HERBICIDE APPLICATION

Some Considerations in Choosing Methods

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A number of theoretical considerations must be taken into account in choosing a herbicide application method. Mode of entry of herbicide into the plant, nature and extent of translocation within the plant, nature of plant responses to the herbicide, variations in species and varietal response, effects of stage of growth and the physiological condition of plant, effects of atmospheric environment, relative persistence of the herbicide in soil, effects of soil environment on availability, leaching, and absorption, possible contamination effects adjacent to treated areas, toxicological considerations, and physical properties of the compound are discussed with respect to several well-known herbicides. In choosing the best method of application the chemist must first consider physical properties and possible formulations, the plant physiologist must understand the nature of plant absorption, translocation, and response, the agronomist and the engineer must take into account practical problems of field application, and the toxicologist must warn against practices that might endanger human or animal life. Only if these specialists work together can the most effective, most efficient, and safest application methods be developed.

HERBICIDE SYMPOSIUM

Herbicides are chemical tools useful in controlling weeds and unwanted vegetation. Like any tool, each herbicide must be used in the right way, at the right time, and in the right place in order to be most effective. Choosing the best chemical for a given problem and formulating it properly are obvious first steps, but equally important is the choice of application method.

Questions of timing, volume, spray pattern, and pressure are but a few of the factors that must be considered before application methods and application equipment are chosen. A number of theoretical considerations must be taken into account in choosing an application method; these same considerations must be given their due weight in the choice of herbicide and formulation.

Mode of entry of the herbicide into the plant.
Nature and extent of translocation within the plant.
Nature of plant responses to the herbicide.
Variations in species and varietal response.
Effects of stage of growth and the physiological condition of the plant.
Effects of atmospheric environment.
Relative persistence of the herbicide in the soil.
Effects of soil environment on availability, leaching, and absorption.
Possible contamination effects adjacent to treated areas.
Toxicological considerations.
Physical properties of the compound.

2,4-D and 2,4,5-T

These closely related compounds are absorbed by foliage and actively translocated to stems and roots. The nature of plant responses is still not well understood; however, it is recognized that abnormal growth occurs following treatment, and susceptible species gradually die.

Smith (*4*) in 1946 in tests with 2,4-dichlorophenoxyacetic acid (2,4-D) found that a low-volume spray of a relatively large droplet size gave excellent results. Subsequent field tests by many workers have confirmed that a low-volume spray that gives relatively few droplets per square inch is equal, if not superior, to the same quantity of 2,4-D applied as a wetting spray in high volume. Most of the 2,4-D used for selective spraying of grain and other crops is applied at volumes from 5 to 20 gallons per acre at low pressure.

For certain applications, low-volume sprays are not satisfactory. Much of the best control along rights of way is with mixtures of 2,4-D and 2,4,5-trichlorophenoxyacetic acid (2,4,5-T) applied at from 75 to 125 gallons per acre. Low volumes would do the job if they could be uniformly distributed, but dense growth makes this difficult. Although a few droplets per leaf may give maximum effect, just wetting the outer leaves of dense, bushy growth is not sufficient and high pressure–high volume sprays have proved desirable. On the other hand, certain woody plant problems—for example, mesquite growing on range land in the Southwest—have been satisfactorily handled with a volume of 3 to 5 gallons per acre applied by plane. The growth of mesquite is very open, and a low-volume aerial application results in surprisingly uniform coverage of the entire plant. In other instances where access to woody growth is poor, aerial application is being used, even though results might be somewhat better if the herbicide could be economically sprayed with a high-volume application from a ground rig. In this instance in deciding upon volume, one must consider the way the plant responds, the density of growth, and the practicability of applying a high-volume spray.

In choosing a suitable application method for 2,4-D and 2,4,5-T, one must consider possible contamination effects adjacent to treated areas. Aerial application cannot safely be practiced adjacent to sensitive crops, because a small amount of drift may cause injury. Care must be exercised with any type of application to avoid drift where sensitive crops are growing adjacent to sprayed areas.

A method that has been devised for applying 2,4,5-T in oil solution to the base of standing woody plants or to cut stumps has the advantage of being more effective than foliage sprays on certain species and it may be applied at any time of the year. It is frequently more costly, but there is no danger of contamination effects on annual crops if it is applied at other than their growing season. Thus,

Table I. Some Physical Properties of Solutions of Amine 2,4-D and Sodium TCA, Alone and in Combination

Herbicide	Amount Dissolved	Vol. of Water, Gal.	Surface Tension at 23°, Dynes/Cm.	Contact Angle	Spreading Coefficient
2,4-D amine salt	2/3 pint	5	49.6	88° 21′	−48.2
Sodium TCA	8 pounds	5	61.6	94° 5′	−66.0
2,4-D amine salt plus sodium TCA	2/3 pint 8 pounds	5	42.3	80° 5′	−35.0
2,4-D amine salt	2/3 pint	20	51.8	94° 1′	−55.4
Sodium TCA	8 pounds	20	65.2	104° 44′	−81.9
2,4-D amine salt plus sodium TCA	2/3 pint 8 pounds	20	49.6	87°	−47.0

safety and adaptability to winter spraying make this method of application attractive for brush control in certain situations. Farmers, particularly, who may be too busy during the growing season for such work, have found this method useful.

Timing of application is very important in the control of perennial vegetation with 2,4-D and 2,4,5-T used as foliage sprays. Spraying operations must necessarily extend over as long a season as possible to make industrial use of herbicides a practical proposition. There is often a tendency to begin spraying brush and rapidly elongating herbaceous perennials with 2,4-D and 2,4,5-T at an early date, but experience has shown this practice to result in relatively poor kill. This phenomenon appears to be related to the transport of the herbicide from leaves to stems and roots, which Mitchell and Brown (*3*) have found occurs in association with organic food materials within the plant. Spraying of woody plants before foliage is fully developed and is providing excess products of photosynthesis for downward movement frequently gives inferior results in terms of root and crown kill. Likewise, applications early in the growth of a herbaceous perennial frequently result in a poor kill of underground parts, apparently because the plant is still drawing on underground reserves and has not yet begun to return an excess of food materials to storage organs. Ignoring plant physiological principles in the timing of herbicidal spray applications can often result in poor control.

Sodium Trichloroacetate

Among the more recently developed herbicides to come into wide use for industrial vegetation control is sodium trichloroacetate, often called sodium TCA. This compound, which has a growth-suppressing and, at suitable dosages, a lethal effect on many grasses, is widely used as a component of mixed sprays for railroad beds and other areas where complete vegetation control is desired. Special problems such as control of Phragmites grass, cattail, and Johnson grass are currently being handled with sodium trichloroacetate or with a mixture of this herbicide with other compounds. Noxious perennial grasses on farm lands and annual grasses in certain sodium trichloroacetate–tolerant crops including flax and sugar beets are being controlled with this herbicide.

Sodium trichloroacetate enters the plant primarily through the root system (*1*). Experiments by the writer have shown that variations in volume from 5 to 500 gallons per acre do not influence results. In fact, dry applications have been very successful. Application to upturned sod has been found to be considerably more effective than application to foliage of perennial grass species, and preplowing, wherever practical, is now a standard recommendation for the control of many perennial grasses on farm land with sodium trichloroacetate. In this instance, agronomic research which followed basic plant physiological research pointed toward spraying freshly plowed sod with whatever volume was convenient as being a suitable method of application.

Over the years, a considerable acreage of flax has been treated with 2,4-D in volumes of 10 gallons or less per acre. When it was discovered that flax is also tolerant of sodium trichloroacetate, it was obvious that a combination of 2,4-D and sodium trichloroacetate in a single spray for dual control of grass and broadleaved weeds would be desirable. Experiments have shown (*2*) that under some conditions a combination spray is more likely to have an adverse effect on flax than the two chemicals applied separately. The plants tended to show an increase in 2,4-D response, such as might be expected with an overdosage.

The greater phytotoxic effect of the 2,4-D type which has sometimes been observed on flax from combination sprays appears to result from a lowering of the surface tension of the spray solution with a consequential greater wetting of the plant. Data on the physical properties of various solutions on which this conclusion was based are presented in Table I. Sodium trichloroacetate, 90%, and 2,4-D weed killer Formula 40 (containing 4 pounds of 2,4-D acid equivalent per gallon as alkanolamine salts) were used in the solutions. The amounts of each herbicide that will often be used per acre were dissolved singly and in combination in 5 gallons and in 20 gallons of tap water. These two volumes were chosen as representative of low and medium gallonage spraying.

The surface tension of the sprays was measured by the ring method using a du Noüy tensiometer. The contact angles were measured against a carnauba wax surface. The spreading coefficient was calculated from the formula:

$$\text{Spreading coefficient} = T(\cos\theta - 1)$$

where T is the surface tension and θ is the contact angle.

The spreading coefficient has a negative value and the nearer it approaches zero, the better the spreading properties of the liquid. For selective wetting, which is desirable in this case, the spray should have as poor a spreading coefficient as possible.

The spreading coefficients of the materials alone and in combination show why the combination sprays may wet the flax somewhat more than either material alone. The sprays diluted with 20 gallons of water exhibit poorer spreading characteristics than those

Table II. Some Physical Properties of Solutions of Amine MCP and Sodium TCA, Alone and in Combination

Herbicide	Amount Dissolved	Vol. of Water, Gal.	Surface Tension at 23°, Dynes/Cm.	Contact Angle	Spreading Coefficient
MCP amine salt	2/3 pint	5	56.0	93° 14′	−59.1
Sodium TCA	8 pounds	5	61.7	93° 47′	−65.8
MCP amine salt plus sodium TCA	2/3 pint 8 pounds	5	45.0	85° 51′	−41.8
MCP amine salt	2/3 pint	20	62.5	96° 52′	−69.9
Sodium TCA	8 pounds	20	67.2	99° 15′	−78.0
MCP amine salt plus sodium TCA	2/3 pint 8 pounds	20	58.2	91° 21′	−59.6

mixed in 5 gallons of water. This indicates that it may be desirable, especially when combination sprays are used, to employ the larger volume of water to obtain the maximum degree of selective wetting.

Similar data for 2-methyl-4-chlorophenoxyacetic acid (MCP) and combinations of it with sodium trichloroacetate are presented in Table II. Dow MCP amine (containing 4 pounds of 2-methyl-4-chlorophenoxyacetic acid per gallon as alkanol amine salts) and sodium trichloroacetate 90% were used in preparing the solutions.

Again the mixtures at a given volume had better wetting properties than either herbicide alone. Solutions of the formulation of 2-methyl-4-chlorophenoxyacetic acid employed did not wet as well as solutions of the 2,4-D used in the tests recorded in Table I.

In the above instances, plant physiological, agronomic, and chemical investigations pointed the way toward safe use of a combination of the herbicides.

Substituted Phenols

Dinitro-*o-sec*-butylphenol and pentachlorophenol are two compounds in this class widely used as herbicides. These chemicals are known as contact herbicides. Translocation of the toxicant does not occur within most plants. Tissues wet with the spray are killed. Thus, the above-ground parts of plants that are wetted and absorb the toxicant will die, but protected growing points such as underground buds which occur on many perennial plants will regrow. A coarse, low-volume spray may result in only a partial burning of the leaves. Medium to high volume is essential for satisfactory use of these compounds. Timing is also important. Both pentachlorophenol and dinitro-*o-sec*-butylphenol are most active when atmospheric temperatures are relatively high. When a substituted phenol is used as a salt of the parent compound, in aqueous solution for postemergence selective spraying, one must consider the stage of growth and the physiological condition of the plant. Only young weeds will be adequately controlled by such a spray at a concentration that is safe to the crop. When the plants are in a hardened condition because of slow growth, concentrations must be increased.

Methyl Bromide

This volatile compound is now widely used for killing weed seeds and vegetative organs in plant beds, particularly in connection with tobacco production. Because of the physical properties of the compound, a surface application of the spray is out of the question. Even the conventional soil-fumigant type of application is not successful because of loss of the vapors from the soil. The liquid must be released under a gasproof plastic tarpaulin sealed with soil at the edges.

Discussion

The examples cited emphasize the many considerations that must be recognized in choosing the best method of application. The chemist must first consider physical properties and possible formulations. The plant physiologist must understand the nature of plant absorption, translocation, and response, the agronomist and the engineer must take into account many practical problems of field application, and the toxicologist must warn against any practices that might endanger human or animal life. Only by these specialists' working together can the most effective, the most efficient, and the safest application methods be developed.

Literature Cited

(1) Barrons, K. C., and Hummer, R. W., *Agr. Chemicals*, **6** (6), 48 (1951).
(2) Barrons, K. C., Thiegs, B. J., and Watson, A. J., *Down to Earth*, 7 (4), 11 (1952).
(3) Mitchell, J. W., and Brown, J. W., *Botan. Gaz.*, **107**, 393 (1946).
(4) Smith, H. H., *Ibid.*, p. 544.

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HERBICIDE MECHANISM

Mode of Action Other Than Aryl Oxyalkyl Acids

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The field of weed control by comparison to plant pathology and entomology is still in its infancy. Tremendous developments have accrued in the practical or applied side of this field since the advent of 2,4-dichlorophenoxyacetic acid. Fundamental knowledge regarding the action of the powerful chemicals that have been placed in the farmer's hands has not received due attention. It is only through this fundamental knowledge that further advancement of this field may be brought about.

HERBICIDE SYMPOSIUM

With an increasing population and the concomitant increasing demand for food, we are faced with the prospect of a dwindling supply of arable land upon which to produce our food. Though man may look with covetous eyes on the vast unexplored reaches of the tropics, experts on tropical agriculture warn him against depending upon the nearly unmanageable raw soils of these regions coupled with a climate that seriously restricts crop production. Reluctantly, therefore, he turns to the land resources available, in an attempt to wring from them the last possible drop of production. Great have been the achievements of plant breeders and those concerned with plant nutrition in increasing the production of our arable land, but man still faces the insidious attacks of plant diseases, insects, and weeds. The cost exacted annually by these three pests in the United States has been estimated at over $8 billion or nearly 20% of the total value of agricultural production by the farms of this country.

To stem the onslaught of these rapacious destroyers of man's food supply, the chemist has been called on to provide the armaments of the arsenal. He has responded abundantly, and agriculture has become the second largest customer of the chemical industry. In spite of the present shy, mistrustful attitude of these two industries, it is safe to assert that these two giants will become yet more dependent each on the other.