AN ASSESSMENT OF THE PROBLEMS OF EFFICIENTLY SPRAYING HERBICIDES ONTO WEEDS IN CROPPED AREAS

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Summary. The efficiency of herbicide spraying is reviewed. The proportion of herbicides lost outside the target area and within the target area are discussed. Difficulties associated with accurately defining the target and the target area are emphasised. The inputs for a model are proposed to enable prediction of the optimum time to spray weeds in cropped areas.

INTRODUCTION

Robinson (1978) estimated that $3,513 million was spent world wide on herbicides in 1977. There is obviously an economic advantage from using such products judiciously.

To assess the efficiency of spraying, predictions of the effectiveness of herbicide usage must be considered against a number of criteria including efficacy, economics, productivity and side effects. Spraying efficiency is considered in this paper with the notion that its aim should be to effectively distribute the minimum amount of toxicant on the target to consistently produce the required effect with the minimum contamination of the non-target area.

An understanding of the parameters influencing spray losses is regarded as essential before it is possible to improve the efficiency of the spraying operation. During spraying, herbicide is lost outside (exo-losses) and inside the target area (endo-losses) (Combellack 1979, 1981a). To reduce such losses, Combellack (1979, 1981a) emphasised the need to define the Biological Requirement as the first step in any spraying operation. This is "the theoretical minimum amount of toxicant that will produce the required level of control of the target". A comparison of the toxicant doses needed to achieve the required level of control can be used to calculate herbicide spraying efficiency using the formula:

$$\frac{\text{Biological Requirement}}{\text{Actual Dose Used}} \times 100 = \%\ \text{spraying efficiency.}$$

This equation assumes that the herbicide is sprayed at the optimum droplet size, concentration and spacing on the most efficient uptake site when the target plant is in its most susceptible state.

A method of predicting the efficiency of any given spraying operation would be an advantage to users and researchers. It would enable users to select the most appropriate spraying method under the prevailing conditions and it would be used by researchers as the basis for comparing changes to the spraying operation such as changes in the formulation or in the droplet spectra, and for comparing pressure with rotary or electrostatic atomizers. This paper reviews the complexity of the problems confronting researchers who attempt to predict efficiency of herbicide spraying.

REPORTS ON THE EFFICIENCY OF HERBICIDE SPRAYING

With an ideal herbicide spraying system, each individual weed would receive a just-lethal dose and no herbicide would reach any of the crop or soil or move outside the target area, thus achieving maximum efficiency and selectivity. Though it is obviously not possible to achieve this ideal, such information is valuable if one is to clarify the practical dosage levels.

The dose/response relation forms the basis for estimating spraying efficiency, so it is necessary to ensure that variability in response of different individuals within a population is taken into account. This necessitates adjusting the dose to ensure that all individuals within the population to be treated receive sufficient herbicide to provide the level of control required. Thus, if one selects a dosage which will give a LD 99., it will result in 99% of the population being over-dosed and 1% underdosed (Graham-Bryce 1977). This has to be regarded as unavoidable wastage.

Whilst no reports on spraying efficiency have been noted in the literature, two assessments of herbicide efficiency have been found. Brian, as quoted by Graham-Bryce (1977), noted that paraquat was up to 30% efficient when applied to grass weeds grown in a glasshouse. Combellack (1979) estimated the efficiency of 2,4-D to be 0.5 to 2.0% when spot spraying seedling weeds and 30-60% when spot spraying mature plants. The reason for the lower figure for the former was the wastage when trying to direct a spray at a small target and spraying non-target areas surrounding the target weed. These figures compare favourably with insecticides. For example, Graham-Bryce (1975) stated that the efficiency of certain insecticides against aphids and capsids to be 0.02%, whilst Rainey (1974) and Matthews (1977) suggested the spraying of insects in crops to be $1 \times 10^{-6}\%$ efficient.

ASSESSMENTS OF HERBICIDE SPRAY LOSSES

A comprehensive review of the literature on this topic for ground sprayers has been compiled by Combellack (1981b). Most studies have measured or experimented with ways of reducing the losses of droplets from the target area. Ground spraying tests show that droplet losses beyond 3 m were rarely over 5% of the spray volume and that the volume drifting beyond 10 m was frequently less than 1%. However, the limited work on vapour losses of volatile herbicides demonstrates that such toxicants are potentially far more hazardous. For example, the studies of Grover *et al.* (1972) found droplet losses of 3 to 4% with the amine salt of 2,4-D, whilst an additional 25 to 30% of the butyl ester was collected as vapour drift, thus indicating the differences in potential spray loss between such formulations. Combellack (1981b) concluded that further studies on measurements of vapour loss were more important than those of droplet losses. He suggested that mathematical modelling is the only way of predicting herbicide spray exo-losses over a range of situations.

The review also clearly showed that nearly all research has been directed toward the measurement of exo-loss, with little effort devoted to measuring endo-losses. Taylor and Merritt (1975) showed that the barley crop intercepted between 10 and 60% of the spray liquid. As the crop is not the intended target when spraying weeds, this must be regarded as endo-loss.

PREDICTIONS OF SPRAY LOSSES

As can be seen from Figure 1, the groundcover when spraying seedling weeds is very small if they are assumed to be planar. Indeed, in theory the planar area of such target weeds would represent the proportion of toxicant collected providing their collection efficiency was optimal and the droplets all fell in a vertical plane. However, in the normal spraying operation, neither the collection efficiency of weeds is optimal nor do the droplets all fall in a vertical plane. The reasons for the former are that some of the droplets approaching the target do not impinge on the target as they become entrained in the diverging airstream (Brooks 1947, Hadaway and Barlow 1965, and Johnstone 1973), or are reflected from the target's surface (Hartley and Brunskill 1958, Holly 1964, Ford and Furmidge 1967, Furmidge 1968, Lake 1977) or, as in high volume spraying, the droplets on the target surface coalesce and run off (Johnstone 1973). The consequences of the latter are that the target weeds cannot be viewed as a simple planar surface but should be regarded as three-dimensional objects. Thus the droplet deposition models developed by Miles *et al.* (1978) have only limited value. It is thus recommended that a droplet deposition model be developed to include the following:

a) the notion that the target is a three-dimensional object;

b) the droplets' trajectory to the target (e.g. Berry 1974; Marchant 1977);

c) the impaction and retention of the droplets on the target (e.g. Hartley and Brunskill 1958, Ford and Furmidge 1967, Furmidge 1968, Johnstone 1973, Boize *et al.* 1976, Lake 1977).

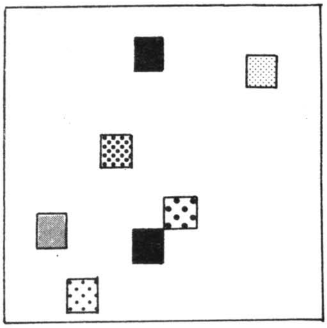
Such a model could be used to determine the optimum time of application by predicting the optimal droplet collection efficiency by the target. This could then be related to the optimum time of removal of the weeds from the crops as suggested by Reeves (1976) and Wells (1979). A comparison of the two, using a model, would then determine the optimum time of spraying.

DEFINING THE TARGET

There are very few reports on defining the target, which is the most susceptible part or parts of the weed. One exception is the work on wild oats (*Avena fatua*) by Moser *et al.* (1976). Similar studies on other species are needed if optimum spraying efficiency is to be obtained. It is also necessary to define the optimum distribution of the herbicide on the target to ensure the maximum efficiency. Though information on this aspect has been reported (Ennis and Williamson 1953, Behrens 1957, Buehring *et al.* 1973, Lake and Taylor 1974, Combellack and Harris 1978), this has shown that weeds vary in their response and thus further studies are necessary before predictions are possible.

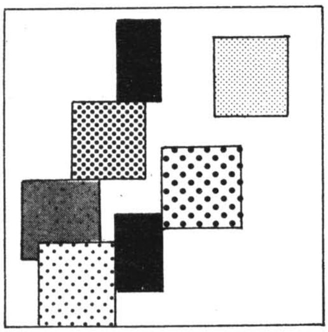
CONCLUSIONS

Though large quantities of herbicides are sprayed annually to control weeds in crops, little attention has been paid to the efficiency of the operation. In particular, research effort on endo-losses is lacking, yet they probably account for greater losses than exo-losses which have been relatively well researched. Computer models and simulations of the processes involved to determine optimum spraying efficiency are recommended. It is suggested that such information be used to determine the optimum time of spraying.



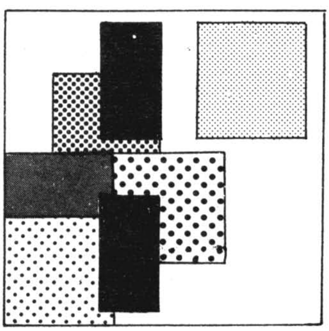
TIME 1

	Planar area (%)	Target area (%)
Crop	2.0	2.0
Weed	5.0	5.0
Total	7.0	7.0



TIME 2

	Planar area (%)	Target area (%)
Crop	9.0	9.0
Weed	45.0	43.50
Total	54.0	52.50



TIME 3

	Planar area (%)	Target area (%)
Crop	16.00	16.00
Weed	80.00	56.25
Total	96.00	72.25

Figure 1. Planar/Target areas.
Note - (1) Solid Shade = crop (density 80 m^{-2}); Etched areas = weeds (density 200 m^{-2}); (2) Crop is dominant species; (3) % Planar area = theoretical planar surface area available for droplet collection; (4) % Target area = theoretical planar surface area when viewed from above (i.e. it accounts for the shading effect of crop on weeds or weeds on weeds).

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