DICHLOBENIL AND CHLOROTHIAMID: A REVIEW

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Summary

Dichlobenil and chlorothiamid are most useful as herbicides when applied to the soil to inhibit seed germination, and to kill perennial weeds. They are not effective knock-down herbicides. When used on container grown plants, they should be applied to the surface of the soil, not mixed with the soil prior to planting. These materials should not be used pre-emergence over seeded crops. The physical properties which govern their persistence, in the soil, and possible mechanisms of crop resistance are briefly discussed. A list of crop plants which have shown resistance to at least 3 lb a.i. per acre of these materials is appended.

THE USE of dichlobenil as a herbicide was first reported by Koopman and Daams in 1960, although other people appear to have been working with this material about the same time. Following the normal procedure, several people studied the herbicidal properties of analogues of dichlobenil, and in 1963 Thompson reported on the use of chlorothiamid as a herbicide.

Since that time there have been a number of reports of these materials as herbicides, and a few reports about the physical and chemical properties of these two materials. The aim of this paper is to present a review of existing knowledge of these two materials.

Dichlobenil is widely phytotoxic, and is commonly believed to have no selective action. Because of its high vapour pressure (5×10^{-4} mm Hg at 20°C) and low water solubility (20 ppm at 25°C), it is readily lost by volatilization, or, if it enters the soil, does not move far through the soil. These physical characteristics are enhanced by the strong affinity which the material exhibits towards clay and organic matter. Massini (1961) showed that potting soil (constitution not stated) had 30 times greater absorption coefficient for dichlobenil than sandy soil, and 400 times greater than sand.

Once the dichlobenil has been absorbed by the soil complex, it is remarkably persistent. Barnsley and Rosher (1961) found that, when 8 lb (all rates in active ingredient per acre) as a spray was cultivated and watered into the top 6 in. of soil, 72% could be recovered from the top 3 in. of soil after 4 days, and no further reduction had occurred after 42 days. Even after 105 days, 42% of the material could be recovered from the top 3 in., and 57% from the 3 to 6 in. level. No evidence could be found of the material being leached below the 6 in. level. In the same trial dichlobenil applied at the same rate, but not watered or cultivated in, disappeared in a few days.

Thus, dichlobenil is capable of acting as a long-term herbicide in the soil provided that adequate precautions can be taken to ensure that losses do not occur through volatilization. Losses by leaching are not likely to occur, especially on soils with good adsorptive power, the material in fact "staying put" in the desired area.

Chlorothiamid has a lower vapour pressure than dichlobenil (5×10^{-7} mm Hg at 20°C) and greater water solubility (750 ppm at 25°C). Because of these properties, chlorothiamid is less likely to be lost by volatilization and has a greater tendency to penetrate the soil when irrigated or "watered in". Milborrow (1965) has shown that the herbicidal properties of chlorothiamid are due to its conversion to dichlobenil in the soil, and that as this conversion proceeds the dichlobenil produced is rapidly absorbed into the clay colloids and organic matter. Since the conversion is fairly rapid, unduly deep penetration by leaching is restricted.

Dichlobenil can be absorbed from the soil by imbibed seeds and by intact plants. Massini (1961) showed that seeds had greater powers of absorption of dichlobenil than roots and that lignin had a very high adsorptive capacity for dichlobenil. In the gaseous phase, dichlobenil can also be absorbed by leaves through the stomata, but translocation from the leaves is restricted. The site of activity within the plant appears to be at the meristems.

Because of their physical properties and their absorption and translocation characteristics, dichlobenil and chlorothiamid are most useful as herbicides when applied to the soil. Herbicidal effects can be secured by absorption through the leaves, but as much as 10 times more material may be required for effects in this way (Barnsley and Rosher, 1961). Both materials therefore have a relatively low knock-down effect, and it is doubtful whether they should generally be used for this purpose. Indeed, where they are applied to a dense stand of vegetation, knock-down may be achieved by volatilization at the expense of any soil penetration. In such circumstances, the long-term herbicidal effect may be lost entirely.

As mentioned earlier, it has been customary to ascribe crop resistance to the fact that resistant crops have a root system which is below the level when the herbicide is held in the soil, but it is doubtful whether this explanation is a complete one. The effectiveness of dichlobenil against perennial weeds, some of which are deep rooted, and the resistance of some shallow-rooted woody plants to the material, makes a simple explanation less than satisfactory. In addition, the fact that woody plants, in general, are resistant to the material while non-woody ones are susceptible, suggests that some more complex mechanism is involved in resistance.

One aspect of resistance to the material may be that in woody plants any dichlobenil absorbed may be held on the lignin in the roots, from which it may be released only slowly. Plants in which lignin is abundant would thus hold dichlobenil in an area where it is physiologically inactive. In addition, Massini (1961) has suggested that plants may be able to metabolize dichlobenil and this could account for some features of crop resistance. Where both mechanisms were operative, reasonable applications of dichlobenil could be coped with by resistant plants, material absorbed being bound on the lignin of the roots and then metabolized as it was released. Such a system would conceivably be unable to cope with high rates of application of dichlobenil. If part of the mechanism were absent from a plant—e.g., a plant lacking the

ability to metabolize dichlobenil—no resistance, or reduced resistance, would occur.

Such a mechanism could operate in a situation such as exists with deciduous azalea which is susceptible to injury at herbicidal rates of dichlobenil, whereas evergreen azaleas are tolerant of much higher dosage rates. Varying ability to metabolize dichlobenil could also account for the fact that some plants—e.g., apple—will tolerate very high rates of dichlobenil (16 lb) whereas others will tolerate less—e.g., raspberries 8 lb and gooseberries 4 lb. Some woody plants—e.g., *Larix* spp.—are susceptible to as low as 1.5 lb.

At rates of 3 lb, incorporated into the soil by cultivation or irrigation, good control of annual weeds and most perennial weeds has been secured (Richards, 1965). Perennial weeds controlled include Californian thistle (*Cirsium arvense*) convulvulus (*Convolvulus arvensis*), couch (*Agropyron repens*), docks (*Rumex* spp.), dandelion (*Taraxacum officinale*), plantain (*Plantago* spp.) and sorrel (*Rumex acetosella*). Satisfactory control of oxalis has not been secured at these rates, although a very great reduction in numbers has been secured at 9 lb.

At dosage rates of 3 to 4 lb, incorporated into the soil, most woody plants are not affected, notable exceptions being *Azalea mollis* and *Escalonia* spp., both of which may be checked by applications of this order; and *Larix* spp., and *Sambucus*, both of which may be killed at 3 lb.

Unrooted cuttings of *Populus*, *Rosa*, *Prunus*, *Cydonia*, and *Ribes*, planted in soil where 4 lb dichlobenil had been applied, were unaffected by the treatment (Sloccock, 1964).

Because of these characteristics, dichlobenil and chlorothiamid have been most useful in orchards, berry fruit gardens, woody plant nurseries, and in afforestation areas. Some herbaceous plants may show sufficient resistance to enable these herbicides to be used, but in general these materials have been too phytotoxic to be useful herbicides among herbaceous plants, or as pre-emergence herbicides on seeded crops, such as vegetables.

In woody plant nurseries, there is an increasing trend towards growing plants in containers, and there has been a need for a herbicide suitable for controlling weed growth in containers. Early experiments in which dichlobenil and chlorothiamid were mixed with the soil before it was placed into the containers were generally unsuccessful, resulting in a very high percentage of plant damage. This may, in fact, have been due to the difficulty of relating dosage rates per acre in dosage rates per cubic yard.

Application of dichlobenil or chlorothiamid to the surface of the containers, at rates equivalent to 3 to 4 lb has given good results in terms of weed control without plant damage.

Two methods of formulating these materials have been used, namely, wettable powders and granules. Wettable powders have the advantage of ease of application through existing equipment, whereas there is at present no readily available equipment for the distribution of granules. Wettable powders applied as a spray are, however, very susceptible to volatilization losses, whereas granules are less subject to this problem. Provided that even distribution of granules can be secured, which may be less difficult than it sounds, granular material may give the best results.

Because penetration into the soil is likely to be more readily achieved in cool, moist conditions, it may be an advantage to apply these materials in late winter or early spring when such conditions will occur. Fortunately, this time of application will often fit in with desirable times of application to the crops for which these materials are particularly suitable.

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APPENDIX

PLANTS WHICH ARE REPORTED TO RESIST AT LEAST 3 LB OF DICHLOBENIL
OR CHLOROTHIAMID IN THE NURSERY

<i>Abies</i> spp.	<i>C. cashmeriana</i>
<i>Acer campestre</i>	<i>Daphne burkwoodi</i>
<i>A. negundo</i>	<i>D. leucanthe</i>
<i>A. palmatum</i>	<i>Erica canaliculata</i>
<i>A. pseudoplatanus</i>	<i>E. oatesii</i>
<i>Adenandra uniflora</i>	<i>Erica</i> var. <i>carnea</i>
<i>Agonis flexuosa</i>	<i>Eleagnus angustifolia</i>
<i>Alnus glutinosa</i>	<i>Euonymus</i> (except <i>E. vegetus</i>)
<i>Amelanchier canadensis</i>	<i>Fagus sylvatica</i>
Apple (<i>Malus</i> spp.)	<i>Feijoa sellowiana</i>
<i>Azalea indica</i>	<i>Felicia angustifolia</i>
<i>A. kurume</i>	<i>Forsythia</i> spp.
<i>Beaufortia sparsa</i>	<i>Fraxinus</i> spp.
<i>Berberis</i> spp.	<i>Gardenia jasminoides</i>
<i>Betula pendula</i>	<i>Hedera helix</i>
<i>Boronia megastigma</i>	<i>Hydrangea hortensis</i>
<i>Buxus sempervirens</i>	<i>Ilex</i> spp. (except <i>I. crenata</i> , <i>I. rotunda</i> , <i>I. vomitoria</i>)
<i>Camellia japonica</i>	<i>Juniperus chinensis</i>
<i>C. saluensis</i> hybrids	<i>J. communis</i>
<i>C. sasanqua</i>	<i>J. horizontalis plumosa</i>
<i>Caragana</i> spp.	<i>J. sabina tamariscifolia</i>
<i>Carpinus</i> spp.	<i>J. virginiana</i>
<i>Celtis</i> spp.	<i>Leptospermum scoparium</i> vars.
<i>Chaenomeles japonica</i>	<i>Leucospermum oatherineae</i>
<i>Chamaecyparis lawsoniana</i> vars.	<i>Leucothoe cataesbi</i>
<i>Citrus sinensis</i>	<i>Lonicera</i> spp.
<i>Crataegus</i> spp.	<i>Magnolia stellata</i>
<i>Cupressus macrocarpa</i>	

Magnolia deciduous species
Magnolia evergreen
Malus spp. & vars.
Michelia spp.
Osmanthus spp.
Phebalium *billardieri*
Philadelphus *coronarius*
Photinia *glabra rubens*
Picea abies
P. pungens
P. sitchensis
Pieris japonica
Pinus contorta
P. nigra
P. sylvestris
Pittosporum tobira
Podocarpus spp.

Populus spp.
Prunus spp.
Pseudolarix
Pyracantha spp.
Quercus robusta
Raphiolepis delacourci
Rhododendron species & hybrids
Ribes spp.
Rosa multiflora
Salix spp.
Syringa species & hybrids
Taxus spp.
Thuja spp.
Ulmus americana
Viburnum spp.
Vinca minor