F. Soil moisture should be moderate (but not too wet), because the moisture content of weed seeds must be high for good control (see chapters 4 and 13).

When fumigation of the nursery is done by a contractor, special problems may arise. Often a contractor is available at the nursery for only a few days and has to fumigate the nursery under less than ideal conditions. In one case, the contractor arrived at the nursery and began fumigating, but had to stop because of a snowstorm. If fumigation is done in the spring, any delay by the contractor can delay sowing.

Remember that methyl bromide has no residual activity. Weeds will grow vigorously on fumigated soil if the area is contaminated by weed seed from straw mulches, nonfumigated soil, or by wind-carried seed.

From 1972 to 1979, nine studies at seven pine nurseries were conducted to compare weed control obtained from methyl bromide fumigation with that obtained from herbicides. All but one of the tests indicated that herbicides alone provided better weed control than did fumigation (South and Gjerstad 1980, South 1980).

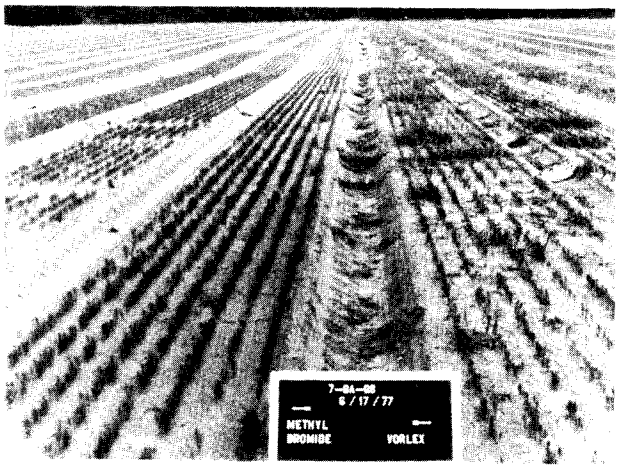

Figure 15-5.—Weed control with methyl bromide (left) and Vorlex (right).

At most nurseries, the cost of fumigation is unjustified for controlling annual grass and broadleaf weeds. However, methyl bromide can be justified when controlling high populations of nutsedge or when pathogens are a problem.

Fumigating for Perennial Weeds

When fumigating to control perennial weeds such as nutsedge, only methyl bromide with 2 percent chloropicrin should be used. With this formulation, up to 444 pounds per acre of methyl bromide may be applied. The methyl bromide formulation with 33 percent chloropicrin should not be used because only 231 pounds of methyl bromide can be legally applied (along with 119 pounds of chloropicrin). The increased dosage allowed with the 2-percent formulation provides more control of the perennial weeds.

Table 15-4.—Fumigants for control of nursery pests (Adapted from Williams and Hanks 1976)

Common fumigants	Some common trade names	Pests controlled
chloropicrin	Larvacide, Picfume	Nematodes, root rots, insects.
dichloropropene + dichloropropane	Vidden D, Nemex, D-D Mixture, Shell D-D	Nematodes, fungi
dichloropropene + dichloropropane + methyl isothiocynate	Vorlex	Root rots, damping-off
dimethylltetradrothiadiazinethione	Mylone, Cragfungicide 974, Dazomet	Root rots, damping-off
ethylene dibromide	Dowfume W-85, Soilbrom, Soilfume	Nematodes, fungi
methyl bromide + chloropicrin	Bedfume, Brom-O-Gas, Pestmaster Weedfume, Metho-O-Gas, Brozone, Dowfume MC-2, Dowfume MC-33, Terr-O-Gas	Bacteria, nematodes, fungi, weeds
dichloropropene + chloropicrin	Telone C, Telone C-17	Nematodes, root rots, damping-off
sodium *N*-methyldithiocarbamate-dihydrate	Chem-vape, Vapam, Trimaton, VPM, Mycoban	Root rots, nematodes, weeds
potassium *N*-hydroxymethyl-*N*-methyldithiocarbamate	Bunema	Fungi, nematodes, weeds

When proper soil conditions exist, effective control of perennial weeds can be obtained by fumigating in the fall or spring. However, many more days occur in the fall when conditions are proper for fumigation than in the spring. Due to frequent spring rains, some nurseries have had to fumigate with methyl bromide when soil conditions were too wet while others have had to forego fumigation altogether. Waiting for proper soil conditions in the spring can delay the sowing date. For these reasons, fall application is recommended to control perennial weeds with methyl bromide.

Herbicides

Preplant Soil-Incorporated Herbicides

When applying volatile preplant herbicides, it is important to incorporate the herbicide immediately after application. This timing prevents excessive loss of the herbicide through volatilization.

Trifluralin.—This herbicide is a member of the dinitroaniline family. Trifluralin has been used to control grass and small-seeded broadleaf weeds at a few southern nurseries. However, trifluralin mechanically incorporated into the soil can injure pine roots (Rowan 1978). For this reason, trifluralin is not recommended as a preplant-incorporated treatment. See figure 15-6.

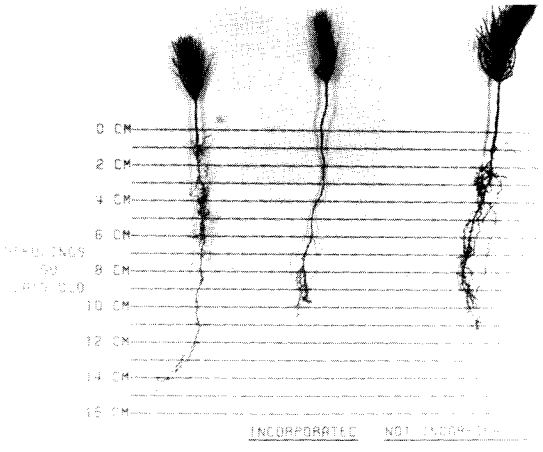

Figure 15-6.—Effect of trifluralin incorporated into the soil: left-control, center-incorporated, right-not incorporated (1.5 Lb ai/Acre).

EPTC.—This herbicide is a member of the thiocarbamate family. EPTC has been used at several nurseries where nutsedge is a problem. However, nutsedge is not controlled, but only suppressed from 4 to 6 weeks. This herbicide controls bermudagrass, but the rhizomes and stolens must be cut up thoroughly so that four or less nodes remain on a strand. One reason EPTC is not popular with southern nursery managers is because a 2-week waiting period is required before seeding. Earlier sowing after treatment may result in injury to pine seedlings (Rowan 1959).

Preemergence Herbicides

In forest nurseries, it is much easier to control germinating weed seeds with a preemergence herbicide than it is to control established weeds with a contact herbicide. It is important to use an effective preemergence herbicide because the most critical period for weed control is during the first 5 to 6 weeks of seedling establishment.

There are several times during the sowing process when herbicides can be applied: (1) after bed shaping and before sowing and mulching, (2) after sowing but before mulching, and (3) after mulching. In some years, applying the herbicide before mulching may increase weed control. At the Pinson Nursery, bifenox at 3 pounds ai per acre was sprayed on top of sawdust mulch in 1974 and 1975 (South et al 1978). During each year, heavy rains after application washed much of the mulch off the beds and along with it the herbicide. Weed control from this treatment was 7 percent in 1974 and 8 percent in 1975. In 1976 and 1977, the herbicide was applied after sowing, but before mulching. Weed control was improved from this treatment to 90 percent in 1976, and 76 percent in 1977.

In 1978, tests were established to compare weed control obtained from bifenox applied before and after mulching. The study was conducted with sawdust mulch at the Pinson Nursery and with hydromulch at the Baucum Nursery. At both nurseries, better weed control was obtained when the herbicide was applied before mulching. At the Pinson Nursery, weed control was increased from 40 to 64 percent, thereby reducing the handweeding requirement per acre by 120 manhours. At the Baucum Nursery, weed control was increased from 95 to 99 percent and handweeding was reduced by 183 manhours per acre. Reasons for the improvement in weed control are believed to be (1) less herbicide is absorbed by the mulch, and (2) less herbicide is washed off the seedbed with the mulch.

Oxyfluorfen.—This herbicide is a member of the diphenylether family. Oxyfluorfen can provide excellent control of most annual grass and broadleaf weeds, but does not control nutsedge, rhizome bermudagrass or sicklepod. A 1/2 pound ai per acre rate usually provides from 4 to 7 weeks of weed control (South and Gjerstad 1980). Because oxyfluorfen does not leach, it forms a thin chemical barrier to germinating weeds. If this chemical barrier is broken by tractor tires or other devices that disturb the soil, untreated soil will be exposed and weed growth can occur. This herbicide may provide better weed control when applied before mulching.

Bifenox.—This herbicide belongs to the diphenylether family. Bifenox provides good control of most broadleaf weeds, but is weak on grasses and does not control nutsedge, bermudagrass, or sicklepod. The 3 pound ai per acre rate usually provides from 4 to 5 weeks of weed control (South et al 1978). Like oxyfluorfen, bifenox does not leach and forms a chemical barrier that should not be broken. This herbicide can provide better weed control if applied before mulching.

Napropamide.—This herbicide is a member of the substituted-amide family. Napropamide provides excellent control of many annual grasses and has been used in combination with bifenox to increase the spectrum of weed control. A tank mix of napropamide at 1 pound ai per acre with 3 pounds ai per acre of bifenox has been used at a number of nurseries with excellent results. However, napropamide has also injured seedlings at several nurseries having low soil organic matter. Because napropamide will leach in soils and can inhibit root growth, do not use it on soils having less than 1 percent organic matter. Napropamide should be applied after mulching.

Diphenamid.—This herbicide belongs to the substituted-amide family. Diphenamid provides fair to poor weed control of annual grasses. Because leaching of this material is enhanced with the frequent irrigation during early seedling establishment, weed control lasts only a few weeks. Because cheaper, more effective herbicides are available, diphenamid is no longer used in southern pine nurseries.

Prometryn.—This herbicide is a member of the triazine family. Prometryn can provide good control of several grass and broadleaf weeds and has been used at a number of nurseries in the past. However, because of a lack of tolerance, millions of pine seedlings have been killed with preemergence applications of prometryn. Germination of seedlings is not affected, but once the seedlings are established, the roots absorb prometryn (which has leached into the root zone and is translocated to the needles). Photosynthesis is inhibited, and the needles turn brown at the tips and continue to die until the entire seedling is brown. On fine-textured soils, most pines tolerate prometryn at 1 pound ai per acre. However, this rate has caused injury on sandy-textured soils with low organic matter. Because of its limited registration and the potential injury to seedling production, this herbicide has very limited use in the South.

Perfluidone.—This herbicide has been used at several nurseries where nutsedge is a problem. Excellent control of both yellow and purple nutsedge has occurred at nurseries with low soil pH. Soil pH does affect the activity of perfluidone and may explain the erratic control which is sometimes observed. Perfluidone inhibits the germination of the nutsedge tubers and, therefore, should be applied before the tubers sprout. Loblolly and slash pine are usually tolerant at 1.5 pound ai per acre, but injury to these species has occurred. Shortleaf pine seedlings are very sensitive to perfluidone and should not be treated. Perfluidone should only be used in areas known to be heavily populated with nutsedge and, if possible, only very tolerant species such as longleaf pine should be planted. Because of limited demand for this product, the 3M Company is no longer marketing perfluidone.

Postemergence Herbicides

Postemergence applications are made after the emergence of pine seedlings. There are two types of postemergence applications: (1) those made before weed emergence, and (2) those made after weed emergence. Herbicides that control germinating weed seeds should be applied before the weeds emerge. This type of application is preferred because it is much easier to control germinating weed seeds than to kill established weeds. When making applications after weeds have emerged, use a herbicide that has contact activity. In addition, the size of the emerged weeds should be less than 1 inch because most weeds become more tolerant to herbicides as size increases.

Oxyfluorfen.—This herbicide is a member of the diphenylether family. Oxyfluorfen has contact as well as preemergence activity. It will control most annual weeds, but will not control nutsedge or bermudagrass. One to three postemergence applications of oxyfluorfen at 1/2 pound ai per acre per application should suffice for most southern nurseries. The first postemergence application should be made 5 to 7 weeks after pine germination. If needed, a second application can be made 10 to 14 weeks after germination. A third application may not be needed at nurseries with few weeds. However, some nursery managers may wish to use a third application 15 to 21 weeks after pine germination.

To obtain the best possible weed control from oxyfluorfen, apply it before weed germination. Oxyfluorfen does have contact activity on small weeds, but weeds will be increased if a surfactant is used and the weeds are no higher than 3 inches. Applying the herbicide after sundown may also increase contact activity on some weed species.

Needle burn (a browning of new needles around the terminal) has occurred with postemergence applications of oxyfluorfen at some nurseries. The injury is usually cosmetic, and seedlings quickly grow out of this condition. The injury normally occurs on the young, succulent tissue that is less than a week old. Nitrogen application can stimulate the growth of the pine seedlings and more succulent tissue is produced. Therefore, to avoid injuring this succulent growth, oxyfluorfen should be applied before nitrogen applications.

Bifenox.—This herbicide belongs to the diphenylether family. Bifenox has both contact as well as preemergence activity on annual, broadleaf weeds. Control of annual

grasses is weak, and nutsedge and bermudagrass are not controlled. Two or three postemergence applications of bifenox at 2 pounds ai per acre per application would be enough for most southern nurseries. Make the first postemergence treatment 4 to 5 weeks after pine germination. The second treatment can be applied 8 to 10 weeks after germination, with the third application at 12 to 15 weeks, if needed.

Apply bifenox before weed germination to obtain the best possible weed control. Bifenox has some contact activity on small, broadleaf weeds, but the best control is obtained by inhibiting weed emergence. When controlling emerged weeds, the use of a surfactant will slightly increase contact activity on weeds less than 2 inches tall. Applying the herbicide after sundown may also increase contact activity on some weed species such as common purslane.

Prometryn.—This herbicide is a member of the triazine family. Prometryn has both contact and preemergence as well as postemergence activity on several grasses and broadleaves. This herbicide can control certain weeds such as sicklepod and prostrate spurge, which are hard to control with diphenylether herbicides. Because pines are not highly tolerant of this herbicide, only one postemergence application of 1 pound ai per acre should be used on seedlings that are at least 6 weeks old after germination. The use of a surfactant can increase the contact activity of this herbicide. Several nurseries have reported injury with this herbicide and thousands of pine seedlings have been killed with postemergence applications of prometryn. Injury symptoms are similar to those discussed for a preemergence application of prometryn. Because of limited registration and because of the potential injury to seedling production, this herbicide is used only to a very limited extent in southern nurseries. See figure 15-7.

Figure 15-7.—Seedling mortality from prometryn applied at 2 pounds per acre.

Trifluralin.—This herbicide belongs to the dinitroaniline family. Trifluralin gives preemergence control of several grasses and small-seeded broadleaf weeds, but it has no contact activity. This herbicide is safe for use on established pines (seedlings established 6 weeks after germination) at the 1-pound ai per acre rate, but must be applied before the weeds germinate. Because trifluralin is a volatile compound, apply it in the cooler part of the day, and irrigate immediately afterwards to incorporate the herbicide into the soil. Weed control using this method of application often varies and poor control can result. Because more effective herbicides are available, trifluralin is not presently used in southern pine nurseries.

Oxadiazon.—The granular form of this herbicide offers preemergence control of many grasses and broadleaf weeds. The liquid form can injure young pines and should not be used in southern nurseries. This herbicide can provide excellent weed control, but because the cost is about 5 to 10 times higher than other effective herbicides, this product is not used in southern pine nurseries.

Glyphosate.—This systemic herbicide controls troublesome, perennial weeds such as nutsedge and bermudagrass. Glyphosate offers no preemergence control because it is inactivated with soil contact. The perennial weeds should be actively growing and have at least 4 to 8 leaves when treated so translocation into the plant can occur. Very early treatment of perennial vegetation may reduce the weed control. Better results have been obtained when treating perennials at or near full maturity. Annual weeds are controlled regardless of growth stage.

The primary use of glyphosate in southern nurseries has been with directed spot applications. This use controls perennial weeds such as nutsedge. Young southern pines cannot tolerate glyphosate and are killed upon contact with the herbicide. Pines in northern nurseries can tolerate low rates of glyphosate (Abrahamson 1980). In nurseries in Kentucky and Tennessee, white pine seedlings in their second growing season have survived broadcast applications of glyphosate. However, because of a lack of tolerance, the herbicide label states that glyphosate should not be broadcast in forest nurseries.

Mineral Spirits.—These contact herbicides belong to the petroleum oil family. They provide no preemergence control. However, when introduced as a selective herbicide in pine nurseries, handweeding costs were reduced by as much as 90 percent (Cossitt 1947). They provide excellent control of small, annual grasses and broadleaf weeds. Good suppression of nutsedge and bermudagrass has been achieved at a number of nurseries. Use of this herbicide has virtually eliminated johnsongrass (*Sorghum halepense* (L.) Link) from southern nurseries.

Application methods and rates used have varied widely among nurseries. In general, weekly or twice weekly applications are required, with rates of 15 to 25 gallons per acre. For mineral spirits to be effective, they must contain a minimum of 15 percent aromatic hydrocarbons. Different brands contain different levels of aromatic hydrocarbons, and some nurseries have bought and used

brands without aromatics, which provided no weed control. Several guidelines exist for use of mineral spirits (Stoeckeler 1949, Wakeley 1954, Cossitt 1959, Draper 1974). Pines usually tolerate mineral spirits, but injury in the form of tip burning can occur (Cossitt 1959) as well as death of seedlings (Stoeckeler 1949, Wakeley 1954).

In 1974, when costs were 35 to 40 cents per gallon, Draper (1974) stated that "Mineral spirits is no longer a cheap commodity." Since then, the cost has quadrupled and will continue to rise with the price of oil. For this reason, use of mineral spirits in southern nurseries has dropped drastically.

CHEMICAL CONTROL OF WEEDS IN COVER CROPS

Weed control in cover-cropped areas should not be neglected. The amount of weed seeds present in seedbeds will be related to the number of mature weeds in the previous cover crop. In the South, most herbicides that can be used in cover crops have no effect upon the following years' seedling growth.

Cover-crop rotation provides an excellent opportunity to control weeds that are resistant to herbicides used in seedbeds. For example, if only diphenylether herbicides like oxyfluorfen were continually used on an area, resistant-weed species such as prostrate spurge could rapidly increase. However, by using a herbicide from a different herbicide family (such as atrazine) in the cover crop area, the spread of prostrate spurge could be checked because it is susceptible to most triazine herbicides.

Recommendations for using herbicides in cover crops vary depending upon the region and weed species to be controlled. Specific recommendations on herbicides and rates used can be obtained from the local extension service. Some of the herbicides used for cover crops in southern nurseries are listed below:

Sorghum or Sorghum-sudan

Atrazine.—This herbicide is a member of the triazine family. Atrazine controls many annual, broadleaf weeds and some grasses. Apply atrazine after the crop has completely emerged and weeds are no taller than 1½ inches.

Propazine.—This herbicide belongs to the triazine family. Propazine controls most annual, broadleaf weeds and grasses. Apply propazine at sowing time or immediately after sowing, but before weeds and crops emerge. Do not use it on sands or loamy sands.

Corn

Butylate.—This herbicide belongs to the thiocarbamate family. Butylate provides good control of most annual grasses and can suppress the growth of nutsedge. However, it is weak on most broadleaf weeds. This herbicide should be mechanically incorporated immediately after application.

EPTC.—This herbicide is another member of the thiocarbamate family, and offers the same control as butylate. However, EPTC also suppresses the growth of bermudagrass as well as nutsedge.

Atrazine.—This herbicide belongs to the triazine family. Atrazine controls many annual broadleaf weeds and some grasses. As a preemergence treatment it can control cocklebur, morningglory, and sicklepod. Atrazine can be incorporated in the soil before sowing, applied in a preemergence treatment after sowing, or its use delayed up to 3 weeks after sowing, but before weeds are 1½ inches tall. This herbicide is often used as a tank mix with butylate or EPTC to increase the spectrum of weeds controlled.

Alachlor.—This herbicide belongs to the acetanilide family. Alachlor controls most annual grasses and some small-seeded, broadleaf weeds. This product does not effectively control cocklebur or morningglory. Apply alachlor during or immediately after sowing. Irrigation or a shallow cultivator can improve control.

Metolachlor.—This herbicide is a member of the acetanilide family. Metolachlor is very similar to alachlor, but appears to be more effective on yellow nutsedge.

CHEMICAL CONTROL OF WEEDS ON RISERLINES

At many nurseries, the beds with the most weeds are adjacent to the riserlines. Weed growth on these areas is often left unchecked until operation of the irrigation lines is impaired or the area becomes unsightly. Weed-free riserlines are characteristic of a well-managed nursery. Use an appropriate preemergence herbicide such as oxyfluorfen, at 1 pound ai per acre soon after the seedbeds are formed. Later in the season, if perennial weeds appear, spray them with an appropriate systemic herbicide such as glyphosate. Shields can be fashioned on spray rigs to prevent drift that could injure young seedlings. Herbicides with soil persistence of more than 1 year should be avoided because cultivation often moves soil from the riserlines into seedbeds.

WEED CONTROL ON FENCEROWS AND NONCROP LAND

Mature, seed-producing weeds often grow along fencerows, ditch banks, and around buildings. These areas are best kept weed-free by regular cultivation, mowing or nonselective herbicides such as glyphosate or hexazinone. If this is impractical because of excessive erosion, a thick perennial vegetative cover could be established. Managed properly, this cover would exclude other

weeds while not producing unwanted seeds or vegetative parts (Aldhous 1972).

MECHANICAL CULTIVATION

Millions of southern pine seedlings have been mechanically cultivated in the past with more or less satisfactory results (Wakeley 1954). Because of narrow row spacing, seedlings were often destroyed by cultivation, and injuries and diseases increased. For these reasons, mechanical cultivation of southern pine seedbeds is no longer practiced. Mechanical cultivation becomes more feasible when row spacing is wider, such as with hardwoods. For the past 20 years, Stanley (1970) has mechanically cultivated hardwoods grown in 36-inch rows. At the Natchez Nursery in Mississippi, hardwoods are planted in four rows to the bed and rotary hoes are used to cultivate between the rows. Several types of seedbed and alleyway cultivators are available (Lowman and McLaren 1976).

PREVENTIVE WEED CONTROL

To maintain a relatively weed-free nursery, follow a comprehensive year-round weed control program. Successful weed control programs are based upon prevention. Insure that new weed seeds do not enter the nursery in contaminated mulches, with cover-crop seeds, or on machinery. Prevent weeds in the nursery from going to seed, or from spreading vegetatively.

Preventing the Introduction of Weeds

In 1975, several nurseries used methyl bromide to fumigate soil on more than 70 percent of their production area. Because introduction of new weed seeds was not prevented, these same nurseries spent more than $900 per acre for handweeding.

Mulches

A main source of introduced weeds is straw mulches (Mullin 1965, Bland 1973, South 1976). Bland (1973), evaluating the cost of mulching materials in loblolly pine seedbeds, compared pine straw with several other natural and synthetic mulches. Pine straw mulch on the average increased weeding times by 105 man-hours per acre. At $3 per hour for hand labor, this work amounted to an extra cost of $315 per acre.

In hardwood seedbeds, the additional weeding cost is even greater because chemical weed control has limited use. In one study on sycamore and sweetgum seedbeds, unmulched plots were compared with plots mulched with pine straw (South 1975). The pine-straw mulched areas required 200 more man-hours of handweeding per acre (an additional expense of $600 per acre). The advantage of soil fumigation with methyl bromide (costing $500 per acre) was lost when the weed-contaminated mulch was used. See figure 15-8. A few authors recommend that mulch be fumigated to eliminate weed seeds and pathogens (Carter and Martin 1967, Geron 1974). See appendix 6-1.

Figure 15-8.—Hand-weeding is necessary on beds mulched with nonfumigated pine straw.

In 1976, experiments involving fumigated and nonfumigated pine straw mulch on both fumigated and nonfumigated nursery soil were carried out at the Miller and Hauss Nurseries in Alabama. Methyl bromide was applied to plastic-covered mulch piles at the rate of 1 pound per 20 cubic feet. After 48 hours, the plastic was removed and the mulch piles were allowed to air. Half of the 50 × 6 foot plots were fumigated at the rate of 1 pound of methyl bromide per 100 square feet.

At the Miller Nursery, fumigating the mulch reduced the weeding time by 58 percent (South 1976). Fumigating the soil resulted in only a 28-percent reduction in weeding time. It appears that at this location most of the weed seeds were not soilborne, but were introduced in the pine straw mulch. At the Hauss Nursery, fumigating the mulch controlled weeds as effectively as did soil fumigation. Although providing the same amount of weed control, soil fumigation costs about $450 more than mulch fumigation. The cheapest method of controlling weeds at both nurseries involved the use of herbicides, but several weed species not controlled by herbicides would be controlled by fumigating the mulch with methyl bromide.

These experiments showed the introduction of weeds by pine straw mulch to be a significant factor. To prevent increased weeding, fumigation of weed-infested mulches or substitution of sterile mulches should be considered. Fumigation of straw mulches is especially important when growing hardwoods because herbicide use is limited. Nursery managers who use wood chips, bark,

or sawdust mulches, which are relatively free of weed seeds, should stockpile the material in a weed-free area.

Other Sources of Weeds

Irrigation Water.—Irrigation water can be a major source of introduced weeds when the water comes from a lake, pond, or river. Use screens at the intake pipe to help keep 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. If you irrigate from ponds, keep the pond edges free of weeds. When installing a new nursery, a deep well is preferred over surface water sources.

Cover-Crop Seeds.—Take care to prevent sowing weed seeds along with cover-crop seeds. Such infestations can be prevented by always using certified seed. At one nursery, the use of cheap, uncertified seed resulted in a large infestation of morningglory. 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. Buy seeds with the lowest percentage of common weeds. Savings cannot result from the use of cheaper, uncertified seed.

Machinery.—Weed seeds, rhizomes and tubers are easily introduced by machinery. Frequently washings reduce the amount of weed seed introduced by soil carried on tillage equipment, tractors, and tractor tires. Weed seeds are often spread by combines used for harvesting cover crops. For this reason, it is better to leave cover crops unharvested unless combines are carefully cleaned before use.

Wind.—Wind will constantly introduce weed seeds, but the impact may be reduced by planting windbreaks between the nursery and adjacent sources of weeds, such as farmlands. 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.

Preventing Weeds from Going to Seed

Preventing weeds from going to seed in the nursery is an important management practice. Weed populations of 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 can produce over 52,000 seeds, a single redroot pigweed 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. Weeds must be prevented from going to seed not only in the seedbeds, but also on the riserlines, fence rows, cover crop areas, and fallow areas.

Preventing the Spread of Nutsedge

Nutsedge is the most troublesome, vegetatively-reproduced weed in southern forest nurseries. Yellow nutsedge and purple nutsedge occur as problem weeds in more than half of the southern nurseries. Successful control of these weeds depends upon prompt treatment because a severe infestation can quickly result from failure to control even a single plant. One tuber of purple nutsedge, planted in a loam soil in the spring, had produced 1,168 plants and 2,324 tubers after 6 months (Ishii, Yamai and Manabe 1971).

Dissemination by Cultivation.—Nutsedge spreads slowly by vegetative means alone. The weed would spread less than 10 feet per year without help from nursery workers and their cultivation equipment (Klingman and Ashton 1975). For this reason, special efforts should be made to treat separately each area infested with nutsedge. Map infested areas in the summer to help identify the areas in which to avoid soil movement (thus spreading nuts) in the winter after lifting. Nutsedge-free areas should be cultivated first to avoid the introduction of tubers. Time taken to prevent mechanical dissemination of nutsedge tubers will be repaid several-fold in the ease of eliminating nutsedge from a nursery.

Chemical Control.—In the past, methyl bromide and EPTC have been used to attempt to control nusedge. Although methyl bromide often reduces large numbers of weeds, the cost is high and some tubers always seem to escape treatment. EPTC seems only to delay the emergence of nutsedge.

Experiments with chemicals such a perfluidone, sodium azide, and cyperquat have shown promise for controlling nutsedge in pine seedbeds, but these chemicals are not yet registered for this use. Glyphosate has been shown to control nutsedge better than perfluidone, sodium azide, or cyperquat (Barr and Merkle 1976). This postemergence herbicide can be used on noncroplands. With proper use, the active ingredient will translocate downward and kill the nutsedge tubers.

One way to eradicate nutsedge in a nursery is by allowing infested areas to lie fallow in the spring. When actively-growing nutsedge has reached the four- to six-leaf stage, apply glyphosate at 2 quarts per acre (2 pounds ai per acre) on a warm, cloudless morning when rain is not expected for at least 12 hours. Initial activity is fairly slow after application and may not be observed for several days. Cultivate the area 2 weeks after treatment to bring any late-germinating, deep-rooted tubers to the surface. Allow these tubers to sprout and encourage their growth by irrigation during dry periods. Make a second application of glyphosate in the same manner as the first.

Kill occasional nutsedge plants with a backpack sprayer or hand applicators. When using glyphosate, do not use galvanized spray equipment. Sowing pines or hardwoods

after treatment is completely safe because the herbicide is inactivated by contact with the soil.

SUMMARY

Many forest nursery managers in the South fail to follow a comprehensive weed prevention program. They place more emphasis on the use of fumigation and herbicides than on *preventing* the introduction, reproduction, and spreading of weeds. This is evidenced by the large hand-weeding requirements of nurseries when prevention is not practiced. In 1975, 80 percent of the State nurseries in the South required more than 90 hours of hand-weeding per acre. In general, industry-owned nurseries have more comprehensive weed control programs. Only 35 percent of the industry-owned nurseries in the South required more than 90 hours of hand-weeding labor per acre in 1975.

It is no easy job to transform a nursery from 300 hours of handweeding per acre to less than 90. Nursery managers must adhere strictly to a comprehensive year-round weed control program that prevents the introduction, reproduction, and spread of weeds. Even with these efforts, several years may be required to deplete the reservoir of weed seeds in the soil. Nursery managers who are successful, however, will be able to produce more uniform, high quality seedlings at a lower cost.

REFERENCES

Abrahamson, L.P. Glyphosate, a selective herbicide in conifer seedbeds. In: Abstracts, 1980 Meeting of the Weed Science Society of America, Toronto, Canada. Champaign, IL: Weed Science Society of America; 1980: 52.

Aldhous, J.R. Nursery practice. London: Her Majesty's Stationary Office; 1972. 184 p.

Barr, Garland; Merkle, M.G. Weed control in a pine seedling nursery. In: Proceedings of the Southern Weed Science Society, Twenty-Ninth Annual Meeting, Dallas, Texas. 1976: 258-261.

Bland, W.A. Study to evaluate the effects and costs of mulching materials in loblolly pine seedbeds. Forestry Note No. 3. Raleigh, NC: North Carolina Forest Service; 1973.

Carter, Mason C.; Martin, James W. Chemical weed control in southern forest nurseries. Circular 156. Auburn, AL: Auburn University Agricultural Experiment Station; 1967. 12 p.

Chandler, J.M.; Filer, T. H. New applicators for weed control in forest nurseries and plantations. In: Proceedings, 1980 Southern Nursery Conference. Technical Publication SA-TP 17. Atlanta, GA: U.S. Department of Agriculture, Forest Service, Southwestern Area; 1980: 68-72.

Cossitt, F.M. Mineral spirits as a selective herbicide in southern pine seedbeds. Southern Lumberman 175 (2201): 203-204; 1947.

Cossitt, F.M. The use of mineral spirits as a herbicide in forest nurseries. In: Proceedings, Southern Region Nurserymen's Training Meeting. Atlanta, GA: U.S. Department of Agriculture, Forest Service, Southern Region; 1959: 106-108.

Draper, Lee. Mineral spirits. In: Proceedings, Southeastern nurserymen's conferences, eastern session/western session. Atlanta, GA: U.S. Department of Agriculture, Forest Service, Southeastern Area; 1974: 138-142.

Geron, Clyde. Mulch. In: Proceedings, Southeastern nurserymen's conferences, eastern session/western session, Atlanta, GA: U.S. Department of Agriculture, Forest Service, Southeastern Area; 1974: 108-110.

Hauser, Ellis W. Development of purple nutsedge under field conditions. Weeds. 10(4): 315-321; 1962.

Ishii, K.; Yamagi, K.; Manabe, T. Development and chemical control of purple nutsedge in the forest nursery. Weed Research, Japan, No. 12: 45-49; 1971.

Klingman, Glenn C.; Ashton, Floyd M. Weed science: Principles and practices. NY: John Wiley and Sons; 1975. 431 p.

Lowman, Ben J.; McLaren, Jan. Nursery equipment catalog. Missoula, MT: U.S. Department of Agriculture, Forest Service, Equipment Development Center; 1976. 111 p.

Mayfield, William. Field sprayer equipment and calibration. Circular No. R-11. Auburn, AL: Auburn University, Agricultural Experiment Station; 1974. 18 p.

Mullin, R.E. Effects of mulches on nursery seedbeds of white spruce. The Forestry Chronicle. 41(4):454-465; 1965.

Radford, Albert E.; Ahles, Harry E.; Bell, C.R. Manual of the vascular flora of the Carolinas. Chapel Hill, NC: University of North Carolina Press; 1968. 1,183 p.

Rowan, S.J. Eptam - weed control. In: Proceedings: Southern Region nurserymen's training meeting. Atlanta, GA: U.S. Department of Agriculture, Forest Service, Southern Region; 1959: 80.

Rowan, S.J. Treflan injury of loblolly pine seedlings. Tree Planters' Notes. 29(3):25-26; 1978.

South, D.B. The determination of nursery practices for the production of quality sweetgum (Liquidmbar styraciflua L.) and sycamore (Platanus occidentalis L.) planting stock. Raleigh, NC: North Carolina State University; 1975. 91 p. M.S. thesis.

South, David. Pine straw mulch increases weeds in forest tree nurseries. Agricultural Experiment Station, Auburn University. Highlights of Agricultural Research. 23(4):15; 1976.

South, David. Weed control with herbicides or fumigation at a forest nursery. Agricultural Experiment Station, Auburn University. Highlights of Agricultural Research. 27(1):14; 1980.

South, David B.; Gjerstad, Dean H. Nursery weed control with herbicides or fumigation—an economic evaluation. Southern Journal of Applied Forestry. 4(1): 40-45; 1980.

South, David B.; Gjerstad, Dean H. Oxyfluorfen: An effective herbicide for southern pine nurseries. Southern Journal of Applied Forestry. 4(1):36-39; 1980.

South, D.B.; Gjerstad, D.H.; Campbell, S.J. Comparison of methyl bromide and herbicide effects on endomycorrhizal formation, seedling production, and weed control in sweetgum seedbeds. European Journal of Forest Pathology. 10: 371-377; 1980.

South, David B.; Gjerstad, Dean H.; Crowley, R. Hugh. Bifenox: A promising new herbicide for southern pine nurseries. Southern Journal of Applied Forestry. 2(1):11-14; 1978.

South, David B.; Gjerstad, Dean H.; White, Terry E. Effects of bermudagrass on production of loblolly pine seedlings in a Louisiana nursery. Tree Planters' Notes. 29(4):20; 1978.

Stanley, Howard. Hardwood weed control. In: Proceedings, southeastern nurserymen's conferences. Atlanta, GA: U.S. Department of Agriculture, Forest Service, Southeastern Area; 1970: 60-61.

Stevens, O.A. The number and weight of seeds produced by weeds. American Journal of Botany. 19(9): 784-794; 1932.

Stoeckeler, J.H. Control of weeds in conifer nurseries by mineral spirits. Station Paper No. 17. St. Paul, MN: U.S. Department of Agriculture, Forest Service, Lake States Experiment Station; 1949. 23 p.

University of Georgia. Weeds of the southern United States. Athens, GA: University of Georgia, Cooperative Extension Service; 1975. 42 p.

Wakeley, Philip C. Planting the southern pines. Agric. Monograph No. 18. Washington, DC: U.S. Department of Agriculture; 1954. 233 p.

Walker, R.H. Summary of weed control principles, methods, material, terminology, and potential problems. Auburn, AL: Alabama Cooperative Extension Service, Auburn University; 1976. 29 p.

Weed Science Society of America. Common weed seedlings of the United States and Canada. Champaign, IL: Weed Science Society of America; 1979, 31 p.

Wilkinson, R.E.; Jaques, H.E. How to know the weeds. 2d ed. Dubuque, IA: Wm. C. Brown Publishers; 1972. 232 p.

APPENDIX 15-1—DEFINITION OF TERMS

The following definitions are to be used as an aid to better communication and understanding of terms used in nursery weed control.

Active ingredient (ai).—The agent in a product primarily responsible for the intended herbicidal effects; the active ingredient is shown on the herbicide label.

Annual.—A plant that completes its life cycle from seed in 1 year, and then dies.

Band treatment.—Applied to a continuous restricted area such as on or along a crop row rather than over the entire field area.

Contact herbicide.—A herbicide that causes localized injury to plant tissue where contact occurs.

Directed application.—Precise application to a specific area or plant organ such as to a row or bed, or the leaves or stems of plants.

Early postemergence.—Herbicide application after emergence during the initial growth phase of crop or weed seedlings.

Emergence.—The visible, emerging phase of the specified crop or weed.

Emulsifiable concentrate.—A single-phase liquid system having the property of forming an emulsion when mixed with water.

Flowable formulation.—A two-phase concentrate that contains solid herbicide suspended in liquid that is capable of suspension in water.

Foliar application.—Application of a herbicide to the leaves or foliage of plants.

Fumigant.—A volatile, chemical disinfectant which, as a gas or vapor, kills destructive animals and plants. Methyl bromide and other fumigants are often referred to as herbicides, but should properly be called soil fumigants because they also control fungi, insects and nematodes.

Granular.—A dry formulation of herbicide and other components in discrete particles generally smaller than 10 cubic milimeters.

Herbicide.—A chemical used to control, suppress, or kill plants or severely interrupt their normal growth processes.

Late postemergence.—Applied after the specified crop or weeds are well established.

Nonselective herbicide.—A chemical that is generally toxic to plants without regard to species. Toxicity may be a function of dosage, method of application, etc.

No-till.—Planting of crop seeds directly into stubble or sod with no more soil disturbance than is necessry to get the seed into the soil.

Perennial.—A plant having a life span of more than 2 years.

Postemergence (POE).—Applied after emergence of the specified weed or planted crop.

Preemergence (PE).—Applied before emergence of the specified weed or planted crop.

Preplant application.—Applied on the soil surface before seeding or transplanting.

Preplant soil-incorporated (PPI).—Applied and tilled into the soil before seeding or transplanting.

Selective herbicide.—A chemical that is more toxic to some plant species than to others.

Spot treatment.—A herbicide applied over small restricted area(s) of a whole unit, i.e., treatment of spots or patches of weeds within a larger field.

Surfactant.—A material that favors or improves the emulsifying, dispersing, spreading, wetting or other surface-modifying properties of liquids.

Tank-mix combination.—Mixing of two or more pesticides or agricultural chemicals in the spray tank at the time of application.

Tolerance.—Magnitude or capacity to withstand herbicide treatment without marked deviation from normal growth or function.

Translocated herbicide.—A herbicide that is moved within the plant. Translocated herbicides may be either phloem-mobile or xylem-mobile, but the term is frequently used in a more restrictive sense to refer to herbicides that are moved in the phloem.

Weed.—A plant that is not normally cultivated and grows where we wish other (or no) plants to grow and has some physical or economic implication for man.

Wettable powder.—A finely-divided dry formulation that can be readily suspended in water.