sulfamate is used as dry crystals or as a concentrated solution, while 2,4-D and 2,4,5-T are used in the ester and amine forms. Some workers use the esters in water. Leonard uses 40% amine and notes very little difference between 2,4-D and 2,4,5-T amine when applied to live oak (*16*). When the phenoxy compound is used, it is most important to apply a continuous supply of the material uniformly around the circumference of the tree. Chaiken has found that 2,4,5-T is satisfactory on the white oak and red oak group, beech, hickory, sweet gum, and black gum (*6*). Ammonium sulfamate has been reported effective in frill treatment on nearly all species.

In using the four chemical methods to control woody plants, a thorough knowledge of the plants being treated is essential—the time when food reserves are lowest, the period during which food materials are being transported, the selectivity of the acids toward the plants to be treated, and the area from which the plant can resprout, whether it be from the root-stem transition zone or from dormant buds on lateral rhizomes.

Unsolved Problems

The two most pressing problems needing more research are the effect of the phenoxy compounds or their breakdown products on the dormant buds in the root-stem transition zone (which affects the results of foliage spraying), and the rather poor movement of the phenoxy compounds or their breakdown products into the lateral rhizomes (which affects the results of basal and stump spraying). Unless these problems are solved, repeated spraying until the plant food reserves are exhausted will remain the only choice.

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WEED CONTROL
Pre-emergence Methods

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Pre-emergence weed control refers to the application of the chemical to the soil after the crop has been planted but before it emerges. Although this weed control practice is still in an early stage of development, several chemicals have given outstanding results. Most favorable results have been reported in this type of treatment from 2,4-D, calcium cyanamide, CMU, 2-sec-butyl-4,6-dinitrophenol, sodium 2,4-dichlorophenoxyethyl sulfate, TCA, and chloro IPC. The factors affecting the results of pre-emergence treatments are: the type of weeds present, moisture content of the soil, rainfall, soil pH, soil type, organic matter content, soil temperature, and type of crop.

WEED CONTROL has become a much more important and complicated science since the advent of organic chemical weed killers. With the discovery of new chemicals also came the discovery of new methods of weed control. Although the science of weed control and its widespread practice are relatively new, the use of chemicals to kill weeds dates back a half century or more to such materials as copper salts, iron sulfate, sodium chlorate, sulfuric acid, and sodium arsenite. All these older herbicides, however, were sprayed on weeds and crops after the plants were growing. The application of a chemical as a pre-emergence treatment represents a new method in weed control. This method of selectively controlling weeds in corn was first reported in 1947 (*2*). Pre-emergence in general applies to the application of a chemical after the crop has been planted but before it breaks through the soil.

Pre-emergence treatment has certain advantages over any postemergence treatment. Weed control for the period immediately following emergence of the crop is often a critical factor in keeping the crop weed-free for the remainder of the season. Should unfavorable weather hinder postemergence operations, whether they be cultural or mechanical, the weeds often tend to grow as large as the crop, or even larger, and the only feasible method of controlling them is by hand-weeding operations. If the weeds can be controlled for 2 to 6 weeks after the crop emerges, it is in general very easy to keep the weeds under control with ordinary cultivation practices during the remainder of the season.

Types of Treatment

In general, there are two types of pre-emergence treatments—contact and residual—depending upon the type of chemical used and the result expected. In a contact pre-emergence spray a chemical is applied which will kill the small weed seedlings present before the crop emerges. Most chemicals applied in this way would also kill the crop plants if they were above the ground at the time of spraying. Some of the herbicides used in this manner are petroleum oils, phenolic contact herbicides, and potassium cyanate, which do not leave a toxic residue in the soil. A residual pre-emergence spray kills weed seedlings that are present at the time of treatment, but also leaves a residue on the soil to kill seedlings that emerge after treatment.

Many investigators in all parts of the country have conducted experiments with a wide variety of chemicals on many crops using residual pre-emergence treatments which have achieved semi-commercial status in some cases. In spite of the resultant accumulated experience, additional information must be obtained on all factors affecting the pre-emergence application of herbicides before the practice will be adopted on large acreages.

The diverse and complex factors affecting the herbicidal efficiency of a chemical applied to the soil are responsible for the difficulty in finding a material which can be used without reservation as a pre-emergence treatment. To be successful, the pre-emergence herbicide must kill germinating weed seeds without injuring the crop. The physical, chemical, and phytotoxic properties of the compound are only a few of the numerous interacting variables involved. The crop treated, the depth of planting, and the type of weed seeds present must be considered. Soil type, rainfall, organic matter, time of application, soil pH, and soil moisture at the time of treatment are among the environmental factors exerting influence on the success of a pre-emergence treatment. All of these affect the movement and availability of the chemical in the soil.

The successful use of a pre-emergence treatment of any chemical depends on a lower concentration of the chemical reaching the crop seed zone than is present in the upper $^1/_8$ to $^1/_2$ inch where most of the weed seeds germinate, or a greater tolerance of the crop than the weed to the chemical.

For successful use of post-emergence weed control the crop plants must have a greater tolerance to the chemical than the weeds or a spray must be directed to cover the weeds rather than the crop.

Because most perennial weeds send up new shoots from subterranean vegetative portions, usually deep in the soil, they are not affected by pre-emergence treatments in most cases. In general, crop seeds are larger than the weed seeds which infest the same area and this has been given as a reason for the selectivity of certain chemicals as pre-emergence treatments.

Susceptibility to Treatment

Plants vary in their susceptibility to a chemical, depending upon their stage of development. Mitchell and Brown (*7*) found that mustard seedlings with radicals 5 mm. long were more susceptible to 2,4-D injury than seedlings in earlier stages of development. Aldrich and Willard (*1*) have reported that the susceptibility of corn seedlings to 2,4-D varies with the stage of germination. Many investigators (*1, 4, 10*) have reported that delaying the application of a chemical a few days after planting lessens the hazard of reducing crop stands. It would be most desirable from a practical standpoint to apply a pre-emergence chemical at the time the crop is planted. This kind of application, however, is the least reliable because there is so much opportunity for environmental factors to exert maximum influence on the movement and availability of the chemical in the soil. If a pre-emergence application is followed by heavy rainfall and the chemical used is water-soluble, it may be leached from the upper zone into the level at which the crop seed is germinating. The result will be maximum injury to the crop with minimum weed control. This has been demonstrated by investigators (*1*) who have reported the ester formulations of 2,4-D to be safer when used as a pre-emergence treatment than the amine or sodium salts of 2,4-D.

Numerous reports suggest that various chemicals are fixed on soil colloids. The early work of Nutman *et al.* (*8*) in England showed that 2,4-D is more toxic to germinating sugar beet, red clover, and wheat seedlings growing in a light sand low in organic matter than to the same seedlings growing in a clay loam high in organic matter. Crafts (*5*) has reported a tendency toward decrease in initial 2,4-D toxicity to test plants as the soil particle size decreases. Weaver (*9*) was able to decrease, and in certain instances eliminate, toxic effects of 2,4-D in the soil by adding synthetic ionic exchanges to the soil. Arakeri and Dunham (*3*) in Minnesota have studied the environmental factors affecting the success of pre-emergence treatments and have indicated rainfall and soil type (pH, organic matter, and clay content) to be the most important. Organic matter content remaining the same, the number of abnormal plants and the degree of injury were found to be closely associated with pH when 2,4-D was used as a pre-emergence treatment on corn. Injury in general was less in soil with either a high pH or large organic matter content. Injury to corn plants from 2,4-D pre-emergence treatments was most severe in soil with low pH, low organic matter content, and a small clay fraction.

Pre-emergence treatments in general work best when the soil is moist enough at the time of planting to allow for rapid germination of both crop and weed seeds. If the soil does not contain enough moisture to provide for germination of the weed seeds, 2,4-D is likely to be partially broken down by soil microorganisms before the weed seeds germinate and, therefore, to be almost totally ineffective by the time moisture is received. None of the chemicals which are being used as pre-emergence treatments today are known to kill dormant seeds; in all cases the weed seeds must be germinating. As in other methods of weed control, a usable chemical which would kill weed seeds would be very desirable.

The uniform application of a chemical to the soil is important when pre-emergence treatments are used. Small spots at the base of clods will be missed by the spray, and loose soil will allow excess leaching and washing, reducing the effectiveness of the treatment. Extra-wide planter press wheels will break up these clods and leave a firm bed on most light sandy soils (*6*). The preparation of a smooth seed bed is probably more important with certain chemicals than with others, depending upon their volatility.

Chemicals of Promise

Of chemicals that have been reported in the literature, the following have shown the most promise for pre-emergence treatments on crops—2,4-dichlorophenoxyacetic acid (2,4-D), calcium cyanamide, 3-(*p*-chlorophenyl)-1,1-dimethylurea (CMU), pentachlorophenols, salts of dinitro-*o*-*sec*-butyl phenol, sodium 2,4-dichlorophenoxyethyl sulfate, and *m*-chlorophenyl isopropyl carbamate (chloro IPC).

The external environmental factors which exert major influence on and affect the success of a pre-emergence treatment vary with the chemical used, depending upon the individual properties of the chemical. The perfect pre-emergence chemical should be a compound having low water solubility, ability to resist fixation in the soil, and ability to remain in the soil in an active form for 3 to 4 months and then be rapidly decomposed, so as not to leave a residue affecting the crops which follow.

Because of the inherent advantages of pre-emergence weed control, its use would soon be adopted if a chemical having all of the above-mentioned properties were found. Some day chemicals may be found that are specific enough to kill all the weeds without injuring a crop by nature of the tolerance of the crop itself. In the meantime the chemicals available today are effective, and with more fundamental information on the factors that affect herbicidal efficiency, each one can be used where it is most effective.

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CONTACT HERBICIDES

As Preharvest Defoliants or Desiccants

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Use of contact-type chemical herbicides, defoliants, or desiccants as harvest acids has been rapidly developing, coincident with thetrend toward more complete mechanization in production of important food and fiber crops. Defoliants are used only on crops that have a mechanism of leaf abscission normally activated by senescence or frost. Chemical desiccants are used to hasten drying of stems and leaves of crops with mature seed or tubers, which do not normally abscise leaves or increment of annual growth. Defoliants or desiccants must be contact in action and nontranslocated, and free of residual properties that would be harmful or objectionable to handlers or consumers of seed, tubers, or fibers of treated crop plants. Ease of application, efficiency in action, and economy of use are important. Chemical defoliation has its greatest development in cotton harvesting. Cyanamides and sodium chlorate-borate formulations are most widely used in this practice. Desiccation of legumes is commonly undertaken with dinitro compounds in an oil carrier. Soybeans have been experimentally handled in the same way. Desiccation of rice is promoted by use of herbicidal formulations popular as cotton defoliants. Flax, potatoes, and other major crops have been treated with contact-type herbicides to hasten maturity and permit more efficient harvesting. Formulation and use of contact-type chemical herbicides as harvest aids will undoubtedly be extended to other crops through the teamwork of industrial and public service research groups.

Contact-type chemical herbicides have been occasionally used as crop defoliants and desiccants for at least 20 years, but it is only in the past 10 years that this practice has shown marked development, and only in the past 5 years have these herbicides become an important market source for agricultural chemicals.

This new development has followed certain important technological advances in modern agricultural production. The first of these has been the trend and development toward more complete mechanization in growing and harvesting of some of our most important food and fiber crops. During the past 20 years there have been great advances and improvements in the development by plant breeders and geneticists of new varieties of food and fiber crops, which more fully utilize the full growing season and the full productivity of the soil, and which are more precisely adapted to local soil and climate conditions. During the same period research scientists and the agricultural chemical industry have made available fertilizers and soil amendments, insecticides, fungicides, and herbicides, that have made possible the consistent and dependable production of maximum growth and development of these newer and better adapted varieties of crops. This combination of improved varieties and efficient use of plant protection products has in general resulted in later maturation and delayed harvesting.

One of the most striking examples of this development has been observed in the potato production areas in the northern states, where not over 15 years

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