Division of Agricultural Sciences
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SELECTIVE CHEMICAL WEED CONTROL

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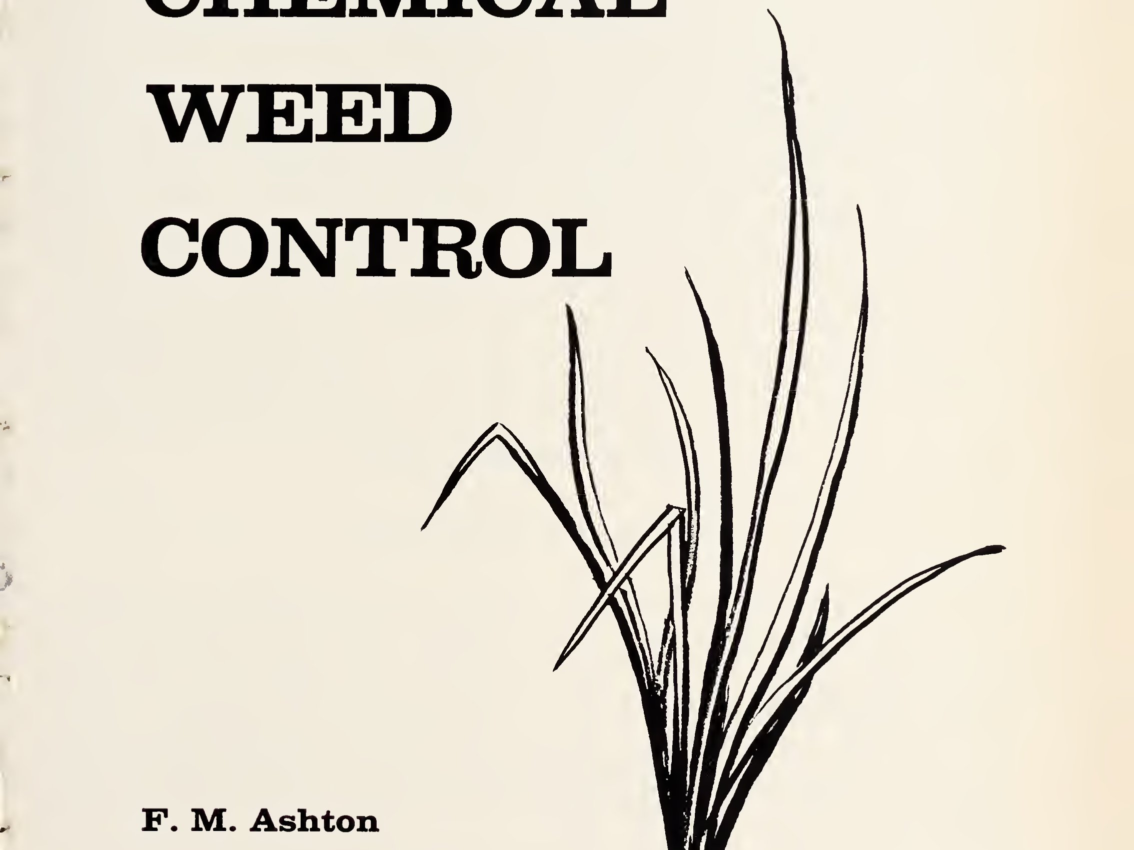

CALIFORNIA AGRICULTURAL
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Selective chemical weed control uses a herbicide to control weeds in a crop without injuring the crop. The chemical "selects" the weed and destroys it because of either a quality inherent in the herbicide, or because of the way a nonselective herbicide is used. Selectivity is relative: it depends on proper use of the herbicide. It will work only within a given range of concentration of the herbicide and under particular conditions.

This circular explains the principles of how herbicides are used on foliage and soil (pages 4 and 5), indicates how herbicides work selectively to kill weeds while keeping crops alive (pages 5 to 14), and suggests how to apply selective herbicides (page 15). Also included is a glossary of terms used in selective weed control (pages 16 to 17).

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This publication replaces circular 505, *Principles of Selective Weed Control,* by F. M. Ashton, W. A. Harvey, and C. L. Foy, and draws heavily on information contained in that circular.

SELECTIVE CHEMICAL WEED CONTROL

Weeds are costly. They take water, fertilizer, and light from the crop plants, and often they reduce yield and quality of crop and livestock products. They also can increase labor and equipment costs, harbor insect and disease organisms, and reduce land values. Weeds cost the American farmer an estimated $7,500,000,000 annually, and losses in California alone have been estimated at $1,500,000 per day—in certain crops the yearly losses due to weeds can exceed $150 per acre. In many crops such losses can mean the difference between success and failure to the grower.

HOW LOSSES ARE REDUCED

Losses can be reduced by three principal means—weed prevention, eradication, and control.

Weed prevention. Weed prevention means primarily good farm sanitation. You start out with weed-free fields, and prevent weeds from being introduced and from spreading. Preventive methods include the use of clean seed, cleaning contaminated equipment, keeping fence row and ditch bank weeds from seeding and spreading, and spot-treating small weed infestations within the field.

Weed eradication. Weed eradication completely destroys or removes all weed plants including regenerating plant parts. Eradication is sometimes justifiable, as in the case of small new infestations of particularly troublesome weeds, even at relatively high costs per unit area or loss of selectivity.

Weed control. Weed control is usually the most reasonable approach. Many weeds are so widespread that eradication, though desirable, becomes economically impractical. But you can reduce the infestation to a level that will enable you to produce a crop profitably in spite of the weeds.

CONTROL METHODS

Weeds can be controlled by one or more of four methods: mechanical, cropping, biological, or chemical. But no single method is most efficient—a long-range program combining all four methods provides maximum results.

Mechanical control

Mechanical weed control includes cultivation, mowing, burning and hoeing; even hand pulling is justified under some conditions.

Cropping control

Cropping control methods take advantage of crop rotation to obtain changes in the environment which will keep weeds down. Often the new crop successfully competes with the weeds from the previous crop. Sometimes other methods of weed control combine with cropping, as for example the use of 2,4-D in grain following a 2,4-D-sensitive crop in which broadleaf weeds have become a problem.

Biological control

Biological methods use living organisms, mostly insects, to control weeds. Examples are the *Chrysolina* spp. beetle to control Klamath weed of California ranges, and the use of geese in cotton for control of grasses.

Chemical control

Weed control by chemicals offers the greatest single potential. Many selective commercial herbicides for use in specific crops against specific weeds are available.

HOW HERBICIDES ARE USED

Herbicides are used either on foliage or in the soil.

Foliage applications

These treatments are made to leaves of growing plants, usually as liquid sprays. They kill plants by two methods—contact or translocation.

By contact. This treatment kills only the plant parts actually contacted by the herbicide. However, the noncontacted parts (i.e. roots) may die because they are deprived of the essential contacted organs (i.e. leaves). Adequate distribution of the herbicide over the foliage is essential. Selectivity may depend upon arrangement and angle of leaves, differential wetting, location of growing points, or upon spray placement. Contact herbicides are most useful to control seedlings.

By translocation. This treatment kills the entire plant because the herbicide moves within the plant. For example, when applied to the leaves the herbicide is translocated to the roots. It may also move from older leaves to young growing points. Therefore, herbicides of this type are used on perennial plants as well as annuals. Selectivity depends primarily on physiological or biochemical differences between plants.

Soil applications

These treatments are usually applied to the surface of the soil but may also be incorporated into the soil by cultivation, or injected below the soil surface.

Timing of the application in relation to the growth stage of the weeds and crop is important. The application may be made preplant, preemergence, or postemergence as related to the growth stage of the crop plant.

Surface moisture must follow surface treatments for most soil-applied herbicides to be effective; you will obtain best results when these herbicides are carried into the soil by rainfall, overhead irrigation, or flood irrigation. A physical incorporation of the surface applied herbicide into the top 2 inches of the soil followed by furrow irrigation is usually as effective as rainfall or overhead irrigation.

PRINCIPLES OF SELECTIVITY

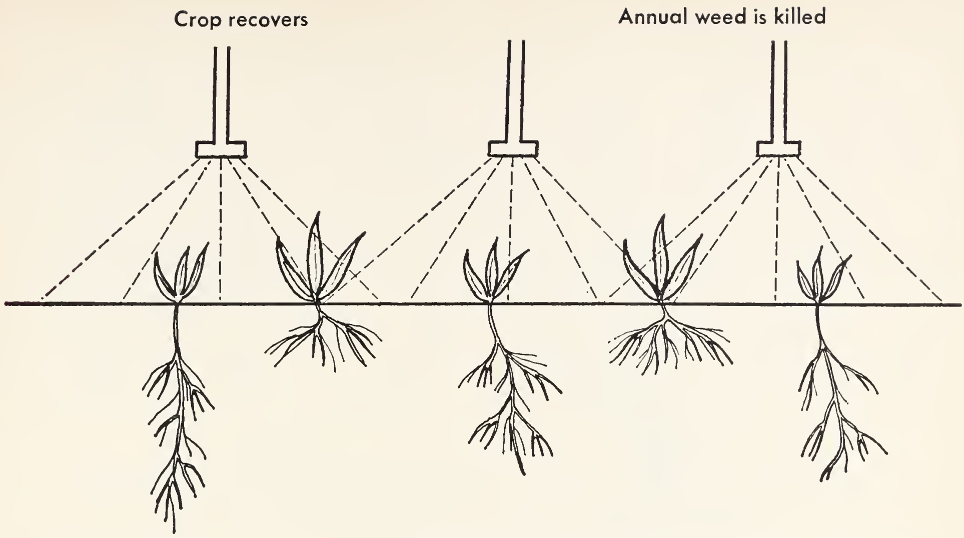
A selective herbicide is one which significantly retards growth of an unwanted plant species (the weed) without significantly damaging the desirable plant species (the crop). Ideally, the weed is killed but sometimes it is necessary only to retard its growth long enough for the crop to become dominant. A herbicide is selective to a particular crop only within certain limits; these limits are determined by various factors because in any area there is a complex interaction between *plants,* their *environment,* and the *herbicide.* Because of these variables, and because of varying environmental conditions and methods of herbicide application, selective herbicide control of weeds is relative, not absolute.

THE ROLE OF THE PLANT

The factors involving plant (both weeds and crops) response to control are: genetic inheritance, age, growth rate, morphology and physiology, and chemical and biophysical processes. Bearing these in mind will help growers use herbicides more effectively.

Genetic inheritance

The genetic complement of a plant determines the extent to which it responds to its environment. These responses vary from genus to genus, but within a genus plant reactions to a given herbicide are usually similar (strawberries are a notable exception—they even vary from variety to variety in their responses to herbicides). Research is in progress to breed resistance to specific herbicides into certain crops.



Growth habits. Crop roots 1, 3, 5 are deep, extensive and therefore recover from surface sprays. Weed roots 2 and 4 are close to surface, easily killed by sprays.

Age

The age of a plant often determines its response to a particular herbicide, and young plants are generally easier to kill than are older ones. Pre-emergence herbicides which kill germinating weed seeds or seedlings commonly have but little effect on established weeds.

Growth rate

The growth rate of plants has a pronounced effect on their reaction to some herbicides. In general, rapidly-growing plants are more susceptible to treatment than are slower-growing ones.

Morphology

The type of morphology of a plant can determine whether it is killed by a specific herbicide. Morphological differences are in root systems, location of growing points, and leaf properties.

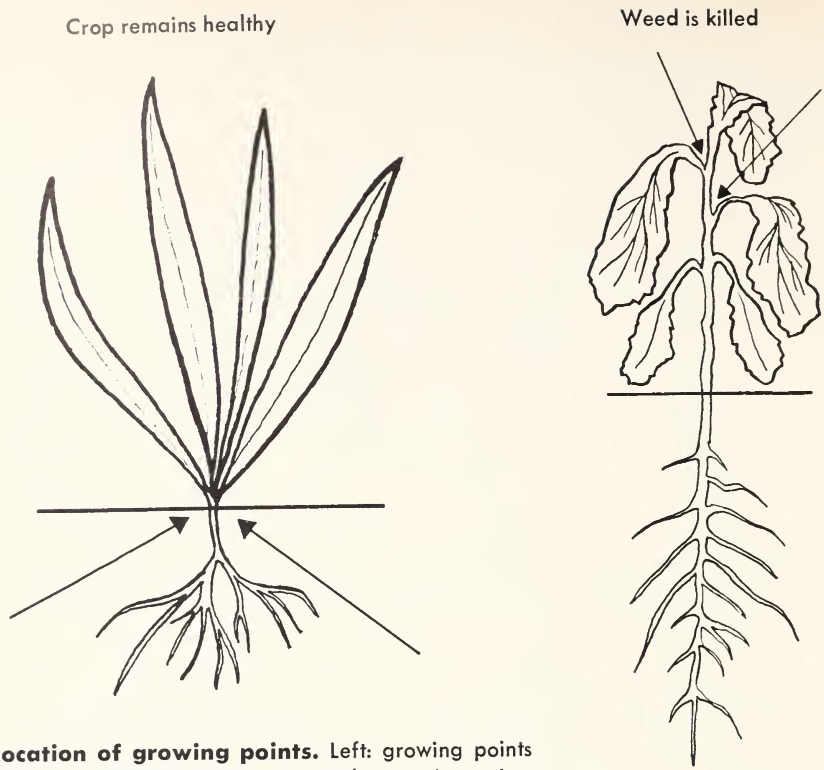
Root systems. Annual weeds in a field of perennial crops can be controlled because perennial crops (e.g., alfalfa) have deep, extensive root systems. Such systems will recover from moderate injury to parts above ground whereas annual weeds, having shallow roots, will be killed. To reduce injury of the alfalfa to a minimum, apply herbicides in winter (dormant period) or immediately after cutting. The type of herbicide used in this method of control is a general-contact spray.

Location of growing points. Growing points of cereals are located at the base of the plant and are protected from contact herbicides by the surrounding leaves. In some cases they are actually below the soil surface. Therefore, any contact spray remaining on cereals may injure the leaves but will not contact the growing points.

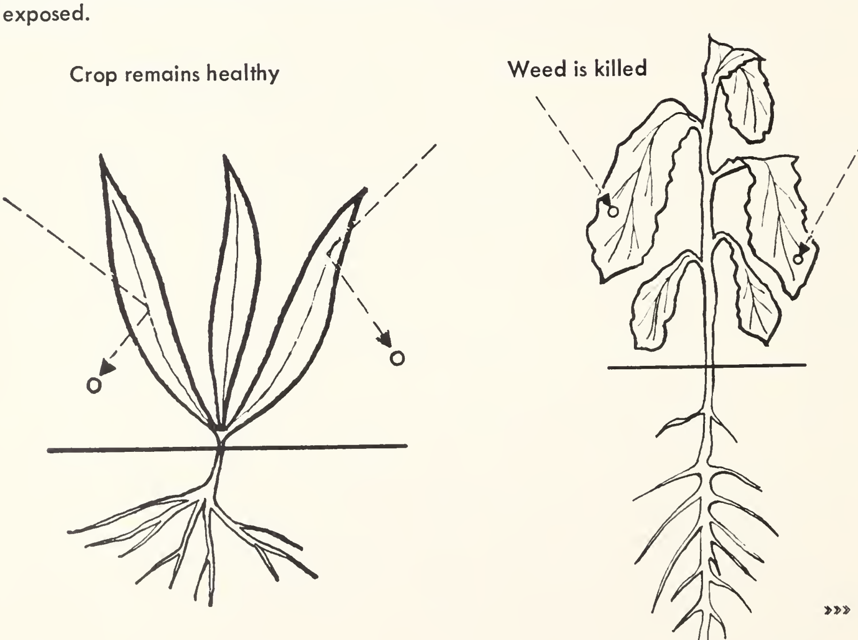
Broadleaf plants have exposed growing points at the tips of the shoots and in leaf axils. Because of this, the contact herbicide actually strikes the growing point.

Leaf properties. Certain leaf properties protect crops treated by selective herbicides. Liquid spray droplets can adhere to only a small portion of the surface of narrow, upright leaves (as in cereals and onions), or waxy leaf surfaces, or leaves that are corrugated or formed of small ridges. Therefore, when sprays hit such leaves they bounce off in droplets or wet the surfaces only in small spots, thus reducing the effect of the herbicide.

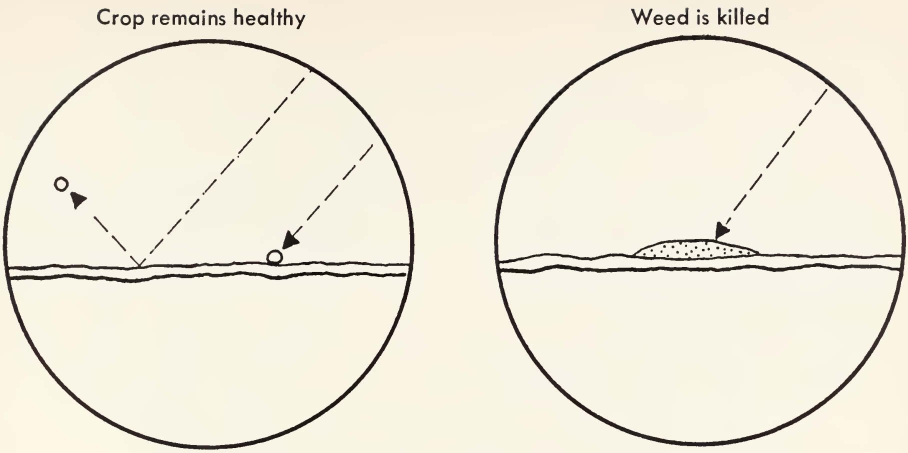
Broadleaf plants have wide smooth leaf surfaces, extending horizontally from the plant stem. Such leaves intercept more of the spray, which spreads over them and does not bounce off. Therefore when broadleaf weeds such as lambsquarters,



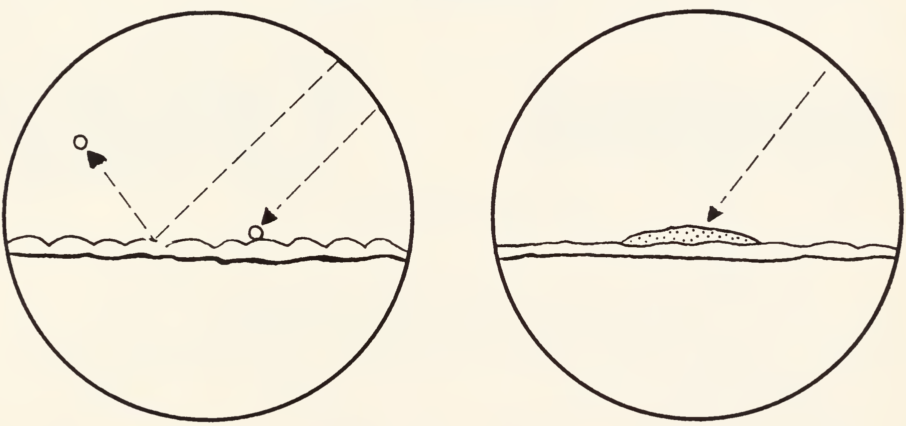
Location of growing points. Left: growing points (arrows) are protected from sprays. Right: growing points are exposed.



Leaf properties. On narrow upright leaves (left) spray bounces off, does not affect plant. On wide horizontal leaves (right) sprays stick and kill plant.



Leaf properties. On waxy leaves (left) sprays bounce off or forms discrete droplets. Right: On nonwaxy leaves, sprays stick and spread.



Leaf properties. On corrugated leaves (left) sprays bounce off and form discrete droplets. On noncorrugated leaves, sprays stick and spread.

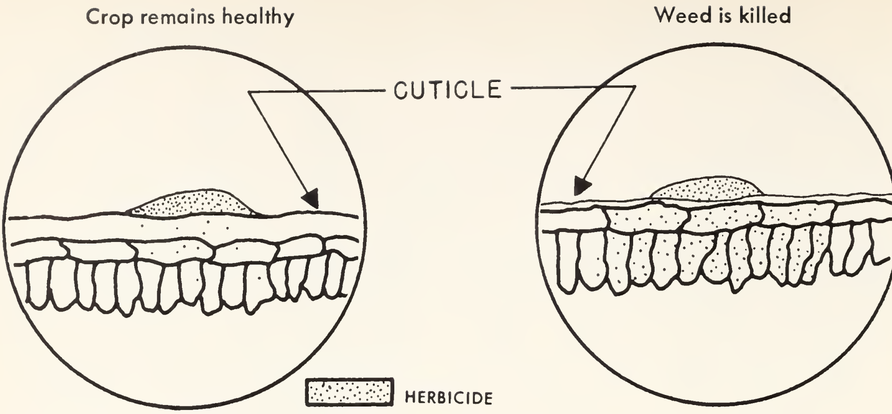
wild radish, pigweed, or wild mustard are sprayed with contact herbicides, the spray solution tends to spread as a thin film or to remain as many small droplets that wet a large portion of the leaf, thus surface-killing the weed. The same sprays on cereals or onions tend to bounce off and leave the plants uninjured.

Physiology

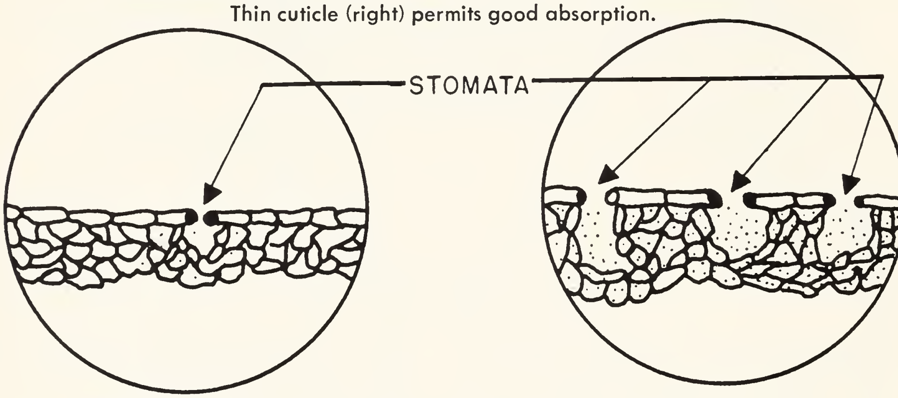
The physiology of the plant determines how much herbicide is taken up by the plant (absorption) and the extent it moves within the plant (translocation). The absorption and translocation of a herbicide varies between different species, and those which absorb and translocate the most herbicide will be killed.

Absorption. Those plants which have thin cuticle or large stomata (minute pores on leaf surfaces) absorb more herbicide. Wetting agents in herbicide formulation are primarily used to increase killing properties by increasing absorption of the herbicide. Suitable wetting agents mainly increase absorption through the somata and, probably, to some extent through the cuticle.

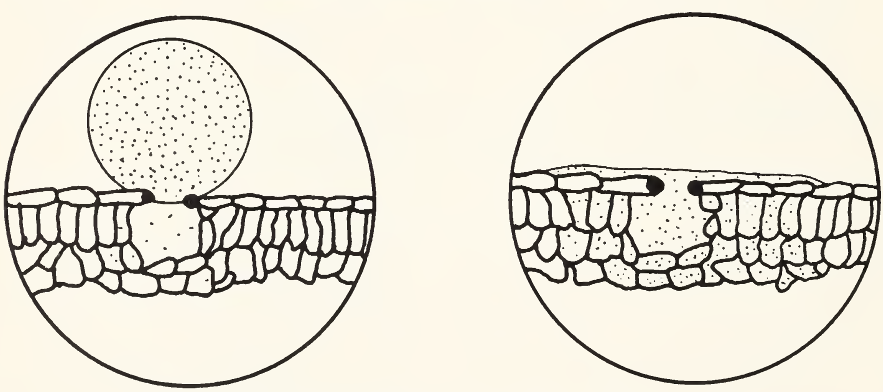
Translocation. Once a herbicide has entered a plant it must move from this



Absorption. Thick cuticle (left) prevents absorption of herbicide. Thin cuticle (right) permits good absorption.

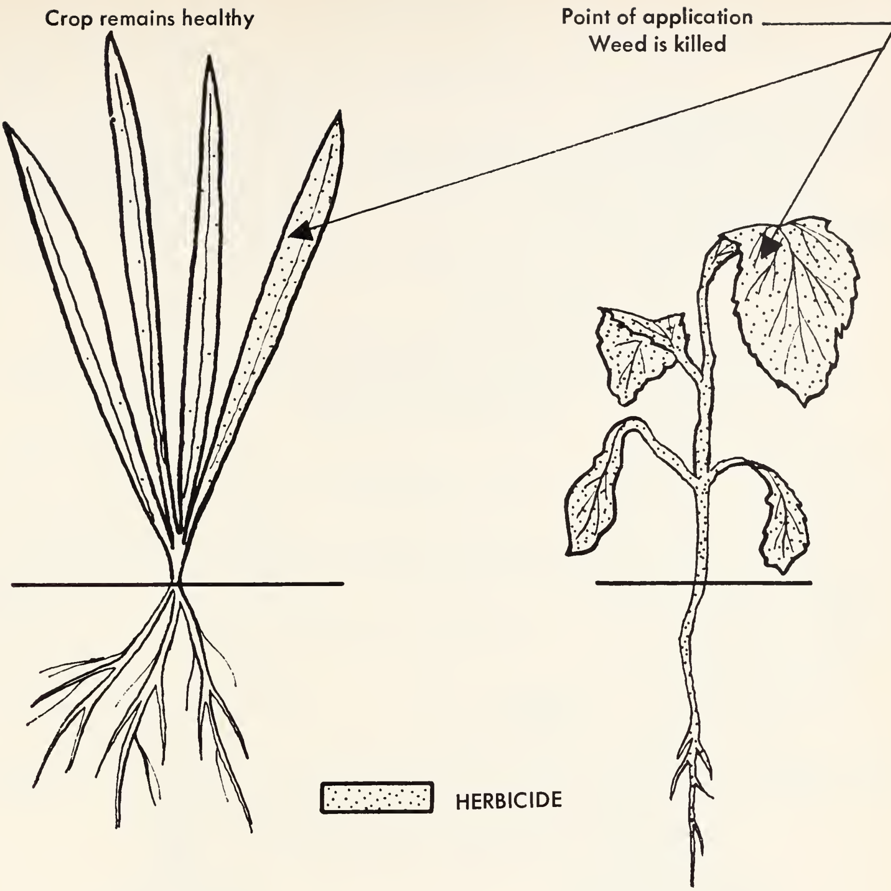


Absorption. Few and small stomata (left) prevent absorption of herbicide. Many large stomata (right) allow good absorption.



Absorption. No wetting agent (left) keeps absorption low. Wetting agent favors good stomata absorption (right).

point of absorption to other parts of the plant to exert its maximum effect. This movement (translocation) occurs both upward from the root to plant parts above the soil, and downward from the leaves to the underground parts of the plant. Translocation rate and the amount of herbicide translocated vary with different herbicides, and among plant species; they even vary within a given species under



Translocation. Poor translocation of 2,4-D in grasses make them resistant to weed killer. Good translocation of 2,4-D in broad-leaved weeds make them susceptible to weed killer.

different environmental conditions. Rate and amount of translocation of 2,4-D, for example, are usually greater in susceptible species than in resistant species.

Biophysical

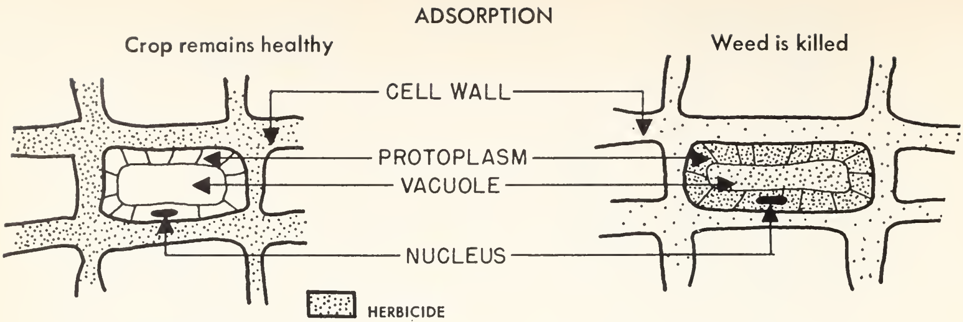
Biophysical differences between plants such as adsorption and membrane stability may determine whether or not a plant is killed.

Adsorption. Adsorption of herbicides by plant cells inactivates herbicidal material, probably by a physical rather than a biochemical process. Radioactive tracer studies have shown that the movements of herbicides are slowed down by the surrounding plant tissues. In extreme cases the herbicides may be so tightly bound to some plant constituent that it is not readily translocated from the point of application to the site of action, or it may even be so tightly held that it is unavailable for herbicidal action.

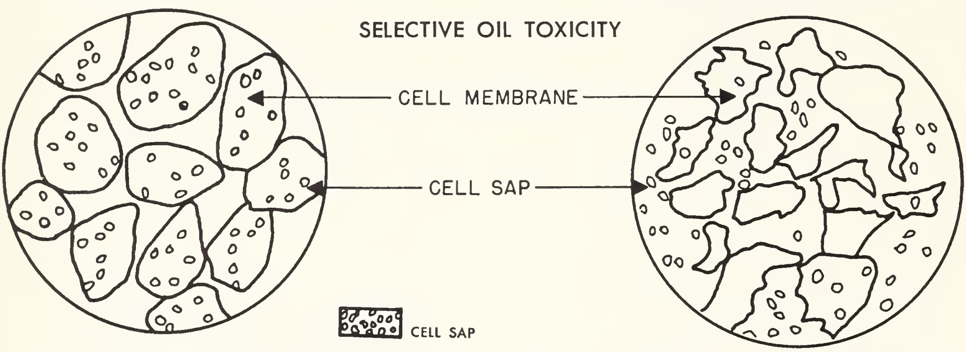
Membrane stability. Oil toxicity in carrots and other crops of the carrot family is one of the oldest examples of biophysical selectivity. The selective oils used for weed control in carrots kill weeds by damaging the cellular membranes and allowing the cell sap to flow into the intercellular spaces; this causes death of the cells and subsequent drying-out of tissues. Because their cellular membranes are resistant to this damage the carrots are not killed.

Biochemical

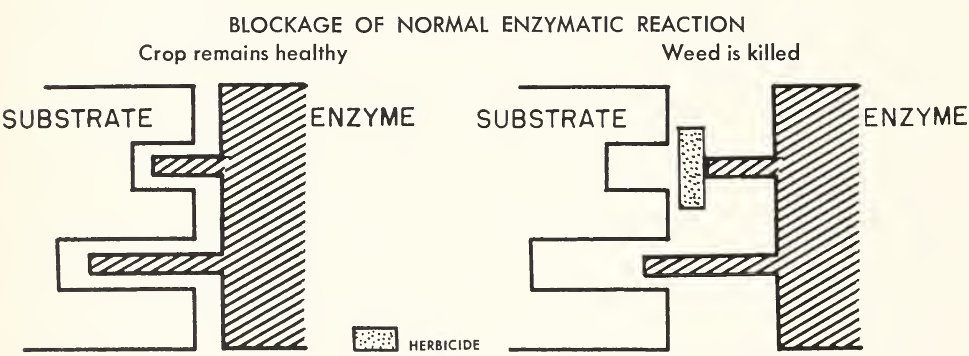
Biochemical reactions in various plants protect them from injury by certain herbicides. Their reactions include enzyme in-



Biophysical. Left: herbicide is adsorbed by cell wall, and is prevented from reaching protoplasm. Right: herbicide not adsorbed by cell wall, reaches protoplasm.



Biophysical. Carrot cell membranes (left) are resistant to selective oil. Membranes stay intact, keeping cell sap inside. Weed cell membranes (right) are damaged by selective oil, allowing cell sap to leak into intercellular spaces.



Biochemical. Herbicide (left) does not interfere with enzyme reaction and metabolism. Herbicide (right) alters structure and attachment of enzyme and upsets metabolic processes.

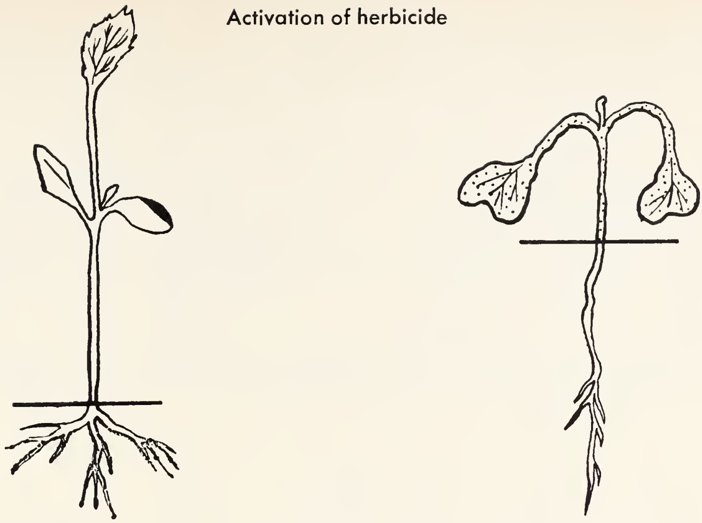
activation and herbicide activation or inactivation.

Enzyme inactivation. Many herbicides reduce enzyme activity in one plant species but not in another, thereby selectively interfering with one or more of the plants metabolic processes. This phenomenon can kill certain plants and leave others unharmed.

Herbicide activation. Activation of a harmless chemical into a plant killer sometimes can be used in selective weed control. For example, the relatively harmless compound 2,4-DB is changed in some sensitive plants into the weedkiller 2,4-D, while in resistant plants (e.g. alfalfa) this reaction takes place very slowly.

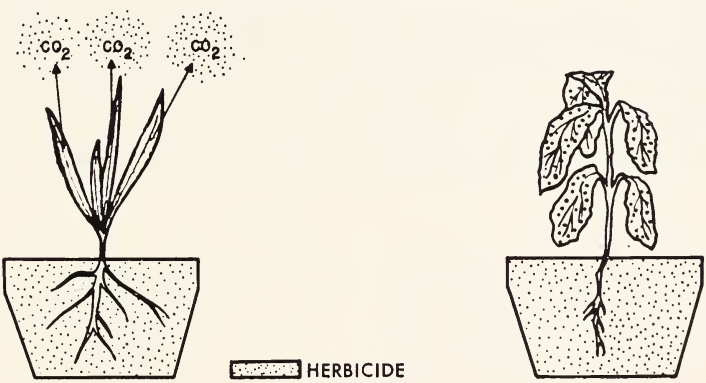
Herbicide inactivation. Some plants

Activation of herbicide



Biochemical. In resistant crop (such as alfalfa) harmless 2,4-DB is not converted to plant killer 2,4-D. In susceptible weed (right) 2,4-DB is converted to 2,4-D.

Inactivation of herbicide



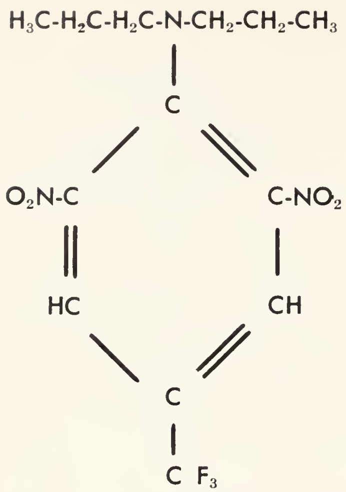
Biochemical. Left: herbicide simazine is decomposed by corn, liberating CO_2 gas and eliminating most of the plant killer. Right: simazine is taken up by weed and remains in plant.

can cause a herbicide to decompose into a harmless compound. For example, corn decomposes simazine and carbon dioxide gas is then given off by the plant; this protects the corn from accumulating lethal amounts of herbicide.

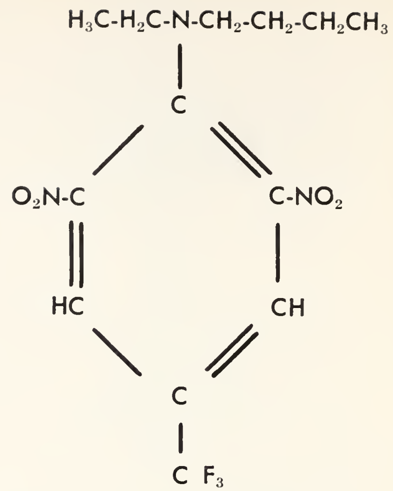
ROLE OF THE HERBICIDE

Molecular configuration

Variation in molecular configuration of a herbicide changes its properties, which in turn modifies its effects on plants. This is illustrated by the drawing at top of next page, which shows the herbicides trifluralin and benefin. The only difference is that a ($-CH_2-$) group is moved from one side of the molecule to the other. Trifluralin kills lettuce even when applied at a minimal herbicidal rate, but benefin will control weeds without harming lettuce.



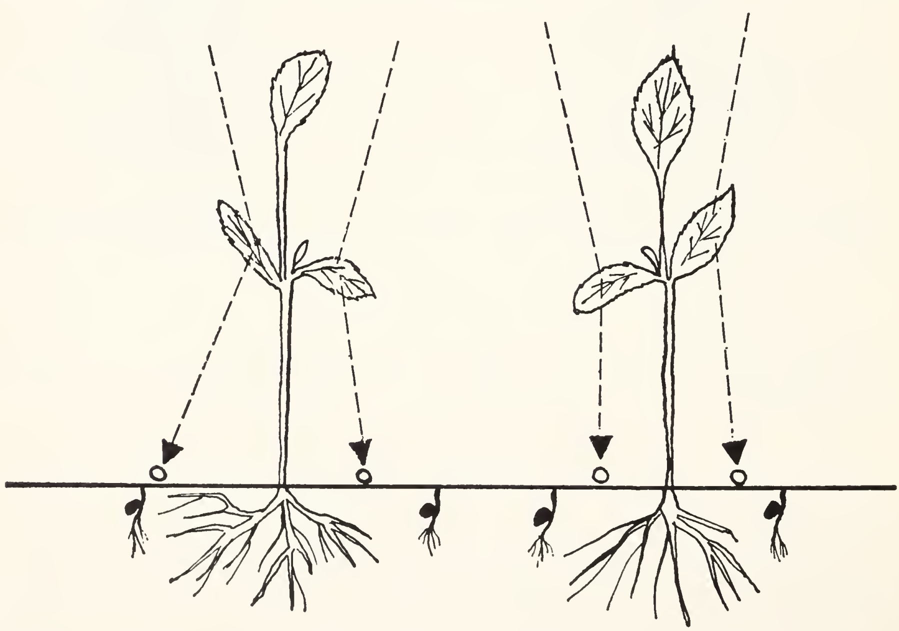
trifluralin



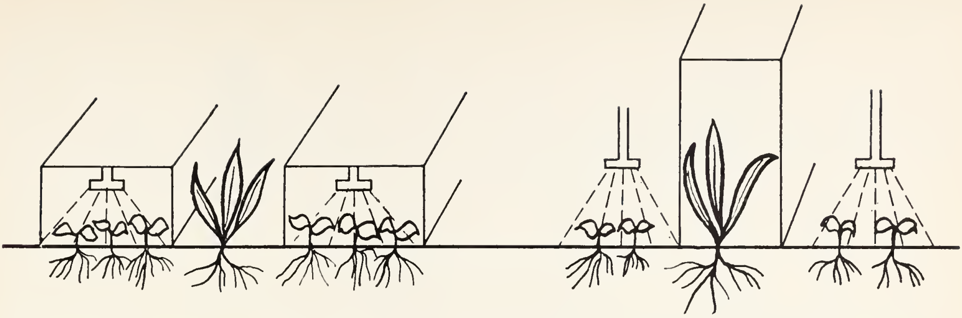
benefin

Formulation

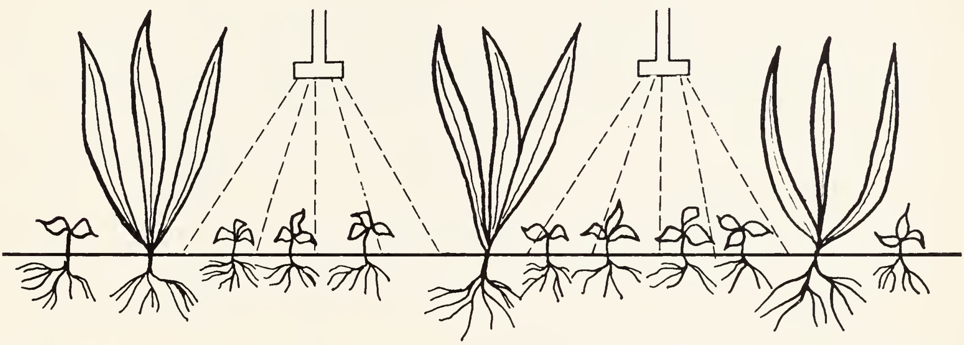
The formulation of a herbicide is of vital importance in determining whether it is selective or not to a given species. Perhaps the most extreme type of formulation to induce selectivity into a herbicide is the solid granular formulation which causes the herbicide to "bounce off" the crop and fall to soil without sticking to the foliage of the crop. Other substances known as adjuvants and surface-active agents (surfactants) are often added to improve the application properties of a liquid formulation—these may increase or decrease toxicity. The addition of nonphytotoxic oils or surfactants to atrazine



Selective placement. Granular formulation of herbicide allows herbicide to bounce off crop and fall on ground to control germinating weeds.



Selective placement. Shielded sprays protect crops from being sprayed with herbicide by having spray confined in shields (left) or crop covered by shields (right).



Selective placement. Directed sprays are directed toward base of crop plant, favoring minimum coverage of crop and maximum coverage of weeds.

or diuron induces foliar contact activity in these normally soil-active herbicides; these herbicides have little if any foliar activity in their usual formulation.

How the herbicide is used

A herbicide can be applied so that little of it contacts the crop and much of it contacts the weed. This can be accomplished by using shielded or directed sprays. Shielded and directed spray methods are normally used with herbicides applied to the leaves.

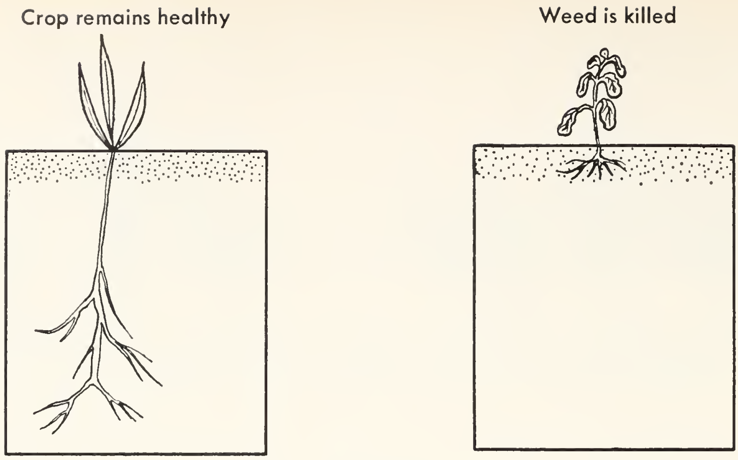
Shielded spray. In the shielded spray method, shields prevent the herbicidal spray from touching the crop while the weeds are covered by the spray. This is accomplished by placing the spray nozzles under a hood, or by covering the crop with a shield.

Directed spray. The directed spray method is usually used where the crop is higher than the weeds. Drop nozzles are used to spray weeds between the crop rows, and very little herbicide contacts the crop.

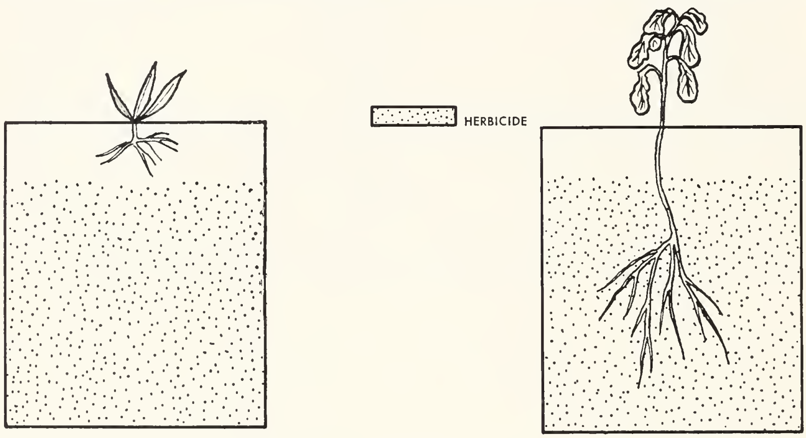
ROLE OF THE ENVIRONMENT

The dominant factors of environment which affects selectivity are soil type, rainfall or overhead irrigation, and temperature. In general, soil type in combination with the amount of rainfall determines the actual location of a specific herbicide in the soil, and temperature controls the rate of plant processes and growth.

Some herbicides not inherently selective may be made to function selectively because of their location in the soil. Such selectivity depends upon different rooting



Position of herbicide in soil. Deep-rooted crop (left) is not affected by herbicide which remains near soil surface. Shallow-rooted weed is killed by herbicide which stay near surface.



Position of herbicide in soil. Shallow-rooted crop (left) remains alive if herbicide moves beyond its rooting zone. Deep-rooted weed is killed when herbicide is leached into the deeper zones of the soil.

habits of crop and weed. If you want to remove deep-rooted weeds while leaving the shallow-rooted crops intact you must use a herbicide which readily moves beyond the rooting zone of the crop into the rooting zone of the weed. On the other hand, if you want to remove shallow-rooted weeds from a deep-rooted crop, you must choose a herbicide which remains near the soil surface.

Among the factors affecting the movement of herbicides in soil are water solubility of the herbicide, amount of rainfall, and soil type. In general, high water solubility of the herbicide, high amounts of rainfall, and light soil types favor a deeper penetration of the herbicide, while low water solubility of the herbicide, less rainfall, and heavy soil types favor a shallower penetration of the herbicide.

HOW TO APPLY SELECTIVE HERBICIDES

As selectivity is relative, it is possible to injure the crop or fail to obtain good weed control if the selective herbicide is not used properly. The following suggestions will minimize your risk.

Read the label. The manufacturers of herbicides have gone to considerable expense and effort to prepare a precise label indicating on what crops the herbicide may safely and legally be used, what weeds it will control, what rates you should use, and what special techniques may be required. Read the label and follow its suggestions.

Find rate of application. You must calibrate the sprayer to obtain the proper rate of application. The rate of application depends upon nozzle spacing on the boom, nozzle pressure, nozzle size, and tractor speed. To determine the volume of spray, run a test using the following procedure:

1. Make sure all nozzles are delivering the same amount of spray and producing a uniform pattern; replace those that are not.
2. Fill tank with water to a predetermined level.
3. Measure off a convenient test distance, such as 500 feet.
4. Select a medium tractor speed and nozzle pressure which can be increased or decreased if necessary.
5. Start the tratcor some distance before the starting marker so that the entire measured distance is traversed at the operating speed.
6. Open the boom valve as you pass the starting marker, and close it at the ending marker.
7. Measure the width of the spray pattern.
8. Refill the tank with water to the predetermined level and measure the number of gallons used.

Use the information gained in this test run in the following formula to calculate how many gallons of the spray you will use per acre:

$$\text{gallons per acre} = \frac{\text{square feet per acre (43,560)} \times \text{gallons used}}{\text{test distance in feet} \times \text{width of spray pattern in feet}}$$

Example:

The sprayer delivered 15 gallons of water over the 500 feet test distance and the spray pattern width was 20 feet wide:

gallons per acre =

$$\frac{43{,}560 \times 15}{500 \times 20} = 65.3 \text{ gallons per acre}$$

If this rate of delivery is not suitable, change nozzle pressure, tractor speed, or both, and recalibrate. Increasing the pressure will increase the rate of delivery, while increasing the tractor speed will decrease the rate. You can also change the rate by changing nozzle size or nozzle spacing on the boom.

Add the recommended amount of herbicide to this volume of spray solution to obtain the desired rate of application. When you use liquid formulation, correct the determined volume for the volume of liquid added in the herbicide formulation.

Watch application rate, particularly with granular application. The use of granular formulations of herbicides is relatively new and equipment for such applications is still being perfected. Be extremely careful to obtain the recommended application rate within safe ranges of selectivity.

Avoid drift hazards. The drift of hormonal types of herbicide onto sensitive crops has long been a problem. You can minimize the hazard by using shielded booms and low-pressure nozzles.

Avoid application under extreme climatic conditions. Certain environmental conditions such as rainfall, soil type, temperature, wind, and humidity may strongly affect your weed-control results. Apply herbicides under extreme environmental conditions only if published research results or personal experience indicate that such use is a suitable practice.

Get necessary permits. To insure safe use, permits are required for purchase of certain selective herbicides such as 2,4-D. You may get these permits from your local County Agricultural Commissioner.

Go slowly. When you first try a selective chemical weed control practice, do it on a limited scale until you have obtained personal experience with it.

TERMS USED IN SELECTIVE WEED CONTROL

Absorption—The process by which herbicides are taken into plants, by roots or foliage (stomata, cuticle, etc.).

Adsorption—The binding of substances on the surfaces of solids.

Annual—A plant that completes its life cycle in one year and then dies. Commonly classified as summer annuals and winter annuals.

Aromatics—Compounds derived from the hydrocarbon benzene (C_6H_6).

Band application—An application of spray or dust to a continuous restricted area, such as in or along a crop row rather than over the entire field area.

Basal treatment—An application of herbicides to the stems of plants at and just above the ground line.

Biennial—A plant that completes its growth in 2 years. The first year it produces leaves and stores food; the second year it produces fruits and seeds.

Broadcast (blanket) application—An application of spray or dust over an entire area rather than only on rows, beds, or middles.

Carrier—The liquid or solid material added to a chemical compound to facilitate its storage, shipment, or use in the field.

Compatible—Quality of two compounds that permits them to be mixed without effect on the properties of either.

Concentration—The amount of active material in a given volume of diluent. Recommendations and specifications for concentration of herbicides should be on the basis of pounds per unit volume of diluent.

Contact herbicide—A herbicide that kills primarily by contact with plant tissue rather than as a result of translocation.

Cotyledon leaves—The first leaf, or pair of leaves, of the embryo of seed plants.

Crown—The point where stem and root join in a seed plant.

Directed spray—An application made to minimize the amount of herbicide applied to the crop. This is usually accomplished by setting nozzles low with spray patterns intersecting at the base of the plants just above the soil line.

Emergence—Appearance of the first part of the crop plant through the ground.

Emulsifying agent—A material which facilitates the suspending of one liquid in another.

Emulsion—A mixture in which one liquid is suspended in minute globules in another liquid; for example oil in water.

Growth stages—(1) Tillering stage—when a plant produces additional shoots from a single crown, as in wheat. (2) Jointing stage—when the internodes of the stem are elongating. (3) Boot stage—when the seed head of a plant begins to emerge from the sheath—usually applied to the grain crops.

Herbicide—A chemical used for killing plants.

Perennial—A plant that lives from year to year. In many cases (in cold climates) the stem dies down but the root persists.

Post-emergence treatment—Treatment made after the crop plants emerge.

Pre-emergence treatment—Treatment made after a crop is planted but before it emerges.

Pre-plant treatment—Treatment made before the crop is planted.

Rate and dosage—These terms are synonymous, but "rate" is preferred. Usually refers to the amount of active ingredient material (such as 2,4-D acid equivalent) applied to a unit area (such as 1 acre) regardless of percentage of chemical in the carrier.

Rhizome—Underground stem capable of sending out roots and leafy shoots.

Selective herbicide—A compound more toxic to weeds than to the crop in the field. Helps control weeds without damaging the crop.

Soil sterilant—A material which renders the soil incapable of supporting plant growth. Sterilization may be temporary or practically permanent.

Spray drift—The movement of airborne spray particles from the spray nozzle to beyond the intended contact area.

Stolon—Runners or stems that develop roots and shoots at the tip or nodes, as in the strawberry plant.

Stool—To produce crown shoots; to tiller.

Surfactant—A material which in pesticide formulation imparts emulsifiability, spreading, wetting, dispersability, or other surface-modifying properties.

Suspension—A liquid or gas in which minute solid particles are dispersed but not dissolved.

Systemic herbicide—A compound which is translocated within the plant and has an effect throughout the entire plant system.

Translocation—Transfer of food or other materials such as herbicides from one plant part to another.

Volatile—Quality which makes a compound evaporate or vaporize (change from a liquid to a gas) at ordinary temperature on exposure to air.

Wetting agent—A compound which when added to a spray solution causes it to spread over wet plant surfaces more thoroughly.

For current recommendations on the use of selective herbicides consult the latest University of California WEED CONTROL RECOMMENDATIONS—these are revised annually and are available from your local Farm Advisor.

Because basic factors of selectivity interact with one another and because they are so complex, the results are not always predictable; therefore, an expected selectivity may be lost under an unusual set of conditions. Public agencies and herbicide manufacturers have gone to considerable expense to prepare recommendations and/or labels indicating on what crops a given herbicide may safely and legally be used, what weeds it will control, what rates should be used, and what special techniques may be required. Thus it is only logical to read these recommendations and labels carefully and to follow their suggestions equally carefully.

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George B. Alcorn, Director, California Agricultural Extension Service.

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