Chapter 1

GENERAL INFORMATION

Section A—Uses of Herbicides and Plant Growth Regulators

1-1. Beneficial Uses. Mechanical and manual methods once were the only effective means of controlling vegetation on military installations. Today, herbicides and plant growth regulators, together with improved management procedures, can be used to eliminate vegetation in areas such as industrial sites and storage yards; to control weeds along highways and railroads; to suppress woody plants in grasslands and utility rights-of-way; to eliminate weeds in ornamental plantings, turf, and aquatic sites; and to slow the growth of turf grasses and other vegetation. Under certain conditions, these chemicals can be used to reduce maintenance costs and to eliminate hazardous mechanical operations.

1-2. Limitations and Requirements:

a. Failure or poor control may result from selecting the wrong herbicide or plant growth regulator, improper mixing of chemicals, poor timing or method of treatment, and unsatisfactory conditions at the time of application. The conditions required for effective use; the potential for injury to desirable plants; and the hazards of the chemical to the operator, livestock, wildlife, and other nontarget organisms should be considered in choosing a herbicide or growth regulator.

b. The choice of a herbicide or growth regulator must include a study of the label. Rates and times of application, hazards, warnings, and cautions are stated on the label of each product.

It is required by law that the label be followed.

Cautions on all herbicide labels *must* be carefully observed:

c. Approval must be obtained from the major command (MAJCOM or MACOM) or engineering field division (EFD) pest management consultant before a herbicide can be used on a military installation. Such approval is included in the installation pest management plan required by DODD 4150.7 (DOD Pest Management Program). Early planning is important to allow time for approval so that treatments can be timely. Timing of application is often critical.

d. Where contamination of a drinking-water supply is possible, only those herbicides approved for use in potable water by the MAJCOM or EFD pest management consultant will be applied.

e. Restricted use herbicides, such as picloram and paraquat, can be applied only by, or under, the direct supervision of a certified applicator.

Section B—Biology of Plants

1-3. Annuals and Biennials. Plants are classified as annuals, biennials, or perennials, based on their life spans, and this is closely related to the ways they reproduce. All weeds pass through four stages of growth: seedling, vegetative, flowering, and maturity, and each class of weed (annual, biennial, and perennial) has a growth stage that is most susceptible to control. These aspects of plant biology dictate control strategies.

a. Annuals are plants that set seed and mature in one season. Seed is required for their initial establishment in temperate climates. Foxtail, crabgrass, common ragweed, wild buckwheat, and several mustards are examples. A variation of the true annual is the winter annual, which germinates in the fall, lives over winter, and matures early in the next season. Pennycress, common chickweed, corn cockle, downy bromegrass, and shepherd's purse are examples of winter annuals.

(1) Individual plants may produce thousands or, in some instances, hundreds of thousands of seeds that provide an enormous source of new plants. Many of these seeds remain alive for years. The high production of seed, the buildup of seeds in the soil, and the length of time the seeds remain viable in the soil are nature's way of ensuing that annual plants will be perpetuated. These properties of annuals make eradication almost impossible.

(2) The seedling stage of growth, at which time the plants are small, succulent, and actively growing, is the best time to apply herbicides to annuals. As the plant grows and passes through the other stages, control becomes more difficult. If the top growth is killed before seed is produced, the lifecycle of that plant is ended, since it cannot recover, but the reservoir of seeds

in the soil may produce new plants for many years.

b. Biennials require two growing seasons to complete their reproductive cycle. The first year's growth is purely vegetative, with top growth usually confined to a rosette of leaves. They are dormant during the winter and in the second season develop stalks with flowers and seeds. Because of this, they are easily confused with winter annuals. Because they reproduce only by seed, they can be treated like annuals. Burdock, evening primrose, common mullein, and wild carrot are examples of biennials.

1-4. Perennial Plants:

a. Perennials are plants that live more than 2 years. Many have several means of reproduction. In addition to reproducing by seed, they may reproduce vegetatively with the aid of storage organs in the form of stolons (prostrate aboveground stems), rhizomes (prostrate underground stems), bulbs, corms, and storage roots. Food is stored in these organs by the plant, and can be used when new growth occurs. New shoots may come from buds that live on these stored food reserves until the new plants become established. Unlike annuals, the top growth of many perennials may be killed, and still the plants can live and propagate by means of their belowground storage organs and dormant buds.

b. To control a perennial plant's vegetative reproduction, the plant's food reserves must be materially reduced, or its storage organs and buds must be destroyed. The food the plant stores is the excess manufactured by the green leaves and stems, over and above what is necessary for growth. Therefore, if photosynthesis can be prevented, the buildup of reserves will be curbed.

c. Cultural methods of control are designed to allow new growth to use up the plant's food reserves. New shoots draw on stored food for about 10 days after emerging. At this time the top growth is killed. This is repeated until the plant's food reserves are exhausted. The cultivation cycle usually takes 3 to 5 weeks, depending on the species and growing conditions, and the program often must be continued for at least two growing seasons.

d. Chemical control may also require repeated applications to deplete the plants supply of nutrients. While perennials do have a seedling stage, and control is easiest at this point, most are very inconspicuous, and accurate identification is difficult. Also, shoots that emerge from established roots are not seedlings and are more difficult to control. During their vegetative stage, perennials are not very susceptible to herbicides because they are drawing on their stored nutrients and not absorbing them from the surrounding environment. Control of perennials is best achieved during the bud and subsequent regrowth stage. As the plant is actively setting buds in order to reproduce, its food reserves are at their lowest levels, thus making it more susceptible to chemical control. Treatment at the early flowering stage is generally as effective as during the bud stage, but, when perennials reach full flowering, control levels decline drastically.

e. Quackgrass, Canada thistle, Johnsongrass, buttercup, and nutsedge are examples of perennials that are difficult to control. Some herbicides, however, are effective even on these hard-to-control perennials.

Section C—Characteristics of Herbicides and Plant Growth Regulators

1-5. Common and Trade Names. Common names and designations of herbicides and growth regulators used in this publication are those accepted or preferred by the Weed Science Society of America and the American National Standards Institute. Chemical names are those preferred by Chemical Abstracts Service of the American Chemical Society. Trademarks or trade names used by the herbicide industry are cited for information only, and do not constitute an endorsement over other products that may have been omitted. Because many users of this publication will be more familiar with trade names than common names, an alphabetical list of trade names with a cross listing of common names is given in attachment 2. Herbicides in other tables in this publication are alphabetized by common name.

1-6. Active Chemical Content and Formulations:

a. The containers of all commercial herbicides have labels that state the amount of active phytotoxic chemicals contained in the particular product. This is expressed in pounds per gallon for liquids and in percentage of active ingredient, acid equivalent, or phenol equivalent for granules and powders. Acid equivalent is commonly used to express the active chemical in herbicides derived from acids such as in dicamba; 2,4-D; glyphosate; and picloram. Phenol equivalent is used to express the active chemical in dinitrophenol derivatives.

b. Most herbicides are purchased as commercial formulations that can be (1) dissolved, emulsified, or suspended in a liquid carrier; (2) distributed dry as granular products or pellets by a spreader or by hand; or (3) injected into soil for vaporization and fumigation. Often an emulsifier, spreader, sticker, or other surfactant is added to facilitate dilution and adhering capacity to increase wetting by the diluted sprays.

c. Granules and pellets are prepared in several ways. Some herbicides are impregnated on granules of clay, vermiculite, or crop residues, such as ground corncobs. This is accomplished by spraying, dipping, or exposing the granules to the herbicide. Pellets and granules are also prepared by mixing a herbicide with finely ground clay or fertilizer salts and forming particles by extrusion or prilling.

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.

1-7. Modes of Action of Herbicides.

The actual mechanisms by which plants may be killed are so numerous, and plant functions are so intimately interconnected, that there can be no single theory on herbicidal action. The physiological responses of plants that may occur after a herbicide reaches a site of action include: changes in respiration, nutrient uptake, and carbohydrate utilization; disturbances in potassium metabolism; abnormal cell production; abnormal phosphatase activity; blockage of photosynthesis; reduction in vital leaf area; arrested cell division; and production of metabolites injurious to the cell.

a. Selective Versus Nonselective Herbicides. Selective herbicides kill certain plant species without seriously injuring other plants among which they are growing. Herbicides that selectively kill crabgrass or dandelions in a lawn are examples. The reasons that herbicides are selective in some combinations of weeds and desirable plants are known. The reasons they are selective in other situations are unknown.

(1) Selectivity is caused by the differing responses of plant species to a herbicide. There are various obstructions to herbicidal action along the critical path from the point of application to the arrival of the herbicide at its site of action in the plant. These obstructions differ among plant species and are part of the basis for selectivity. There are also varying plant responses at the sites of action that form a basis of selectivity. For instance, in some species the breakdown of the herbicide by the plant may keep pace with herbicide accumulation so that lethal concentrations are not reached, whereas in other species lethal concentrations are reached and kill the plant.

(2) Some of the barriers or obstructions that prevent a herbicide from killing plants differ among plant species and may be encountered at each of four steps in a critical path that a herbicide travels after leaving its container. The steps of the critical path are: (1) Achievement of herbicide surface contact with the plant or plant parts; (2) penetration or entry into the plant; (3) translocation to a site of toxic action; and (4) disruption of some vital function.

(3) Nonselective herbicides kill vegetation with little discrimination. A limited number of species, however, are physiologically resistant to the chemical, and some of these escape. Thus, there is no herbicide known that is completely nonselective. Some escapees are perennials that have part of their root systems below treated layers of soil; others are annuals and shallow-rooted perennials that reinfest the area after the chemical has leached below the surface layer.

b. Contact versus Translocated Herbicides. These are distinctly different in use and the types of weed that they will kill.

(1) Contact herbicides kill all tissues that are contacted by the spray. Whether the plant dies or recovers depends on whether it has a protected growing point. Also, many perennials have underground buds that are not contacted by the herbicide and that are capable of generating new plants.

(2) Translocated chemicals are absorbed by the leaves and stems, or by the roots, and move through the vascular system to the leaves, buds, and root tips. Translocated herbicides, when absorbed by the leaves and stems, commonly move in the plant's phloem (food-conducting tissue) with the food materials manufactured by the leaves and stems. When absorbed by the roots, they move in the xylem (water-conducting tissue). The growth-regulator type of translocated herbicide is a synthetic compound that

behaves like a plant hormone. It accumulates mostly in areas of rapidly dividing cells, upsetting the normal metabolism of the plant and causing death of the cells. Foliar applications of translocated herbicides are of great practical value because small amounts are effective and they can be applied in small volumes of water.

c. **Soil-Sterilant versus Preemergence Herbicides.** These both act through the soil but are used in different sites and situations.

(1) A soil-sterilant herbicide makes a soil incapable of supporting higher plant life; but it generally does not kill all life in the soil, such as fungi, bacteria, and other micro-organisms; nor does it kill ungerminated seeds. Its toxic effects may remain for only a short time or for years. Persistent residual toxicity depends on the nature of the chemical and its rate of decomposition or leaching, the colloidal and chemical properties of the soil, the relative tolerance among weed species, and the rate of application.

(2) Herbicides vary in their rate of disappearance from the soil because of differences in their volatility, susceptibility to decomposition by soil micro-organisms, sensitivity to sunlight, chemical reactions, and solubility. For example, some of the carbamates are volatile at moderately high temperatures and rapidly lose their toxic effect during the summer months. Certain soil micro-organisms effectively decompose herbicides such as 2,4-D in a short time. Amitrole is soluble in water and is readily leached.

(3) Some herbicides are readily adsorbed by mineral and organic colloids in the soil and are rendered unavailable, or only slowly available, for plant absorption. For example, diuron is adsorbed on clay colloid particles, making leaching difficult. Paraquat is completely inactivated by soil because its positively charged cations react with the negatively charged clay minerals to form complexes. The fertility and pH of a soil also influence the persistence and availability of certain chemicals.

1-8. Toxicity and Volatility:

a. Toxicity ratings are described in attachment 3, and the toxicities of herbicides and plant growth regulators are given in attachment 4. Those herbicides rated extremely toxic (low LD_{50}) must be handled with great care (while those rated as slightly toxic (high LD_{50}) require less special attention). The dermal toxicity rating is also given, and the same precautions are required.

b. The relative toxicity of chemicals is determined in small animal tests. Unfortunately, humans do not always react the same as small animals. It is always possible that a human will be poisoned by a smaller dose of a given chemical than results with animals would indicate, or vice versa. The extremely toxic herbicides included in this publication are acrolein and endothall, and the general-purpose fumigant, methyl bromide. They must be handled with particular care.

c. Volatility refers to the tendency of a liquid or solid to change to vapor. Vapors of some herbicides kill plants. This is an important consideration in purchasing herbicides such as 2,4-D or other phenoxy herbicides. When using volatile herbicides, the use must be aware of temperature as well as wind speed and direction. Volatility generally increases as temperature rises. 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.

d. Esters of 2,4-D are classified as being of high or low volatility according to the degree of vaporization that occurs. In general, methyl, ethyl, isopropyl, butyl, and amyl esters are considered highly volatile and should not be used. The high molecular weight esters are low in volatility and include: butoxyethyl, butoxyethoxypropyl, ethoxyethoxypropyl, propylene glycol butyl ether, and isooctyl esters.

Section D—Hazards to Non-Target Organisms

1-9. General Information. Nearly all herbicides are potentially dangerous in one way or another, but they are not likely to cause injury if used properly and if recommended precautions are observed. Because several kinds of danger are associated with handling and applying herbicides, and possible injury is not limited to the operator, consider the potential effects on all of the following: operator and handler, livestock, desirable plants, fish and wildlife, water quality, and equipment.

1-10. Operator and Handler. The person who hauls, mixes, and applies the herbicidal spray, or spreads the dry product, could be poisoned from swallowing the herbicide, by skin absorption, or by inhalation. In each case, there is greater danger from the concentrated material than from the diluted spray solution or suspension. Be sure to read the label for each chemical used.

The use of safety equipment is mandatory when mixing and applying herbicides when indicated on the herbicide label.

a. If a concentrated spray is ingested, take immediate and appropriate action for the chemical, as indicated on the label. Notify the military hospital, and, if possible, immediately transport the victim to the hospital emergency room, accompanied by the herbicide label with antidote instructions.

b. Prevent absorption by the skin, and irritation of skin and eyes, by keeping exposure to a minimum. Some individuals are hypersensitive to certain chemicals, and have allergic reactions that are not possible to predict without skin tests. For most herbicides, washing the hands and face with soap and water after handling is sufficient protection. Prolonged contact is more dangerous than short exposures.

c. For the more readily absorbed chemicals and those that are irritating, wear clean clothing that covers the body. Wear long pants and long sleeves. Remove clothing that has become contaminated with the chemical. Use synthetic rubber gloves that are unlined. Where splashing may occur, wear goggles or a face shield and a rubber or plastic apron. If spray or dust is spilled on the skin, wash thoroughly with soap and water. If the herbicide contacts the eyes, flush the eyes with plain water and call the medical facility emergency room. An emergency shower and eye wash must be maintained in the shop area, and a portable eyewash should be carried in any vehicle used for pesticide work.

d. Purchase liquid concentrates and powders in containers that can be readily lifted by the operator in the field, or provide special pumping equipment for transferring chemicals to the sprayers. Packages of powders should be small enough so that it is unnecessary to remove the contents with a scoop. Never transfer chemicals to unmarked, unlabeled containers.

e. Do not inhale vapors, dusts, and spray mists. Using a respirator approved by MESA/NIOSH for the particular type of exposure is mandatory when label directions indicate the need. In the case of a severe exposure, move the victim into fresh air, administer artificial respiration if needed, and call the medical facility emergency room.

f. Some chemicals are flammable or support fire. Avoid ignition from sparks and contact with combustible materials.

g. Some herbicides are dyes that can stain unprotected skin and hair. Handle these with care.

1-11. Livestock and Domestic Animals. For most herbicides, the chief dangers of poisoning livestock come from consuming herbicide remnants that are in open containers or spilled on the ground or floor.

a. Herbicides are often used to improve pasture by controlling undesirable plants that provide poor forage. Desirable plant species will increase as competition from weeds decreases.

b. Herbicides such as 2,4-D and similar compounds may increase the palatability of plants not ordinarily eaten. If these are poisonous species, such as jimson weed, larkspur, hemlock, and cherry, the hazard of animal sickness and death may increase temporarily. The nitrite content of some plants can be increased enough to be toxic to livestock when sprayed with 2,4-D. Significantly increased nitrite content of plants, however, does not usually follow spraying. More commonly, unfertilized soils are so low in nitrogen content that nitrite poisoning is no hazard.

1-12. Desirable Plants. Certain precautions in the use of herbicides are necessary to prevent damage to nearby desirable plants. This damage may result from spray drift, washing, or leaching.

a. Drift hazards are greatest when herbicides are sprayed on foliage. These may be of the growth-regulating type such as 2,4-D, dicamba, and picloram; or of the contact type such as paraquat and petroleum oils. Danger is decreased with granular applications of nonvolatile herbicides. Spray drift occurs not only with volatile herbicides, i.e. high-volatile esters of 2,4-D, but also with sprays that are atomized into a mist by high pressure and a small nozzle opening. Controlling drift is discussed in paragraph 2-7.

b. Wash-off migration of herbicides can be an important hazard on slopes, bare ground, and pavements. The herbicide may be carried by surface runoff water to valuable plants down slope. Problems often occur when water runs across an area treated with soil sterilant herbicides onto lawns or ornamental beds or among trees. Do not drain or flush equipment where runoff to desirable plants may occur.

c. Leaching moves chemicals 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. Desirable trees growing adjacent to areas treated with soil sterilants, or near ponds treated with some aquatic herbicides, are often injured. Avoid treating such areas with soil sterilants. Do not drain or flush equipment where leaching to the roots of desirable plants can occur.

1-13. Fish and Wildlife. Applications of herbicides may have primary and secondary effects on wildlife.

a. Primary effects are from direct poisoning. There are a few herbicides, such as the dinitros, that can directly poison animals; and copper sulphate can poison fish and fish food organisms. A few herbicides are very toxic to fish; but some, such as 2,4-D, can be used safely to control aquatic weeds. In general, most injury results from excessive application rates and spillage.

b. Secondary effects of herbicides on wildlife include animal poisoning due to changes in palatability of poisonous plants, changes in the chemical composition of plants, and effects on organisms in the food chain. All herbicides have the potential of exerting major effects on wildlife habitat by changing the species in the plant community.

c. Indiscriminate spraying can destroy cover, but herbicides can also be useful in management. Openings in wooded areas, such as clearings for rights-of-way, can be beneficial to wildlife. Herbicides can be used to induce sprouting of browse species for deer. Herbicides used to eliminate or reduce weedy plants may allow the increase of other desirable plants, such as in the selective control of brush in rights-of-way, and lead to increases in feed or browse. The control of submersed weeds in ponds and streams can be beneficial to fish populations. Safe amounts of herbicides, expressed in parts of the chemical per million parts of water, vary widely with age, size, and species of fish. Aquatic biologists and natural resources managers should be consulted to determine appropriate uses and precautions. Management of fish and wildlife habitat is discussed in the tri-service Fish and Wildlife Manual (TM 5-633, AFM 126-4, NAVFAC MO 100.3).

d. When any proposed spraying program might endanger fish and wildlife, you should consult federal or state fish and wildlife agencies for advice. Be sure no state or federal endangered or threatened species will be affected. Also check on local water quality regulations regarding pesticide use.

1-14. Damage to Equipment. Thorough draining and cleaning of equipment with water and a detergent is sufficient protection against most herbicides. Some chemicals, however, corrode the metal parts of spraying equipment; and oils and solvents can injure rubber seals, gaskets, and lines. When corrosive chemicals are used, purchase equipment with noncorrosive metals or coat the metal parts of the equipment with protective paint, oil, or undercoating before use. Teflon and neoprene will resist oils and solvents.