25. Chemical Weed Control

Chemical weed killers or herbicides have been used in a limited manner for many years. Until recently, however, research progress was limited, and the total significance of herbicides in agriculture was relatively small. The discovery of the potentialities of certain growth-regulator substances (2,4-D and related compounds) as selective herbicides served to stimulate unprecedented interest in this field and triggered a new era. The last 15 years have witnessed feverish activity by industry, agricultural universities, and the United States Department of Agriculture in developing and promulgating new methods and philosophies of weed control. During this period, dozens of new chemical weed killers have appeared on the market. New ways of applying chemicals have likewise been conceived and advocated. No doubt as progress continues, the herbicides will become more and more important. However, in the following discussion it should be kept in mind that at the present time chemical weed control is usually a supplement to — not a substitute for — good cropping practices; that satisfactory control of most weeds can ordinarily be achieved through application of these practices; that chemicals are expensive, both as to purchase price and application; that the successful use of herbicides requires experience and skill; and that herbicides are capable of injuring crop plants as well as weeds.

A HISTORICAL NOTE

The use of chemical materials for killing weeds lagged considerably behind their employment as fungicides or insecticides. The introduction of the Bordeaux spray for the control of certain plant diseases during the latter part of the last century stimulated interest in the use of chemicals as pesticides. The selective action of copper salts against mustards and other broad-leaved weeds in small grains was discovered around 1900 and was followed within the next decade by similar utilization of dilute sulphuric acid, sodium nitrate, and ammonium sulphate. That there was interest in this field is indicated by a statement by Bolley in 1908, writing from North Dakota: "When the farming public has accepted selective weed controls as a method of attacking weeds as a regular farm operation, the gain of the country at large will be

greater in monetary consideration than that which has been afforded by any other single piece of investigation applied to field work and agriculture."

Between 1915 and 1930, sodium chlorate and the acid arsenicals were introduced, as well as a few other chemicals of limited application. Since the advent of 2,4-D, and especially in the last ten years, many more chemicals have been tested for herbicidal properties than had been in the previous half century.

CHARACTERISTICS AND CLASSIFICATION OF HERBICIDES

Herbicides may be classified in a number of ways: as to the manner in which applied, their formulation, manner of killing, their degree of selectivity, etc. Some of these considerations are discussed below.

Selective and Non-selective Herbicides

Some substances employed as weed killers are poisonous to all vegetation. When applied at proper dosages they will provide a complete kill. Chlorates, borax compounds, and various herbicidal oils constitute examples. Other herbicides (e.g. 2,4-D) are selective in their action; they are capable of killing some kinds of plants, but will leave others relatively unharmed. Since most weed control problems involve killing weeds which grow in crops, it is obviously selective herbicides which have the greatest potential importance to agriculture.

The words selective and non-selective are frequently used as if the distinctions were black against white, i.e. qualitative in nature. This is not the case; the differences are at best quantitative. Dependent upon dosage, formulation, method and timing of application, many herbicides may exhibit either selective or non-selective action; their lethal spectrum may be variously broadened or narrowed. For example, dalapon and some of the urea compounds are employed both as selective and non-selective weed killers. 2,4-D is a selective herbicide but the number of kinds of plants which are affected is greater at higher dosages. Likewise, the action of 2,4-D depends upon manner of application; as a post-emergence treatment it does not kill grasses, but when put on the soil (pre-emergent), germinating seeds of both grasses and broad-leaved (dicotyledonous) weeds are killed.

Manner of Application

Weed killers are applied to the plant or to the soil. In the former case, they are put on as sprays, post-emergence (i.e. after the weeds are up and growing). They are absorbed into plants primarily through the leaves. Action may be nonselective, sometimes termed as general contact (Sinox or Dow General), or selective (2,4-D). When applied to

the soil, the herbicide obtains access into a previously emergent plant through the root system. All portions of germinating seedlings are probably susceptible. Soil sterilants and pre-emergence treatments are administered on the soil.

Soil Sterilants

There are a great variety of chemicals which can be used as soil sterilants — the chlorates, urea compounds, boron compounds, dalapon, and TCA. Many commercial preparations consist of mixtures. If effective, they kill all vegetation, underground parts as well as tops. They often render the soil unfit for plant growth for extended periods of time.

Soil sterilants are usually employed in two types of situations: (1) on non-agricultural soil, industrial areas, around farm buildings, railroad yards and rights-of-way, etc., (2) in agricultural areas when the destruction of persistent noxious weeds takes priority over other considerations. Utilization of sterilants in this latter instance is often limited to spot-treatment on relatively small areas because of the expense of the operation and the fact that the land frequently must be temporarily withdrawn from production. However, reasonably economic short-term sterilant treatment (e.g. with dalapon) is now possible without seriously affecting land utilization. It is usually desirable that subsequent crops be ones reasonably resistant to carry-over affects of the chemical.

With the passage of time, the herbicide gradually disappears as a consequence of leaching and breakdown; the latter is probably largely due to the activity of microorganisms. The rate of dissolution of herbicides is various, and soil sterility may be relatively ephemeral or persist for several years. Expected duration is dependent upon several factors, the physical and chemical characteristics of the treatment chemical itself, the dosage, the kind of the soil to which applied, the prevalence of rainfall, and the amount of organic matter in the soil.

In the use of sterilants, it is desirable to consider the danger of injuring nearby plants. The roots of small plants may extend one to two feet laterally, but those of shrubs may cover a radius of six to ten feet. Therefore, it is easy to affect valuable plants even though the soil treatment may be several feet away. Also, subsequent rains may carry the chemical to plants some distance away.

Pre-emergence Herbicides

Pre-emergence treatments are selective in action. Application is made to the soil, usually at the time of planting, or between planting and emergence of the crop seed. Administration may be as a spray, or dry in granular formulation.

The idea behind pre-emergence treatment is to give the crop a

chance to start out under essentially weed-free conditions. Given such a start, two to four weeks (or more), vigorously growing crop seedlings can usually out-compete subsequently emerging weeds. Thus, from the practical standpoint, weed control can be achieved in one operation.

The theory of pre-emergence weed control goes back several years but actual development and integration into farming procedures is almost entirely within the last decade. A high proportion of recent work in the field of weed control has been devoted to the development of pre-emergence chemicals and procedures. Many of the newer herbicides are of this type, e.g. CDAA, Alanap, simazin.

Pre-emergence application of herbicides is, at the present time, essentially limited to larger-seeded crop kinds. Major attention, in the North Central states, has been devoted to corn and soybeans. Sorghum is now receiving some consideration. Pre-emergence methodology assumes that the major weed problems in these crop kinds are caused by annuals; treatments are ineffective in perennial weed situations.

The efficacy of pre-emergence weed control is essentially based on three facts: (1) applicable herbicides will kill weed seedlings as they germinate, (2) most effective weed seed germination is from the upper 1/2 to 3/4 inch top layer of the soil — weed seeds occurring at greater depth usually remain dormant until brought to the surface by cultivation or other means — (3) large-seeded crops are planted below the zone from which most weed seedlings arise.

On this basis, therefore, the crop seeds are planted, the soil is treated with the herbicide which kills the weed seedlings in the top layer, but the crop seedlings growing from below can penetrate the treated soil without injury.

But there may be difficulties. Movement of the treatment chemical will not necessarily be restricted to the top soil layer; downward penetration can result in injury to the crop as well as weed seeds. Movement tends to be more rapid in light than in heavy soils; the use of pre-emergence herbicides in sandy soils is often hazardous. Heavy rains immediately after treatment may likewise carry the material down to the crop seeds and affect injury. On the other hand, excessively dry conditions may result in little or no movement and yield unsatisfactory weed control. Herbicides differ in their degree of solubility (hence likelihood of leaching downward), persistence in the soil, degree of toxicity to different crop and weed species.

What are the relative merits of pre-emergence versus post-emergence treatment as compared to cultivation? Successful pre-emergence treatment can serve as insurance against weather conditions preventing timely cultivation, can eliminate in-row weeds not easily accessible to later cultivations, can reduce the number of cultivations required, or at best can completely eliminate the necessity of subsequent working of the soil. On the other hand, under unfavorable conditions, pre-emergence treatment may only constitute an expensive operation without correlative yield benefits. Post-emergence treatment is not possible in soybeans with presently available chemicals;

the only opportunity to employ herbicides is before emergence. In corn, it is necessary to weigh the limitations and potential benefits of pre- or post-emergence chemical treatment in order to determine which is the preferable course of action. These topics are more fully discussed under the crops concerned.

Expense may be a major consideration in the employment of pre-emergence herbicides, although, with increasing use, prices have dropped sharply the past few years. Nevertheless, except for 2,4-D, the cost in terms of yield benefits frequently renders complete coverage uneconomic. Application then is often made in bands over the rows. The bands are usually 12 to 15 inches wide, assuming 40 inch rows.

Formulation of Herbicides

Weed killers may be purchased as dry powders, in granular form, or as liquids. They may be applied by spraying, or administered dry.

Materials which go into liquid formulation include (1) powders which form true solutions (amino triazole), (2) wettable powders which do not dissolve but are dispersed by agitation (simazin), and (3) liquid concentrates often in oil solution which must be emulsified in water in preparing the spray solution (2,4-D ester).

There are handling and application problems peculiar to each formulation type. Wettable powders tend to "settle out," require continuous agitation, and may plug up sprayer lines and nozzles. Oil concentrates likewise must be dispersed in water; most of them emulsify easily. Frequently commercial preparations contain an emulsifier to aid in stabilizing the "solution" and a wetting agent to improve spreading and penetrating qualities; sometimes an adhesive agent is also included. In some instances, oil solutions rather than water are employed as the spray formulation (2,4-D — 2,4,5-T mixtures).

Granular herbicides are of considerable current interest. These "granules"[1] consist of an inert carrier onto which the active chemical has been absorbed. They have been tested primarily for pre-emergence or pre-planting application. Approximately the same weed killing results have been achieved for weed killers in granular preparation as when spray-applied. The granules are applied to the ground; if the soil is dry, they are best worked in with a rotary hoe or weeder. Spraying problems, as above discussed, are obviated; toxicity risks to the operator (as with liquid CDAA) may be reduced.

Several of the pre-emergence chemicals are now available either in their conventional dry or liquid form, or as granules.

[1] The word "granular" unfortunately is employed for two different kinds of preparations: those as above described, but also some of the soil sterilants which are merchandised in dry form but without an inert carrier.

Herbicidal Action

It is not within the scope of this text to treat the mechanisms (biochemical and biophysical) of herbicidal action. Brief reference is made to certain theories concerning the action of 2,4-D under the discussion of that chemical.

General factors affecting herbicidal killing include (1) penetration, (2) degree of translocation, and (3) toxic action.

Some of the selectivity exhibited by herbicides can be ascribed to differential penetration, but the importance of this phenomena is less than once believed. Plant leaves and stems possess a protective cuticle, and frequently a waxy coating, and are, in general, susceptible to non-polar molecules. On the other hand, root hairs readily take up polar substances. The use of low gallonage applications and detergents as wetting agents have to a large extent minimized the importance of leaf shape, pubescence, and extent of protective wax covering as causes of differential penetration.

The degree of translocation of herbicides is widely variable. Some appear to move within the plant only to a very limited extent. 2,4-D is translocated up and down quite readily, but less so in horizontal rhizomes or creeping roots. Amino triazole is apparently moved throughout the affected plant.

Status of Our Present Knowledge

Herbicidal weed control is only fifteen years old. During this brief period, innumerable chemicals have been tested for plant killing ability, new ways of applying chemicals have been developed; the total interrelationship between weed control and crop production has been under continuous scrutiny. A considerable array of herbicides are now available of which a high proportion have not yet been on the market five years.

All of this suggests several things: that we are in a state of flux, that we need more information about many of these chemicals, and that there is probably not yet complete agreement as to the merits of various herbicides, or methods of treatment.

One consequence of the above is that recommendations and viewpoints do not all agree. This is a natural consequence of the rapid evolutionary developments in the field. One should be aware of these facts and give them due recognition in adapting new methods in his farming practices. It is desirable to obtain as much information as possible about specific herbicides or procedures and to consider the consequences, economic and otherwise, of their employment. After reaching tentative conclusions, one might like to try herbicidal treatment on a small or experimental scale for a year or so before venturing a major farming operation.