Chapter 2

SELECTING, USING, STORING, AND DISPOSING OF HERBICIDES

Section A—Selecting Herbicides

2-1. Analyzing the Situation:

a. Chemical control of a mixed population of weeds and brush requires a herbicide or a mixture of herbicides to which the many species on a site are susceptible. Therefore, it is important to know the kinds of weeds that are present and the herbicides that will control them. Identifying the main species in the population is the first requirement.

b. The response of a plant to an application of a herbicide depends not only on the species but also on the age of the plant, the rate of application, and the soil and climatic environment in which the plant is grown. Seedlings are killed most easily—even seedlings of some resistant species are killed. Many plants become more tolerant to a herbicide as they grow older. Some perennials are most easily killed when in bloom. Woody plants may be more susceptible to one method of application than to another. A weed may be more susceptible to a herbicide if treated at the optimum time, with the optimum rate, and under the optimum environmental conditions, but may be more tolerant under conditions that are less favorable for control.

c. Selection of herbicide, in addition to controlling the weeds, must also fulfill other criteria. Is it cost effective? Does the herbicide kill all the vegetation, or does it selectively leave some types of plants in the area? Methods of application, modes of action of the herbicide, and effects on the ecology of the area are important considerations. What are the hazards of drift or runoff water from treated areas to nearby desirable plants or other biota?

2-2. Choosing a Formulation. Formulations make an important contribution to the efficacy of herbicides and to their ease of use in the field.

a. Emulsifiable concentrates and wettable powder formulations are readily dispersed in a water carrier, but require agitation during the spraying operation. Water-soluble salts, water-miscible liquids, and water-soluble powders normally do not require agitation. Granular materials are applied with granular pesticide spreading equipment, modified fertilizer spreaders, or by hand.

b. One of the most important properties of granular and pelletted herbicides is their physical selectivity. The particles tend to bounce off dry foliage and other plant parts to the soil or to settle to the bottom of ponds, lakes, and other bodies of water. This enhances the chemical selectivity of the herbicides when used on growing crops or on submersed aquatic weeds. Granules and sprays of many herbicides are equally effective on germinating weed seed in soil. However, when a herbicide is applied as a spray, it is often intercepted by foliage, and its effectiveness in killing germinating weed seeds in the soil is reduced. Granular herbicides frequently have been used because of the scarcity of clean water supplies for spraying in many areas and the need for extra labor and equipment for water hauling.

c. Granular herbicides are of special interest for ornamental plantings because their physical selectivity helps to broaden the use of a few effective herbicides to cover a relatively large number of plant species. That is, sprays of some herbicides would injure plant foliage whereas the herbicide in granular form does not. Therefore, they have been used rather extensively in horticultural plantings after clean cultivation. Granules also fill a specific need in transplanted ornamental crops where preemergence herbicide treatments cannot be used. As a matter of convenience, granular herbicides have also been used extensively in preplant soil-incorporated treatments and preemergence treatments of ornamental plantings.

d. Each herbicide, whether used in spray or granular form, is most effective if used by a certain application technique under specific climate and soil conditions. Recommendations prepared by weed research specialists in state agricultural experiment stations and by the individual manufacturers of herbicides outline these necessary conditions and techniques.

2-3. Comparing Costs. The carrier components contained in herbicide formulations, such as emulsifiers, solvents, and other adjuvants, often improve mixing, spraying, and weed-control results, but the cost of the herbicide largely depends on the amount of phytotoxic chemical that it contains.

a. One of the guides to use in comparing the costs of herbicides is the price per pound of active chemical. The costs shown in attachment 4 were the approximate retail prices per pound of active chemical when the publication was prepared, and may be useful in planning. Actual costs will probably be different.

b. Usually the concentrated commercial formulations are less costly to use than the more dilute concentrations. For example, 2,4-D formulations that contain 4 pounds of acid equivalent per gallon nearly always cost less per pound of active chemical than do formulations containing only 1 or 2 pounds of 2,4-D equivalent per gallon. However, herbicides to be broadcast dry in granules or pellets may require purchasing diluted concentrations such as 4, 10, or 20 percent to permit precise and uniform application.

c. Where a formulation contains a mixture of herbicides, the amount of each herbicide is given on the label and should be considered in determining the relative value of the mixture.

2-4. Effective Herbicides. Herbicides and plant growth regulators that may be useful on military installations are listed by common name in attachment 4 along with costs, commercial formulation, trade name, toxicities, modes of action, and other basic information needed for their use.

a. Common weedy plants are listed in attachment 5, along with herbicides that give fair to excellent control. Genus, species, and, in some instances, variety are given where response to herbicides is specific and information is available. There may be other effective herbicides that are not included.

b. Some herbicides are effective only when used as either preemergence, preplanting, or postemergence treatments. Others are effective as both preemergence and postemergence treatments. Some act only through the soil, and some only from foliage treatments. Usually the preemergence treatments are effective only on germinating seedling plants. Some other herbicides must have well developed plants at treatment time. It is critically important that herbicides be used according to the directions on the herbicide label.

Section B—Using Herbicides

2-5. A Systematic Approach. Many factors contribute to the success or failure of herbicide treatments.

a. Identify the weeds you want to control. If in doubt, obtain assistance from a weed specialist, the EFD or MAJCOM consultant, or other authoritative source.

b. Select the right herbicide to control these weeds without harm to nearby desirable plants. Before applying a herbicide on a military installation, make sure that the product has been approved by the MAJCOM or EFD pest management consultant and is included in the installation pest management plan.

c. Read the label on each container before using the contents. Heed all cautions and warnings, especially the antidote and protective equipment statement for each chemical used. Antidotes for each herbicide used should be printed and posted in mixing and office locations and in vehicles which transport or disperse chemicals.

d. Handle herbicides that are rated extremely toxic (low LD_{50}) with great care. Handle slightly toxic (high LD_{50}) herbicides carefully, also. This applies to both oral and dermal toxicities. Avoid skin contact with the chemicals.

e. Follow mixing and application directions. Do not mix more than will be needed. Do not apply more than is recommended.

f. Always store herbicides in original labeled containers. Neither chemical concentrates nor diluted sprays should be kept in unlabeled containers. Follow label instructions for disposing of empty pesticide containers.

g. Remember that weather conditions, the soil, and the growth stage of weeds affect the action of many herbicides. Hence, for best results, follow label directions on when and how to apply the materials.

h. Avoid any hazard of contaminating groundwater or other possible drinking water sources. Water-soluble herbicides are often more readily leached through soils, but all can be carried in runoff water to streams and other surface water.

i. When applying herbicides to control aquatic weeds, remember local and seasonal variations in water quality and chemistry affect both the response of aquatic weeds to herbicides and the chemical and physical stability of herbicides in water. Salinity and alkalinity of the water are among the more variable and important characteristics. Calcareous deposits on the surfaces of aquatic weeds greatly reduce their susceptibility to herbicides. Water pH influences the ionization state of many herbicides and the formation of salts and complexes that frequently are less reactive and less soluble in water.

2-6. Application Rates:

a. Application rates of herbicides are often given in minimum and maximum amounts, depending on the situation. This range is necessary to accommodate differences in the response of plant species, the stage of growth when treatment is made, the desired period of residual toxicity, the amount and distribution of rainfall, soil texture and composition, and other environmental conditions. Figure 2-1 shows situations when light and heavy application rates are needed.

Variable Factor	Lighter rates	Heavier rates
Herbaceous plants	Susceptible species	Tolerant species
	Annuals	Perennials
	Seedlings	Annuals and biennials in flower
	Perennials in bud	Established perennials-flower to maturity
	Shallow-rooted	Deep-rooted
Woody plants	Susceptible species	Tolerant species
	Foliage applications when plants are in full leaf	Foliage applications before and after full leaf
	Actively growing	Dormant
Residual toxicity of herbicide	Short period	Several years
	Arid regions	Humid regions
	Cool climate	Warm climate
Soil	Low in organic-matter content	High in organic-matter content
	Low in clay content	High in clay content
	Well drained	Poorly drained
Root-absorbed chemical	Bare soil	Heavy trash

Figure 2-1. Factors Influencing Herbicide Application Rates.

b. In some cases, rates are given in units of the chemical per 100 or 1,000 square feet, per square rod, or per acre. It is not necessary, however, to measure the area to be sprayed each time an application is made. Calibrate the sprayer to deliver the proper amount of chemical per unit area (see chapter 9).

2-7. Effects of Weather:

a. Effects of Wind:

(1) Wind causes improper distribution of herbicides and greatly increases the hazard of damage from drift to sensitive plants in nearby fields, gardens, or ornamental plantings (figure 2-2).

(2) Vapors of some herbicides, such as 2,4-D or other phenoxy herbicides, kill plants. When vapors from the herbicide are likely to injure adjacent crops or other plants, an amine salt, or a low-volatile ester formulation should be used.

b. Effects of Humidity. High or moderate humidity increases the effectiveness of most herbicide applications to foliage by reducing evaporative losses of spray and aiding the foliar absorption of herbicides. Low humidity reduces the effectiveness of herbicide sprays by increasing the rate of evaporation. The disadvantages of low humidity can be partly overcome by using oil and oil-water emulsions instead of water as spray diluents.

c. Effects of Temperature. Temperature affects the rate of chemical reactions in plants and animals and also evaporation rates of sprays.

(1) Moderate temperatures, ranging from 70 to 85°F (21 to 29°C), are favorable for spray applications of most herbicides. The carbamates, dinitro compounds, and high-volatile esters of phenoxy compounds volatilize rapidly at temperatures above 80°F (27°C). At temperatures above 90°F (36°C), even the low-volatile esters of 2,4-D and other phenoxy compounds become significantly volatile. In general, do not apply herbicidal sprays when the temperature is above 90°F.

- Use nozzles that apply a coarse spray. Get advise from agricultural engineers and weed-control specialists.
- Use low pressures—no more than 30 lb/in^2 for boom sprayers, 100 pounds for spray guns.
- Avoid spraying on windy days and do not spray with ground equipment or from airplanes when the wind velocity is sufficient to cause drift to sensitive areas. Usually, stop spraying when wind speed reaches 5 mi/h. Never spray above 10 mi/h. 2,4-D and similar herbicides should never be applied when wind of any velocity is blowing across the spray area toward nearby valuable sensitive plants.
- Do not spray when an air-temperature inversion exists. An inversion is characterized by little or no wind and by air temperatures that are lower near the ground than at higher levels. A continuous smoke-generating device on aircraft can be used to indicate the direction and velocity of air movement. Layering of the smoke may indicate a temperature inversion. When spraying large acreages, use the burning tire or other smoke generator to indicate the presence of inversions.
- Spray when a light wind is blowing away from susceptible crops and toward the area being sprayed.
- Where special drift hazards exist, either do not spray or use specialized spray equipment. One of the special drift control agents or formulations in properly designed and adjusted equipment can help reduce drift. Obtain professional advice before using these products.

Figure 2-2. Suggestions for Minimizing Drift Hazards.

(2) Water temperature has a strong influence on the effectiveness of aquatic herbicides. Poor herbicidal activity can be anticipated at temperatures of 60°F (16°C) or lower. Herbicides such as acrolein and xylene perform poorly at high water temperatures due to rapid losses by volatility.

d. Effects of Rainfall. Rainfall affects efficacy of herbicides in other ways than by affecting the plant's rate of growth.

(1) Rainfall immediately after postemergence foliar applications of herbicides may wash spray off of leaves of plants and reduce the effectiveness of water-soluble formulations such as salts of 2,4-D; glyphosate, dinitro, and amitrole compounds; and some other foliar herbicides. Effectiveness usually is not reduced if a moderate rain occurs 4 to 6 hours after postemergence application. Check the weather forecast before applying herbicides.

(2) The effectiveness of preemergence herbicide treatments may be increased by moderate rain occurring shortly after application. In low rainfall areas, sprinkler irrigation is often used with good results when the water is applied immediately after preemergence herbicide application. However, if heavy rains occur soon after preemergence treatments, the herbicide may wash off of treated areas or may leach below surface soil where weed seeds germinate; and weed control may be reduced or crop damage increased.

2-8. Counteracting Misapplications and Spills. If herbicides are overapplied, applied on the wrong plants, or spilled; or if residues persist; they usually can be detoxified with activated carbon such as Gro Safe or Aqua Nuchar A. Fast action is needed. Even 2,4-D injury can be prevented or reduced if the accident is treated immediately, before plant uptake. One hundred to 200 lb. of activated carbon are required to completely absorb 1 lb or active herbicide. Normal field rates are 100 to 400 lb of carbon per acre to detoxify residues. Apply either dry carbon alone, dry carbon mixed with soil, or carbon as a slurry at 1 to 2 lb/gal water. To detoxify residues in soil, thorough incorporation of the activated carbon into the soil is needed.

Section C—Storing Herbicides

2-9. Flash Points. Chemicals with low flash points (40°F or less) are dangerous in storage.

They should not be stored unless special precautions are taken (figure 2-3). Chemicals with flash points of less than 100°F are flammable and require special handling.

2-10. Temperature and Moisture:

a. Chemicals may crystallize out of solution at temperatures below 32°F. If this happens, warm the products to 40°F or higher and roll the drums or shake the containers. If the crystals return to solution, no harm has been done. Low-volatile esters of 2,4-D do not freeze if stored in unheated rooms.

b. Dusts and wettable powders cake when wet, and packages may deteriorate. They present no problem as long as they are kept clean and dry. Water-soluble solids also cake when wet and when subjected to great changes in temperatures. If packages are left open, hygroscopic chemicals become wet by absorbing water from moist air. Chemicals such as chlorates, borates, and ammonium sulfamate cake when they are wet.

c. Liquid formulations should be stored on pallets or duckboards to keep the metal containers from rusting. The containers should be tightly closed. Air vents punched in cans to facilitate pouring should be plugged. Even small amounts of water introduced into emulsion concentrates or oil solutions can make them gel and cause deterioration of the container.

2-11. Facilities and Procedures. Pesticides should be stored in a dry, well ventilated building which is separate from offices and laboratories and where fire protection is provided. Pesticides should be protected from freezing or overheating. All pesticides in storage *must* be labeled.

a. Where large quantities are stored, the entire storage facility should be secured by a fence, and doors and gates should be kept locked to prevent unauthorized entry.

b. Highly visible, waterproof identification signs on doors, gates, buildings, and fences to advise of the hazardous nature of contents, with telephone numbers and names for additional information, should be posted in areas where they will be visible.

c. Pesticides must be stored according to special storage requirements and compatibility properties as specified on the label, and separately from other products and materials in storage areas.

d. A current inventory of all pesticides in each storage unit must be posted in an inside location accessible and visible to program personnel. This inventory will include the name(s), listed in order of toxicity category with the appropriate signal words of each pesticide; the number and kind of containers; and the date each was received.

e. All quantities of highly toxic and experimental pesticides must be secured in a lockable storage unit with limited access.

f. Pesticides must be stored off the floor. Wooden pallets should be used.

g. Insecticides, herbicides, fumigicides, and plant growth regulators must all be stored so as to prevent cross-contamination. Liquid pesticides should be stored in such a manner that a spill or leak would not contaminate nonliquid pesticides. Fumes from volatile herbicides can cause contamination, so secure containers and adequate ventilation must be provided.

h. Pesticide containers should be stored with the labels plainly visible. If containers are not in good condition when received, the contents should be placed in a suitable container and properly relabeled.

i. Containers should be checked regularly for corrosion, leaks, and gas formation. If such is found, the contents should be transferred to a sound, suitable container and be properly labeled or disposed of.

j. Materials such as adsorptive clay, granulated activated charcoal, hydrated lime, and sodium hypochlorite should be kept on hand for emergency treatment or detoxification of spills or leaks. On discovering a spill or leak, isolate the contaminated area and keep out all unauthorized personnel. Allow no smoking in the area. Ventilate the area thoroughly. Immediately contact your safety and health manager so pesticide and container can be disposed of in an acceptable manner.

k. Adequate fresh water and soap or special solvents for decontamination of personnel and equipment should be available.

l. Additional guidance is in Armed Forces Pest Management Board Technical Information Memorandum 17, Pest Control Facilities.

- Store herbicides in a cool, dry place that is vented and where negative pressure is maintained.
- Store herbicides away from foods, fertilizers, feed, seed, and other types of pesticides.
- Make sure that the storage area is lockable and not accessible to children, unwary adults, or animals.
- Store herbicides only in the original, labeled containers.
- Rotate the stock. Use old product before new.
- Follow local regulations for stacking heights. Check with the local safety office and fire department.
- Record the lot numbers of herbicides in your inventory system. Every herbicide container has a lot number.
- Have emergency phone numbers available, including those for medical facility emergency room, environmental coordinator, bioenvironmental engineering official, and facility fire department.

Figure 2-3. Basic Precautions for Storing Herbicides.

Section D—Disposing of Herbicides

2-12. Waste Herbicides and Containers. Mix only the amount of herbicide that you will need for the job. Any that is left over should be used, if you have a valid requirement for it. Otherwise, it may have to be treated as a hazardous waste. Pesticide containers must be disposed of according to instructions on the label. Often this involves burning paper and cardboard containers in approved incinerators; burying polyethlene and other synthetic containers; or triple rinsing, puncturing, crushing, and burying metal containers in a Class I landfill.

2-13. Hazardous Waste Requirements. Be sure to comply with federal, state, local, or host nation hazardous waste regulations. Waste herbicides and containers that qualify as hazardous wastes must be disposed of according to those regulations. The label provides instructions. The Armed Forces Pest Management Board's Technical Information Memorandum 18, Pesticide Disposal Guidelines for Pest Control Shops, also provides guidance. If you have any questions, ask the MAJCOM or EFD pest management consultant.