DETERMINATION OF FOLIAR UPTAKE OF HERBICIDES — A REVIEW OF TECHNIQUES

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SUMMARY

Precise knowledge of the extent of foliar uptake of herbicides and pesticides is essential in determining mechanism of efficacy and selectivity. Some of the techniques currently employed in foliar uptake studies are examined. The reliance on radio-labelled materials and the difficulties in precisely applying the chemicals to leaves makes the relevance of some data questionable and not easily compared with field results.

INTRODUCTION

There is a definite requirement for information on the extent of foliar uptake and subsequent translocation of herbicides, other pesticides and plant growth regulators. Such information is an aid in interpreting the variable performance of chemicals, but more importantly it may explain the basis of selectivity after manipulation of environmental conditions or changes in product formulation. Currently there are no simple qualitative or quantitative tests for the measurement of foliar uptake of chemicals.

The principle objective and major problem is to apply a known dose of chemical to a leaf surface in droplets that conform to the size range appropriate to those produced by an hydraulic spray nozzle or other field applicator. The chemical dose received by a crop or weed plant is dependent not only on water rate, chemical concentration and the specifications of the equipment but also on the stage of plant development. The interception and retention of spray droplets depends typically on the architecture of the plant canopy, the leaf area index and the relative contributions of the component species in the sward. Thus in calculating the droplet frequency and distribution on a target leaf there are a number of variables which, while not always considered at the time of field application, may be crucial to the effectiveness of controlled experiments designed to investigate herbicide uptake phenomena.

Some workers (Johnstone 1973) have carefully considered the physical and plant factors that influence spray droplet formation, contact and retention on the leaf surface. A great deal of this information has not been considered in laboratory studies and it is rare for parallel investigations on foliar retention and uptake to be carried out.

This paper examines the experimental methods currently used in the study of foliar uptake and describes some of the problems in determining the true validity of the results obtained.

REVIEW OF EXPERIMENTAL METHODS

In order to recover foliar applied herbicide after uptake, translocation and metabolism it is usually necessary to apply it in radio-labelled form. It is normally possible to obtain or convert the radio-labelled herbicide to the appropriate salt or ester, but addition of other constituents of a commercial formulation is difficult, primarily because of the understandable reluctance of companies to reveal such information. One alternative approach is to add radio-labelled herbicide to the commercial formulation and to assume that the effect of the added mass is negligible. The technique may frequently add between 2-5% more of the active ingredient to the formulation although the size of the increase can be minimized if high radioactive specific activity material can

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be obtained. The addition method has been used by many workers (Zabkiewicz and Gaskin 1981) and is useful provided removal of some component from the commercial formulation is not required. There are problems in investigating the effect of surfactants, particularly where a replacement material is of interest.

The use of a conventional hydraulic spraying system for applying radio-labelled herbicides is out of the question on the grounds of safety and the cost of using large amounts of expensive radio chemicals that are frequently not readily available. For these reasons most workers have used one of the following techniques which offer greater control of the applied material:

1. Application of discrete droplets from a calibrated microsyringe. Because of surface tension effects, the smallest droplet that can be applied is 0.2 - 0.5 μL (Coggins and Baker 1983) but they are more normally 1 μL (Merritt and Drinkwater 1977). A 0.2 μL droplet has an inflight diameter of 725 μm which is very large in relation to the normal range of droplet diameters from an hydraulic nozzle; normally having an inflight range of 100-500 μm diameter (Holly 1976).
2. Droplet production by means of a mechanical applicator, such as the hand operated unit developed at the Weed Research Organisation, (Merritt and Drinkwater 1977) or the motorised version described by Brunskill (1956) has been described. The mechanical droplet applicator allows reasonably accurate placement of single droplets that are generated by a needle which is vibrated after immersion in the test solution. By changing the depth of immersion it is possible to produce droplets of specific size, within the 80-500 μm diameter range. Recent work with this device suggests that the major practical problem is one of maintaining the correct configuration of the needle producing the droplet and the level, and hence shape, of the meniscus of the test solution.
3. A laboratory micro-sprayer was described by Uk (1978) and has recently been modified by Coggins and Baker (1983). While being able to convert small volumes of solution (0.1 - 0.2 ml) into droplets of specific size, within the 50-500 μm diameter range it is not easy to target the droplets and the developers concede that there may be unreasonable wastage of radio-labelled herbicides (Coggins and Baker 1983).
4. The application of radio-labelled herbicides by painting solution onto the leaf surface obviously does not reproduce the effect of applying discrete droplets. However, where surface wetting and spreading is good this approach may have some use. Total surface applications are useful in translocation studies, where measurement of uptake is not a consideration (Phung and Field 1979).

Following the application of a radioactive herbicide the subsequent determination of uptake can be derived by recovering chemical from the leaf surface by washing and then subtracting from the amount supplied or by additionally trying to recover all the chemical initially applied. Washing chemical from leaf surfaces may recover a substantial proportion of chemical residue but the variable nature of surface cuticle and wax deposition probably precludes absolute recovery. The assumption that chemical not washed from a leaf has completed passage through the cuticle and into the living phase of the leaf is probably not valid and may lead to errors that are not consistent between plant species or chemical treatments. If determination of uptake requires recovery of chemical from the plant tissue, simple solvent extraction may be inadequate and complete carbon combustion more reliable. Rigorous testing of the experimental method is required for each plant species - chemical treatment combination.

DISCUSSION

It is clear that the major limitations of work on the foliar uptake of herbicides are the inadequacies of the techniques available and the lack of attention to the detail of corresponding field applications. All the techniques described in the preceding section have limitations but the relatively recent development of the single droplet applicator (Merritt and Drinkwater 1977) and the laboratory micro-sprayer (Coggins and Baker 1983) that can produce droplets in the 80-500 μm diameter range are major advances.

However, for these developments to be effective it will be necessary to carry out applications in precisely prescribed and controlled environments, with much greater emphasis placed on describing the growth, development and morphology of the treated plant. Very little consideration is ever given to the effect of a total herbicide treatment on the uptake of single droplets of a radio-labelled herbicide. This may be a major consideration, particularly in longer term uptake experiments. Similarly the validity of experiments involving detached leaves or excised disks is questionable, although data from such experimental systems has previously been reported prominently (Sargent 1976).

One of the dominant limitations to effective research on herbicide uptake is lack of knowledge on the nature of product formulations. While respecting the commercial necessity of such confidentiality some of the most interesting and useful data is likely to be obtained by use, and maybe manipulation, of the fully formulated product. The addition of radioactive herbicide to formulated product requires that high radioactive specific activity material be available, which is rarely the case. In fact the low radioactive specific activity of some radioactive herbicides adds to the problems of preparing solutions with the correct concentration that contain sufficient radioactivity for detection and measurement. This problem is more serious when a limited number of small droplets are applied or when determination of herbicide metabolism is a consideration.

This paper has attempted to demonstrate the inadequacies of research on the foliar uptake of herbicides. However, there is no doubt that in spite of the apparent experimental limitations it is possible to obtain valuable information on herbicide performance and selectivity (Sargent 1976). An improved knowledge of the fate of foliar applied herbicides in the field, would increase the value of basic research on herbicide uptake. Until there is a closer relationship between field and laboratory experiments the true worth and accuracy of controlled environment studies on foliar uptake will still be questionable.

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