26. Important Herbicides

The number of chemicals now commercially available and under test is very considerable. Each substance possesses a chemical designation; for example, that of 2,4-D is 2,4-dichlorophenoxyacetic acid, merchandised as either an amine salt or various ester derivatives. Chemical names provide a precise means of designating compounds and furnish a concise description of the chemical structure. However, they are too cumbersome for popular use, and a system of common names has been standardized by the Weed Society of America. In some instances, the names are alphabetic appellations derived from the chemical description, for example CDAA for 2-chloro-N, N-diallylacetamide, DNBP for 4,4-dinitro-ortho-secondary butylphenol. The origin of "2,4-D" is likewise obvious from the chemical terminology given above. The names of other herbicides (e.g. dalapon and monuron) are words which bear little relationship to their chemical characterizations.

Herbicides are usually sold under various trade and brand names. Randox is a well known proprietary designation for CDAA; DNBP and related compounds are sold as Sinox, Premerge, Dow General, etc.

Obviously, some classification of herbicides is necessary to provide a pattern for discussion and understanding. In the following treatment, a chemical grouping has, in most instances, been utilized; that is, those compounds having the same basic chemical structure are discussed together. This procedure has merit in that structurally similar substances tend to possess analagous attributes and unit generalizations can be employed. For example, the first group-heading below considers the phenoxy compounds, or growth hormone herbicides. These include 2,4-D, 2,4,5-T, and MCP, all of which have similar weed killing properties and are employed in somewhat the same manner. Insofar as possible this procedure is followed throughout the following section.

Trade names are employed to some extent in the subsequent enumeration — but with the usual non-warranty that no superiority of one manufacturer's product over another is to be implied.

The herbicidal field is an active and highly specialized area. The following treats only those herbicides most widely used or which are the subject of current interest. No doubt certain recent developments, of considerable potential significance, have been omitted.

2,4-D AND RELATED CHEMICALS

These are variously termed growth regulator or hormone type weed killers, or phenoxy compounds. Their most noteworthy characteristics as a group are (1) a high degree of selectivity with regard to different kinds of plants, and (2) the fact that the chemical can be used in relatively low dosages in comparison with many other herbicides. The phenoxy compounds are employed primarily for the control of broad-leaved weeds among tolerant grasses, and with pre-emergence application, primarily in corn, for the control of annual broad-leaved weeds and grasses.

2,4-D is an organic acid (2,4-dichlorophenoxyacetic acid). It is available in either amine or ester form. The amines are usually employed in small grains, flax, corn, and on lawns. The esters, of which several are commercially available, are liquids which are insoluble in water but are soluble in oils. They are usually formulated by dissolving in oils. For application, the concentrate is emulsified in water with the help of an emulsifying agent or, in some instances, is applied in oil. The esters are used selectively in corn, for pasture and roadside spraying, as components of brush-killers, and for pre-emergence treatment of corn.

Dosages of 2,4-D are usually given in pounds per acre of acid equivalent, regardless of the formulation employed.

2,4-D as a Post-emergence Herbicide

There are distinct differences between the post-emergence characteristics of 2,4-D esters and amines. The esters are more toxic to plants than the amines. They are somewhat volatile, but the several kinds differ in this characteristic and are sometimes designated as low- or high-volatile forms. If esters are used in proximity to susceptible ornamental plants or crops, volatility and spray drift constitute hazards. They are frequently valuable in situations in which injury to crops is not critical.

Conditions under which 2,4-D is applied modify its effectiveness. In general, propitious times are those favoring rapid growth of the plants, temperatures 70^0 or above, and freedom from rainfall for 24 hours after treatment. The affected plants are killed slowly. They stop growing and become distorted. The leaves become twisted, brittle, or sometimes water-soaked. Subsequently, the stems and leaves dry up and disintegrate.

Penetration by amines is slower than penetration by esters. Hence, a rain a few hours after spraying is not as likely to remove the effect of an ester as that of an amine. On the other hand, the amine can be "souped up" with a wetting agent. However, this will cut down upon its selectivity. Esters more easily penetrate certain "resistant" perennial species — leafy spurge *(Euphorbia)*, Russian knapweed *(Centaurea)*,

perennial peppergrass *(Cardaria)*. In other instances, massive penetration by the esters may result in injury to vascular tissue before significant translocation to the roots can take place. The slower, less spectacular effect of the amines may thus result in a more complete kill. Also, there is some evidence that too heavy applications, resulting in premature death of the tops, may render kill of underground parts of perennial weeds as unsatisfactory as an underdose. An additional consideration after application of 2,4-D to perennial weeds is to allow time (2 to 3 weeks) before cultivation for movement of the herbicide to the underground parts.

Grasses are not readily killed by 2,4-D, while the majority of broad-leaved weeds are variously susceptible. In addition to grasses, common or important weeds which are quite resistant to 2,4-D include white campion *(Lychnis)*, milkweed *(Asclepias)*, bouncing-bet *(Saponaria)*, Russian knapweed *(Centaurea)*, tanweed *(Polygonum)*, and leafy spurge *(Euphorbia)*. Somewhat resistant weeds (several applications usually required for complete kill) include Canadian thistle *(Cirsium)*, prickly lettuce *(Lactuca)*, horsenettle *(Solanum)*, perennial sowthistle *(Sonchus)*, wild buckwheat *(Polygonum)*, and purslane *(Portulaca)*. Sensitive or easily killed weeds include butterprint *(Abutilon)*; cocklebur *(Xanthium)*, shoofly *(Hibiscus)*, kochia *(Kochia)*, ragweed *(Ambrosia)*, wild carrot *(Daucus)*, hoary vervain *(Verbena)*, whorled milkweed *(Asclepias)*, docks and sorrel *(Rumex)*, yarrow *(Achillea)*, poison ivy *(Rhus)*, mustards *(Brassica)*, annual morning-glories *(Ipomoea)*, plantains *(Plantago)*, biennial thistles *(Cirsium)*, and chickweed *(Stellaria)*.

Some dicotyledonous crops are resistant to 2,4-D and/or other phenoxy compounds to the degree that selective utilization can be made. Subject kinds include flax and, under some conditions, various of the leguminous forage crops. The herbicides must be applied in light dosages; only highly susceptible broad-leaved weeds will be affected.

The fact that 2,4-D and its congeners do not ordinarily kill grasses does not mean that serious damage to crops cannot be brought about. Corn and small grains are most apt to be affected in the seedling stage, or after the flowering head has begun to form. In the latter instance, the seed set may be affected. The "safe" periods then are between the seedling and flower-initial stages, and after the seeds are fairly well matured. Even though spraying operations are carefully timed, injury may result under certain combinations of conditions: hot weather, the plants rapidly growing, and overdosage. Such injury may be manifested in abnormal growth, root weaknesses, and stalk brittleness (favoring lodging) and general reduction of vigor.

Beyond considerations affecting the crop being sprayed, unintentional injury to other plants may be wrought. The consequences of spray drift and volatility should always be kept in mind. Soybeans are frequently adjacent to corn fields, and home gardens to lawns. Careless roadside spraying may cause havoc in adjacent fields. Considerable difficulty has been experienced in several of the southern states (e.g. Arkansas and Louisiana) in areas where both rice and cotton are

produced. 2,4-D is useful for controlling broad-leaved weeds in rice, but cotton is easily killed by traces of the herbicide. These states have laws regulating the use of 2,4-D and similar herbicides.

Subsequent use of equipment for other jobs (e.g. applications of insecticides) may result in unexpected crop injury if sprayers are not carefully cleaned (methods are discussed in a following section). For home lawn applications it is best to have one knapsack sprayer reserved exclusively for the use of herbicides.

2,4-D is non-toxic to animals, but treated areas probably should not be grazed immediately after spraying. It is possible that 2,4-D could mask the flavor of unpalatable or poisonous species, or that 2,4-D injured plants may produce and accumulate abnormal chemical constituents. Thus the herbicide might indirectly contribute to stock injury.

What does 2,4-D do in order to kill? After penetration it is apparently translocated to meristematic regions. This translocation may take place readily up and down but appears limited laterally, especially in underground roots or rhizomes. The translocation is in the phloem and seems to be correlated with the movement of photosynthates.

The action of 2,4-D involves a reduction in growth and an increase in respiration, but the mechanism is not clearly understood. It has been suggested that, as a consequence of the increase in respiration, the plants simply respire themselves to death. It is probably not this simple. One recent hypothesis involves the substitution of 2,4-D in the respiratory cycle in which it catalyzes the splitting of high energy phosphate linkages. Another theory is that, acting in the leaves, it prevents synthesis and/or movements of certain proteins found in the leaves. This suggestion is attractive for it affords an explanation of the high degree of selectivity between plants, such selectivity being upon the basis of different proteins. It has also been inferred that 2,4-D interferes with the normal auxin balance.

2,4-D as a Pre-emergence Herbicide

The second major utilization of 2,4-D is for pre-emergent treatment in fields of corn. Application is made to the soil at or immediately following planting. The effect on the soil seems to be limited to a few weeks following planting.

The above generalization that the esters are more apt to cause crop injury (as compared to the amines) is reversed. With respect to pre-emergence treatment, the esters are less subject to leaching and thus, in event of rain, are less likely to be washed down to the crop seeds.

Ordinarily, as indicated by the above discussion, 2,4-D is applied by spraying in liquid solution or suspension. Relatively recently it has become available in granular form and may be applied dry for pre-emergence use or in mixtures with other substances as a sterilant.

The pre-emergence utility of 2,4-D is discussed in further detail under treatment of weed control in corn.

Herbicides Similar to 2,4-D

The above discussion has related specifically to 2,4-D, but most of the generalizations apply equally to several of the related phenoxy compounds. 2,4,5-T (2,4,5-trichlorophenoxyacetic acid) is usually employed in mixtures with 2,4-D for spraying woody plants. MCP (MCPA, 2-methyl, 4-chlorophenoxyacetic acid) is somewhat milder in toxic effect to some crops than 2,4-D and is most frequently recommended in situations where possible injury to crop plants is critical, e.g. flax, oats with a legume understory, peas, or in lawns. This "milder" action of MCP does not necessarily apply to all weeds; Minnesota has reported certain kinds more easily killed than by 2,4-D.

Two relatively new phenoxy-butyric acid derivatives, termed by the designations 4-(2,4-DB) and 4-(MCPB) tentatively "look good" in legume seedings or in established stands for seed productions. These chemicals have been tested at sufficiently high dosages to kill numerous weed kinds, and without injury to the forages. They should not be used on legumes to be grazed, or cut for hay as tolerances have not yet been set by the Food and Drug Administration.

Silvex (selective in turf) is a phenoxy-propionic acid. Sesone (SES, Crag Herbicide-1) constitutes another choice for pre-emergence use.

Erbon (Baron) also chemically falls in the 2,4-D family. It is a soil sterilant. 2,4-D itself is sometimes mixed or applied with other compounds as a double action soil sterilant, e.g. borate – 2,4-D combinations.

OTHER HERBICIDES

Dinitro Compounds

These are also known as dinitro phenols or substituted phenols and have received various designations as DN, DNOSBP, and more recently DNAP and DNBP. Sinox, Dow Selective, Dow General, and Premerge all fall into this group.

The dinitros have found utilization the past 15 years in a variety of general contact or selective roles. With the continuing advent of new kinds of weed killers, this role may be diminishing. Some pertinent (and to some extent controversial) areas of utilization in the North Central states are: (1) Corn. DNBP amine. The herbicide may be applied before or as the crop seedlings emerge, or when the young plants are six to ten inches tall; reports as to effectiveness are not in agreement. (2) Legumes. Post-emergence in seedings or (heavier

dosages) on dormant alfalfa. (3) Soybeans. Pre-emergence. Satisfactory results against both grassy and broad-leaved weeds are usually obtained unless the weather is excessively dry. Bean injury sometimes results. (4) Small grains. There is less likelihood of injuring the legume understory than with 2,4-D. (5) Flax.

These compounds have some shortcomings from the handling standpoint. The cresol forms (general contact herbicides) are oily liquids and must be emulsified in water; they are poisonous and readily stain hands and clothing. The DNBP sodium and amine salts are water soluble and selective in action. Toxic action is correlated with temperature, and this fact must be kept in mind in predicating dosages if crop injury is to be avoided.

Urea Compounds

These substances are capable of playing two roles: (a) soil sterilants, and (b) at reduced dosages, selective herbicides.

As sterilants, at moderate level treatments — usually in small areas since the unit cost is relatively high — they may be employed in cropped soil where the objective is to kill persistent perennial weeds and if possible to avoid extended soil sterility. "Complete kills" are most frequently achieved with shallow-rooted weeds (e.g. quackgrass). Higher rates of treatment are used on industrial or non-agricultural ground, irrigation ditch banks, railroad right-of-ways, etc. where continued soil sterility is the specific objective.

Some of the subject chemicals are Monuron (Telvar), Diuron (Karmex), Neburon (Kloben), Fenuron (Dybar), and Urox. Dosage and nature (whether dry or in water) of application depends upon the specific weed killing objectives to be achieved, and the particular herbicide used. When water suspension application is employed, continuous agitation is necessary to prevent settling and sprayer trouble.

Soil sterilants are frequently mixed in various ways. BMM (Ureabor) for example, is a monuron-borate mixture.

The urea compounds have several potentialities as selectives. For example, recent work in Wyoming has demonstrated that Diuron (2 to 3 pounds per acre) is very effective in eliminating most annual weeds in established alfalfa. Monuron has proved successful in weed control in citrus orchards in California without injury to the trees. Both of these substances are employed selectively in several kinds of vegetable crops.

Carbamates

The carbamates include the weed killers designated as IPC and CIPC, and EPTC or Eptan.

CIPC has proved useful in such diverse areas as reducing broad-leaved weeds in legumes and barnyard grass in rice. It has been

attempted for pre-emergence employment in soybeans but has not gained wide acceptance. It may have potentialities against dodder in legumes for seed production. Partial control of both grassy and many broad-leaved weeds is feasible in dormant alfalfa.

EPTC has had a short and troubled career. It was commercially available in 1958 and 1959 seasons, when it appeared to have considerable potentialities as a pre-emergence herbicide, especially in corn. However, an unexpected degree of crop injury was encountered and the manufacturer has placed it on restricted sale for the 1960 season pending further research.

Amino triazole (Amizol, Weedazol, Amitrol)

This compound, a white powder soluble in water, kills most vegetation. Readily translocated, its application results in chlorosis; lethal action is slow and new shoots may appear but they likewise are chlorotic. It has been recommended as a means of controlling perennial weeds (e.g. Canadian thistle and quackgrass), and should be applied at the rate of 8 pounds of 50 per cent preparation per acre in approximately 50 gallons of water when the plants are 6 to 10 inches high. A wetting agent may increase effectiveness. Subsequent mowing is undesirable as it may prevent translocation of the chemical to the roots. Cultivation should be delayed for 2 to 3 weeks. Since this chemical affects all plants, it can scarcely be used in crops or pastures. Early spring application in some areas may be followed by a late planted crop (the material has no carryover effect in the soil). Treatment of non-crop areas or spot applications may be made later in the summer. If a knapsack sprayer is used for the latter, 4 to 6 tablespoons of the chemical per gallon of water per square rod will provide a reasonable dosage. Hard-to-kill weeds (e.g. tanweed, *Polygonum*) may require several applications.

TCA (Trichloroacetic acid, sodium salt)

TCA has demonstrated usefulness in a variety of roles. It can be employed as a selective herbicide, about 5 pounds per acre for some forage legumes and in flax. It is sometimes recommended for the control of perennial grasses, quackgrass in the North, Johnson grass in the South. Dosages range from 1 pound per gallon per square rod for complete kill on small areas to 20 to 40 pounds per acre for stand reduction. Application may be made as heads appear or in late summer. The grass should be mowed, followed by removal of the hay and/or disking. Effectiveness is influenced by several factors, e.g. rainfall or amount of organic matter in the soil. Injury to subsequent crops may ensue if abnormally dry conditions prevail.

TCA is an unpleasant material to use. It is somewhat difficult to

get into solution and is sold either as a solid (sodium salt) or ready-made solution. It is injurious to the human skin (should immediately be rinsed off) and is extremely corrosive to spray equipment.

Dalapon (Dowpon, 2, 2-dichloropropionic acid, sodium salt)

Dalapon is a translocated herbicide. In the North Central states considerable attention has perhaps been devoted to its possible usefulness in quackgrass control. For example, Wisconsin workers suggest its employment applied in the spring at 5 pounds (74 per cent acid equivalent preparation) per acre. Plowing may follow 3 to 7 days after treatment, but planting should be delayed 2 to 3 weeks or crop injury may result. Alternately, fall applications at 10 pounds per acre may be made, but control was found to be less complete. Similar Minnesota studies have related to the control of quackgrass in potato growing areas. The investigators suggest spring application of 10 pounds of dalapon per acre. They indicate that subject areas can be plowed and planted to potatoes a week to ten days after treatment without injury to the crop.

In small areas, 1/8 pound per gallon of water per square rod, fall and subsequent spring treatment, has been found to be reasonably effective. Higher dosages can be used if extended soil sterility is desired.

Dalapon has also received attention for Johnson grass control and applied at heavier rates, it can be employed as a sterilant. It has proved useful as a selective herbicide against annual grasses in seedings of alfalfa or birdsfoot trefoil at 2 to 4 pounds per acre with no companion crop. It has been recommended in low dosages (1 pound per acre) for grass seedlings in flax.

Simazin and Atrazine

Simazin is one of the newer pre-emergence herbicides for corn. It is available as an 80 per cent wettable powder, reasonably safe to handle and noncorrosive. Reference is frequently made to the difficulty of keeping the preparation in suspension and resultant sprayer clogging. These difficulties have largely been alleviated in the presently available formulation — the previous 50 per cent powder was less finely ground.

The chemical is usually applied 1 to 4 pounds an acre in 30 to 40 gallons of water. Effectiveness of treatment against both grassy and broad-leaved weed seedlings, relatively speaking, is excellent. The danger of injury to the corn is quite slight. Persistence in the soil is better than, for example, 2,4-D. Some usual limitations of pre-emergence chemical application must, however, be expected; i.e. the degree of effectiveness may be mediated by timeliness of rainfall; it is

necessary to use lighter applications on sandy soils. Simazin, as compared to 2,4-D is rather expensive. Band application (1 to 2 pounds an acre in 10 to 20 gallons of water) is capable of cutting cost in about one third (to approximately $5.00 an acre).

There has been some concern as to possible carry-over action of simazin in the soil. Within the dosage ranges indicated above, the danger of deleterious effects on subsequent crops is probably limited, but the planting of so-called tolerant crops (corn) the subsequent season may be advisable. Heavier applications as a soil sterilant will be more likely to result in substantial carry-over.

Atrazine is a recently released product chemically similar to simazin. While it is still rather early to evaluate its merits on a comparative basis, it would seem to be as good as or possibly better than simazin for corn. It can be applied early post-emergence as well as pre-emergence. It is more soluble than simazin, hence will not be effective over as long a period, but with limited rainfall might yield better immediate control.

CDAA (Randox and Randox-T)

CDAA is effective against grass seedlings in corn and soybeans. Possibly it can also be used in sorghum but injury is more likely. It is not useful when dicotyledonous, broad-leaved weeds constitute the principal problem.

The chemical is merchandised as a liquid or in granular form. Application is usually made at levels of about 4 quarts commercial preparation per acre in 30 to 40 gallons of water; or if band treatment is employed, 1-1/2 quarts in 6 to 10 gallons of water.

Under ideal conditions, CDAA is extremely effective and causes a minimum of crop injury. However, it has certain limitations. It is toxic and handling precautions (i.e. rubber gloves, goggles) are necessary if the liquid formulation is employed; overdosage, or use on light or sandy soils is apt to result in crop injury; effectiveness is all too dependent upon the whim of weather; the material costs about $3.00 an acre for band application. It is perhaps most valuable in grass-infested, heavy soils.

Randox-T, a recent release, is capable of affecting both broad-leaved and grassy weeds. If present preliminary reports are borne out, its broader weed-killing scope should render it more widely useful than the older preparation.

NPA (Alanap)

Much work has gone into efforts to devise a dependable, pre-emergence chemical treatment for soybeans. As with other available herbicides, Alanap perhaps falls short of desired goals but may have

especial value for this crop. The chemical is available as a liquid soluble in water or in granular form. It can be applied as complete coverage or band treatment. Economic considerations usually favor the latter. Under ideal soil and rainfall conditions, it is capable of giving the beans a weed-free start.

MH (Malic Hydrazide)

Malic hydrazide is a translocated growth inhibitor which has received attention for quackgrass and other grasses. It is not as effective as some of the above-discussed materials but can be used sparingly under trees.

Crabgrass Killers

Crabgrass is now the most conspicuous weed in home lawns in the North Central states. Several chemically unrelated herbicides are available to aid the harassed home owner or turf manager. Their action is essentially selective. The annual crabgrass and its seedlings are killed; the established perennial bluegrass is frequently yellowed but survives. Success in eliminating crabgrass through the employment of herbicides is frequently incomplete because several applications 2 to 3 years in succession are often necessary before seed resources in the soil are exhausted. Proper renovation of the bluegrass turf is necessary if reinfestation is to be prevented.

Currently recommended weed killers include PMA (phenylmercuric acetate), DSMA (di-sodium methyl arsenate), chlordane, and KOCN (potassium cyanate).

Ammate (AMS, Ammonium Sulfamate)

A non-selective killer and soil sterilant, ammate is used for poison ivy and miscellaneous perennial weeds (for example, leafy spurge) which are resistant to 2,4-D. It prevents re-sprouting on stumps and aids decomposition. It is sometimes employed as a sterilant along sidewalks, paths, and driveways. Foliage spray applications usually require 1 to 3 gallons of water per square rod (about a pound of the chemical in a gallon), thus it is obviously too expensive to use in large areas. The material is corrosive to equipment.

Sodium Chlorate

The chlorates are non-selective herbicides and soil sterilants. They have been used for weed control purposes for 30 to 40 years.

Dry or foliage application may be employed (2 to 4 pounds per square rod). All vegetation is killed, and the soil is rendered sterile for several months. While expense prohibits use over large areas, the chlorates have been valuable weed killers for eradicating small patches of perennial noxious weeds. They are sometimes applied jointly with borax compounds, e.g. polyborchlorate.

The chlorates are strong oxidizing agents and may be flammable or explosive under certain conditions. Do not let solution get on clothing and dry! Atlacide contains additives which decrease this hazard.

Borax Compounds

Borax compounds (e.g. Borascu) are soil sterilants. They are frequently merchandised in combination with other herbicides: polybor chlorate with sodium chlorate; BMM and Ureabor with monuron; DB granular with 2,4-D; Benzabor with TBA.

Application is usually in non-agricultural soil, especially in industrial areas, railroad yards, lumber yards, and oil installations. Persistent, perennial weeds in crop soil can be effectively destroyed. Total elimination of all vegetation and soil sterility must be assumed.

Some preparations are applied dry, often available in granular form, and others are put on by spraying. They are relatively cheap but must be used in large amounts.

Benzoic Acid Derivatives

Two recently released soil sterilants are designated TBA and PBA. They have given very satisfactory control of bindweed without long term soil sterility. They do not possess corrosive or poisonous attributes of some of the other sterilants.

Arsenic Trioxide

The very poisonous, arsenical compounds were once used in a variety of ways as herbicides. They have largely been replaced by safer (less toxic to animals) and more satisfactory herbicides. However, arsenic trioxide is still employed as a soil sterilant and is perhaps the most satisfactory compound available where long term sterilization is desired. Tests in California have indicated that the effect on the soil may last up to 10 years. Frequently arsenicals are mixed with other herbicides which have a stronger initial toxicity in order to kill existing vegetation more rapidly.

Oils

A great variety of oils have been employed as herbicides, principally in two ways: (1) as complete, contact killers for above-ground weed growth along railroad right-of-ways and similar areas, e.g. kerosene, used crankcase oil, fuel oil, or diesel oil; (2) as selective herbicides in crops of the carrot family. Carrots and relatives are reasonably immune to specific grades of oils, while most annual weeds are not. The crops involved include carrots, parsnips, parsley, caraway, and dill.