Hormone-like Herbicides in Weed Control

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Introduction

The discovery of (2,4-dichlorophenoxy)acetic acid (2,4-D) as a plant growth regulator in 1942 began the development of synthetic "hormones" for weed control (37). Since 1942, additional chlorophenoxy aliphatic herbicides such as [(4-chloro-o-tolyl)oxy]acetic acid (MCPA), 2-(2,4-dichlorophenoxy)propionic acid (dichlorprop), 4-(2,4-dichlorophenoxy)butyric acid (2,4-DB), (2,4,5-trichlorophenoxy)acetic acid (2,4,5-T), 2-(2,4,5-trichlorophenoxy)propionic acid (silvex), and new compounds, 3,6-dichloro-o-anisic acid (dicamba), and 4-amino-3,5,6-trichloropicolinic acid (picloram), have been developed as effective hormone-like growth regulators.

In 1966, the Terminology Committee of the Weed Science Society of America listed common names of over 4000 weed species that occur in the United States and Canada (23). The list consists of herbaceous, aquatic, and woody plants and includes all noxious and more significant weeds in Alaska and Hawaii. Weeds have plagued agriculture for centuries. Many are controlled by small amounts of hormone-like herbicides. No chemical or non-chemical method has been developed, however, for some weeds. Research, education, and practical application of chemical weed control are none the less progressing yearly. The modern miracle, chemical weed control, has allowed the grower to manipulate his environment safely, and it has enabled him to increase crop production significantly. This capability is reflected in lower food costs and a higher standard of living.

The estimated loss caused by weeds in the United States and the cost of control is over five billion dollars per year (54); the urgency for effective weed control is therefore obvious for food production. Our methods must be expedient, effective, and safe. We must be cognizant of the risks and consequences of herbicide effects on non-target organisms in the ecosystem. Research and long-term use (over 20 years) of the phenoxy herbicides (2,4-D and 2,4,5-T) at recommended rates in the natural environment have had no known harmful effects on man or on animals. However, further research and long-term observations of their possible effect on plants, animals, and man are continuing.

In 1968, over 136 million pounds, or about one third of all herbicides produced in the United States, were made up of the various formulations of 2,4-D and 2,4,5-T acids, esters, and salts, and this gives testimony to man's dependency and intention to control undesirable vegetation with these herbicides (28).

I will confine my remarks in this report to mainly 2,4-D, 2,4,5-T, dicamba, and picloram.

Herbicides

Phenoxyaliphatic acids. The phenoxyaliphatic acids and their derivatives constitute a major group of organic herbicides (1). The group consists of various benzene-ring substituted derivatives that involve halogens and hydrocarbons (Figure 1). They are of interest because of their selectivity, their phytotoxicity to a wide range of plants, their ability to be translocated within plants, and their short residual life in the natural environment. Salt, ester, and amide formulations of the 2,4-D and 2,4,5-T acids are usually much more toxic to broad-leaf plants than grasses and can be used in many grass crops to kill broad-leaf weeds selectively. The phenoxyaliphatic acid herbicides are relatively low in acute oral toxicity to animals (27).

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Substituted benzoic acids. Dicamba, effective as a weed killer for many annual grasses, and on broad-leaf weeds in grain crops (51), is also being studied as a brush control herbicide in Texas alone and in combination with picloram and 2,4,5-T. It differs in structure from the broad-spectrum herbicide 2,3,6-trichlorobenzoic acid (2,3,6-TBA) only by replacement of a chlorine in the second position with a methoxy radical, but this change produces considerable added selectivity (Figure 1).

Substituted pyridines. Picloram is an extremely active systemic growth-regulating chemical when used on many species of plants (Figure 1). It is effective against a broad spectrum of plants and may persist in soil for more than a year, except where extensive leaching occurs. Apparently picloram is slowly metabolized by plants and has a low order of toxicity to warm-blooded animals. It has a solubility of 430 ppm in water, at 25°C. It is a relatively strong acid with an ionization constant of \(1.03 \times 10^{-3}\). Picloram is poorly adsorbed by soil and very mobile in plants and soils with water (1).

Physiological Aspects

Entry. Herbicidal action may be limited because of a series of barriers, any one of which may reduce or negate its effectiveness. For example, a heavy cuticle on the leaf surface may be a physical barrier to herbicide penetration (1). In controlling weeds, therefore, it may be necessary that such barriers be overcome in some way such as with the use of oil carriers or surface active agents in the spray solution. However, limitations in herbicidal activity may be biochemical in that the herbicide is detoxified by the plant. Recent work by Linscott (38) indicates that alfalfa (Medicago sativa L.) is resistant to 2,4-DB, be-