PESTICIDE APPLICATION AND EFFICACY FROM THE APPROVAL POINT OF VIEW

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Summary It is envisaged that only pesticides already approved would be developed for use through controlled drop applicators. Approval for such uses can therefore be compared to the approval of a new use of an existing pesticide rather than a completely new development. In order that approval can be granted, a label recommendation will be required, provisional or commercial clearance obtained for the recommendation, detail of drop size, volume and machine given and adequate trials data will need to be supplied in support of the recommendation.

INTRODUCTION

The evaluation of pesticide efficacy consists basically of determining the properties of a pesticide and the effect on them of all known variables(Makepeace, 1975). The result will be a recommendation for use hedged in by the constraints of the known variables which can be climatic, edaphic, biotic or mechanical. In the latter are variables such as stability, formulation, compatibility and application.

Efficacy and crop selectivity can either be limited by the variables above or in many circumstances the variables can be used to enhance selectivity and performance. Obvious examples are the depth protection of drilled seed used to complement the limited selectivity of soil-applied herbicides and the use of meteorological data to predict infestation periods in certain diseases and the subsequent timing of protective sprays.

The role of application methods in pesticide evaluation has on the whole been neglected in the face of more complex constraints. As a result, spray application machinery has been accepted as standard and only where application techniques determined the primary use of a pesticide were application methods investigated in order that a particular use may proceed in its development. The most obvious examples here are those of seed treatments and granular pesticides.

As a generalization it is not unfair to state that hitherto new developments have been sought primarily from new compounds rather than new techniques. Evaluation has consisted of checking the constraints affecting efficacy on a success or failure basis. Where a candidate compound can be applied through farm machinery there has seldom been seen any need to examine the use of novel application techniques in order to enhance efficacy, increase selectivity or even to reduce the dose of chemical required. Much the same can also be said of formulation chemistry, and the study of spray distribution on the target surface. For these reasons, the application of pesticides is often crude and the actual efficiency in the field quite low (Rutherford, 1976).

One result of the above approach has been that whilst innovators of new compounds devote immense capital to the production of new active materials, few have any sizeable development budgets devoted to the innovation of new spray technology.

The attitude of many chemical manufacturers has been that they have no desire to get involved in machinery aspects of the application of pesticides that they may have spent many millions of pounds getting onto the market. This results in either the perpetuation of current spraying machinery, with all its faults, or the production of machinery entirely confined to the application of a single product.

In the case of controlled drop application the developments have been dependent on the initiative of research carried out in government institutes, the machinery design having been carried out before the chemical marketing organizations have become involved (Cussans and Taylor,1976; Farmery et al,1976; Lake et al,1976).

The development of CDA has been something of a novel approach to pesticide evaluation but may be indicative of future trends in pesticide development. In the future it is likely that the flow of new compounds will not be so great as it has been over the last decade. Added to this, pesticide development will be affected by the following:

a) The demands of increased regulatory requirements. This will make some developments uneconomic as well as increasing the time between discovery and marketing for the remainder.

b) The increasing likelihood that one or more products already exist for the same problem.

c) The ending of many patents will deter any further development on them if it cannot in turn be patented.

d) The increased costs of development will lead to more crops or pesticide problems being designated as minor uses by large international commercial organizations.

These factors place more onus for innovation in the hands of the independent research worker. He will be more deeply involved in these developments. He will certainly have to get trials clearance through the Pesticide Safety Precautions Scheme and determine the needs of the Approval Scheme possibly before a chemical manufacturer has become involved in the development.

CONTROLLED DROP APPLICATION AND APPROVAL

The normal method of development of a pesticide is to use experimental sprayers in field trials and if the results are acceptable extension trials would follow in which the candidate pesticide is applied through increasingly larger sprayers ending up finally with farmer usage trials. In these trials, selected growers would be asked to apply from $\frac{1}{2}$ - 2 ha of the test material through his farm sprayer compared with his normal material. The application and evaluation of results should be carried out or supervised by technical trials staff. Unless problems are encountered peculiar to the method of application, only different volumes of water and compatibility are likely to be examined in the trials programme. The only label requirement will be the rate of use of a compound and the volume of water in which it is to be applied. This assumes that the sprayer on any farm will comply with the range of sprayers encountered in the usage trials.

Inadequacies from this approach generally arise as complaints in the first and second commercial years of use. They most commonly take the form of too low a volume of water, too little pressure and unsatisfactory results from certain types of sprayer, especially low-drift sprayers.

Deviation from the above occurs where the formulation of seed treatment or granule, or the use of soil sterilant, dictate that conventional application techniques are unsuitable. In these circumstances great emphasis is put on the correct method of application. The result is that having discarded conventional spraying techniques the criteria for the new method of application will demand a far higher standard of performance than is obtainable from most conventional sprayers.

It must, however, be made clear that in the examples mentioned above the novel application techniques have been born of necessity. In this respect they differ from CDA which was born out of an interest in improving the current spraying systems by increasing the accuracy of application, reducing the volume of water used and increasing the work rate so that most can be made of the limited spray days available to the farmer. Results from trials to date indicate that CDA meets the description above and that there is sufficient information with certain herbicides for approval to be considered using tractor mounted spinning disc applicators.

The needs of the Agricultural Chemicals Approval Scheme can be summarised as follows:

a) A label bearing the CDA recommendations must be drawn up. It is the basis upon which approval will be granted.

b) The applicant must have been granted provisional or commercial clearance by the Pesticides Safety Precautions Scheme for the CDA recommendations on the label supplied.

c) The recommendation will need to state the mean drop diameter, the volume applied and the machine recommended for the application.

d) Sufficient trials data will have to be supplied to establish that compared to conventional farm sprayers' results obtained through CDA application are both consistent and comparable.

LABEL RECOMMENDATIONS

The label is the recognised document on which the full requirements of both the Pesticides Safety Precautions Scheme and the Agricultural Chemicals Approval Scheme are printed. Where space or packaging causes problems it may be replaced by an attached leaflet.

Methods of application are always shown on Approved labels which will apply to most pesticides considered for use through CDA sprayers. In these cases the CDA use will need to be treated separately on the label with a clear distinction between the methods of application. At present, Approval has been granted to the herbicides shown in Table 1.

Table 1

Products Approved through CDA sprayers and their uses

Chemical	Product	Use
asulam	Asulox	Control of bracken
2,4-D	Silvapron D	Weeds in forestry and grassland
2,4,5-T	Silvapron T	Woody weeds in forestry and grassland
propyzamide	Kerb 50W	Weeds in forestry

These approved recommendations represent the first generation of CDA labels. They all, however, share in common a similar area of use, namely non-arable situations and they are confined to hand held spinning disc atomisers.

CLEARANCE FOR USE

Confusion has arisen on the need for separate clearance for different methods of pesticide application. Alteration in methods affect both the nature and physical characteristics of a spray. It is absolutely necessary therefore that such uses are first cleared by the Pesticides Safety Precautions Scheme before trials or commercial applications are carried out. In the case of CDA the drop in volume of water used compared to conventional spraying must lead to an equivalent increase in the concentration of pesticide in the drops. Only the Safety Scheme are competent to judge whether such an increase in concentration constitutes an acceptable safety risk or not.

DROP SIZE

Drop size is important in crop spraying from the point of view of evaporation, drift, impaction on the target etc. One of the contributions of CDA to crop spraying is that the user can determine what drop size is most suitable for the situation in hand whilst avoiding some of the difficulties inherent in conventional application. This has resulted in questions being asked about the quality of conventional nozzles and the drop spectrum produced by them.

This feature can now be examined when testing sprayer components. The Central Testing Scheme of the British Crop Protection Council will soon have facilities to test drop size outputs from nozzles. Table 2 shows the outputs from two types of spinning disc and a fan nozzle. The figures were obtained during testing runs using a Malvern Electronics Droplet Size Analyser (Matthews,1978).

Table 2

Drop sizes produced by two types of spinning disc and a Fan jet nozzle

Drop sizes	Micron Herbi disc		Micron Mini Ulva disc		Fan jet nozzle	
Drop sizes µm	% by mass	% by numbers	% by mass	% by numbers	% by mass	% by numbers
562.8 - 261.7	47.60	8.63	0.00	0.00	9.59	0.11
261.7 - 160.3	48.60	65.73	0.00	0.00	48.77	4.01
160.3 - 112.9	3.40	16.80	0.00	0.00	24.51	7.43
112.9 - 84.3	0.39	5.22	1.40	0.05	9.61	7.75
84.3 - 64.6	0.07	2.04	16.41	1.45	4.07	7.63
64.6 - 50.3	0.01	0.87	30.03	5.78	1.81	7.39
50.3 - 38.9	0.00	0.42	25.74	10.59	0.88	7.72
38.9 - 30.3	0.00	0.19	14.10	12.43	0.40	7.51
30.3 - 23.7	0.00	0.09	6.76	12.51	0.19	7.40
23.7 - 18.6	0.00	0.00	3.10	11.95	0.09	7.40
18.6 - 14.6	0.00	0.00	1.38	11.01	0.04	7.35
14.6 - 11.4	0.00	0.00	0.61	10.11	0.02	7.36
11.4 - 9.1	0.00	0.00	0.25	8.49	0.01	6.77
9.1 - 7.1	0.00	0.00	0.13	8.58	0.00	7.51
7.1 - 5.7	0.00	0.00	0.05	7.05	0.00	6.66

The use of spinning discs for the production of restricted drop size is an extension of ULV techniques (Bals,1973) and the first were used for herbicide application during investigations of the effect of reduced volumes on the efficiency of barban on wild-oats (Lake and Taylor,1974). This led to field trials with a number of herbicides using drop sizes from 150 - 350 µm and volumes from 5 l/ha to 40 l/ha (Cussans and Taylor,1976). The use of CDA spraying has been largely confined to applying herbicides to cereals and the success of the original work at the ARC Weed Research Organization has progressed to collaborative field trials programmes with ADAS (O'Keeffe et al, 1976; Bailey and Smart, 1976; Evans and Kitchen, 1976) and with some chemical manufacturers (Lush and Palmer, 1976).

The results obtained show that for most herbicides a drop size of 250 µm is optimum although the question still remains whether the contact herbicides such as ioxynil and bromoxynil might give better results with drop sizes below those tested to date.

Results with the herbicide bentazone (Brown,1978) have shown that against the weeds *Solanum nigrum* (Black Nightshade) and *Urtica urens* (Small Nettle) using 1.5 kg/ha at 20 l/ha weed control increased from 0 - 30% with 350 µm drops, 52 - 55% with 250 µm drops to 87 - 93% with 150 µm drops. This was compared to a Van der Weij sprayer applying 250 l/ha which gave 95 - 100% weed control on these species.

There is little information on fungicides but there was an indication that they may give better results at drop sizes below 250 µm. ADAS trials show little difference from altering drop size (Jenkins,1977; Yarham,1978). Other trials with tridemorph have shown that there is a benefit in disease control from using a drop size of 250 µm (Brown, 1978), compared to a drop size of 150 µm.

Little information exists on the use of CDA for the application of insecticides. There is a large amount of information relating to the control of insects using ULV sprayers from the air and on the ground but this information is taken from work carried out on pests and crops not found in the United Kingdom. These data indicate that drop sizes from 30 µm - 150 µm are suitable in tropical and semi-tropical situations (Yeo,1974; Bals,1974). In so much as the mode of action of herbicides seems to determine their suitability for CDA so with insecticides there will be a need to examine systemic and non systemic insecticides through current CDA applicators to find out what drop size will be best suited for each active ingredient.

VOLUME

The reason for the development of CDA came primarily from the benefit to be gained by reducing volumes of water being applied with pesticides. In cereal trials it was shown that with herbicides (Ayres,1976; Wilson,1976), reducing volumes below 20 l/ha gave reduced levels of weed control. Better results were sometimes obtained with volumes above 20 l/ha. At 20 l/ha, with current multiple disc units, the rate of flow onto the discs is such that spraying cannot be carried out much faster than 6 - 7 km/h. It remains to be seen whether this is a necessary minimum volume of water for the successful use of insecticides and fungicides through CDA machinery.

MACHINERY

CDA was first used commercially in the United Kingdom through single disc, battery driven, hand held atomisers (Bals,1974) or through motorised fan assisted spinning disc atomisers (Fuller-Lewis,1974). Being hand held they suffer the disadvantage of being dependent on the walking speed of the operator for both rate of use and volume of application. Only the battery operated spinning disc machines are recommended for the approved uses listed in Table 1.

The work at the ARC Weed Research Organization was carried out by a tractor mounted experimental CDA sprayer (Taylor et al, 1976) and portable twin-head plot CDA sprayers. The first prototype commercial CDA sprayer appeared in 1977 (Farmery, 1975,1976). All these machines produced drops from shrouded triple-disc spray heads.

On the commercial prototype the heads are positioned to give a 50% overlap. This gives an even distribution of drops across the boom width and also allows for matching up between boom swaths without the risk of double overlap. Results with the prototype machine have been equal to those from farm sprayers (Grosjean,1977) comparing hormone cereal weedkillers. It is hoped that a second season's trials will confirm this level of performance and enable Approval to be granted. Until other machines are developed for CDA use the above machine will be the only one that can be mentioned on an Approved label in a CDA recommendation.

RATE OF USE AND PERFORMANCE

Approval is concerned with the actual field performance of a pesticide and not just its relative efficacy compared to an approved standard. The presence of standards in trials is more to give a means of judging the effect of field variables in order to better assess the performance of the candidate compound. To this must be added the 'performance' of the control and the 'double dose' treatments of the candidate material. The resulting Approved label should therefore represent what is likely to occur when the product is applied to crops under all the likely conditions it could meet. It is thus possible for phytotoxic or inferior pesticides to be granted approval. This could apply equally to CDA as to any other use of a pesticide. The real point of approval is that the evidence must be of sufficient quality and quantity to be certain that the result of application is constant within manageable limits. If this involves a reduction in absolute efficacy compared to the standard as long as it is reliable in action at this level other more important considerations such as cost, efficiency or crop safety may more than compensate for any slight drop in efficacy. In the case of CDA this could mean that increased work rates would allow a grower to spray all his cereal crops with herbicides within the safe period of use instead of spraying a proportion of the crop outside the recommendation for the herbicide.

In the CDA trials to date the rates have been varied. Standard and reduced rates have been compared with different volumes and drop size (Ayres,1976; Wilson,1976). Results have consistently shown that with herbicides, rates of use cannot be reduced without the loss of efficacy. The limited trials with fungicides would serve to support this in cereal diseases. Some insecticides in fruit have appeared to give adequate aphid and sucker control when the concentration of the drop has been kept constant but the volume reduced (Morgan,1974). Whether this will also apply to cereal aphids with CDA remains to be seen.

In order to be able to approve a reduced dose of an already Approved pesticide purely on the grounds of enhanced efficacy due to CDA application, a considerable body of data collected over a minimum of two seasons would be required.

FORMULATION

The first formulations of herbicide tested and approved for use as CDA sprays were esters of 2,4-D and 2,4,5-T formulated in refined emulsifiable oil. These have proved effective in the uses for which they were designed (Table 1). In cereals, however, it has been found that salts and esters will act just as well applied in water as in oil (Taylor and Merritt,1974). This opens the door to all existing commercial pesticides with current spinning disc CDA application machinery. This does not rule out the possibility of enhancing results with specific pesticides using oil or any other carrier. Some difficulties have been encountered with wettable powders due to their adverse affects on flow rates to the disc units and accumulation on the discs themselves. Propyzamide is the only wettable powder approved for CDA use and here added wetter is required to maintain flow and prevent deposit on the discs. Recent trials have indicated that flowable formulations of some triazines and substituted ureas have been satisfactorily applied through experimental and field CDA sprayers.

TRIALS PROGRAMMES FOR CDA RECOMMENDATIONS

It is not envisaged that a new compound would be evaluated using CDA techniques. Candidate materials can therefore be assumed to be already approved pesticides with known characteristics. Evaluation through CDA machinery can therefore be approached on similar lines to a new use of an existing approved pesticide. The trials required can be further reduced if the CDA use is for the same dose, in the same crop and at the same time of application. The requirement for approval of CDA recommendations in this situation has most in common with a major change of formulation. The difference between CDA and the latter would be that one would compare plots applied by different machines instead of plots sprayed with differing formulations of the same compound. The difference would manifest itself in the plot size which for comparisons of application techniques would need to be relatively large.

The first stage would be to examine the pesticide in replicated field experiments in which application would be with portable CDA sprayers and conventional field plot sprayers. In these experiments the standard rate only need be used unless there is a reasonable chance of phytotoxicity in which case one treatment with a double dose should be included. In addition, volume rates and drop size should be varied. Assessments would be along conventional lines but particular note must be taken of known weaknesses of the pesticide, which in the case of herbicides would be semi-resistant weed species and crop phytotoxicity. Yield data should be obtained from such trials.

These small plot trials would constitute Year 1 in the trials programme. At least six sites would be necessary. If the results indicate that the candidate pesticide is well suited to CDA techniques, with a clear indication of rate of use, volume and drop size, a proposed recommendation can be drawn up to be tested in Year 2 compared to a conventional application. In Year 2 the proposed CDA recommendation would be applied through a commercially available CDA sprayer on approximately 1 - 2 ha compared to a conventional application of the same pesticide through a farm sprayer on a similar area. There should be two replicates and at least twelve separate sites. Controls can consist of small areas either deliberately avoided or covered by polythene sheets during spraying. Assessments would be similar to those carried out in the small plot trials but sampling the whole of the areas treated. Yield data would only be required if unforeseen crop effects appear in these trials not encountered in the small plot trials.

NON CEREAL CROPS

The technique of CDA spraying has been confined to the application through hand-held single disc machines in forestry and grassland and multiple disc portable or tractor mounted machines in cereals. The greatest amount of effort has been put into trials carried out in cereals, especially winter wheat. To date there is no information on the use of the technique in other arable crops, especially oil-seed rape, sugar beet, potatoes and field legumes. If the pesticide formulations are suitable for application through CDA machinery there would appear to be no biological reasons why the technique could not be successfully used for soil-applied herbicides. This assumption cannot be applied to foliar applied pesticides and only suitable field trials will provide the answer.

In the bush and tree crops the use of soil-applied herbicides would appear to present no problem through CDA, particularly as drop emission from the disc units is horizontal. This enables the boom to be held close to the weed or soil surface and beneath overhanging branches and foliage. Herbicides are, however, only a minor constituent of fruit crop spray programmes. The use of motorised fan assisted spinning disc atomisers is reported to give comparable results in apples (Morgan,1974) to conventional fruit tree spraying against aphid. Similar results on apple powdery mildew (Frick,1970) illustrated that the system is of potential interest in the control of fruit diseases. A suitable experimental CDA fruit tree sprayer has been reported (Jones et al,1974) but at present there is no commercial machine available for this application in fruit.

ULV AND AERIAL SPRAYING

There are several definitions of ULV spraying (Fryer and Makepeace,1977;Joyce, 1970) which although differing between themselves in detail, agree that ULV spraying covers applications of 11 l/ha and below. CDA is not the same and provided the drop size can accurately be defined it can apply to any volume of spraying between ULV and medium volumes around 250 l/ha. The emergence of 20 - 40 l/ha as a likely optimum volume for CDA spraying puts the technique in the area of very low volume spraying.

The machinery for the production of controlled drops was developed for ULV and VLV applications of pesticides at drop sizes ranging from 10 - 150 µm. The use of aircraft for spraying was pioneered in the locust control programme in Kenya (Gunn et al,1948). Considerable advances were made in the spray machinery used so that drop size could be controlled (Yeo,1974; Bals,1974) using a variety of atomisers, especially rotating gauze atomisers and spinning disc atomisers (Maas,1971).

By adapting the spinning disc for ground application CDA spraying has introduced a more precise method of crop spraying than we have enjoyed in the past. Aerial application of pesticides in the United Kingdom, except in potatoes and lately cereals has not enjoyed the success that it has overseas. Many applications have been faultily applied and the technique has not compared favourably with ground application, except in the cases mentioned above. Improvements can be expected under the regulations laid down by the Civil Aviation Authority. One step forward is that any pesticide that is to be applied from the air must be cleared for this particular use by the Pesticides Safety Precautions Scheme. Approval of aerial application can be sought, as with other label recommendations. The list of Approved aerial recommendations can be found in Approved Products for Farmers and Growers,1978 (HMSO).

THE FUTURE OF CDA

The adoption of CDA as an accepted technique will depend on its success in controlling pests combined with its other advantages to the grower. We may only be at the beginning of a series of developments employing the use of CDA. Other methods of drop formation could radically alter its application. Higher flow rates could enable suitable machines to be used at high ground speed, possibly on the low ground pressure sprayers being examined at present. We do not yet know the role that could be played by simultaneous production of more than one drop size. Possibilities exist of charging drops to ensure arrival at the target surface. We may be able to reformulate pesticides and use the technique to reduce amounts of chemical required. These, and other avenues of research, are all potential ways of using CDA to better advantage. What is required in the immediate future is as much evaluation as possible with our current machinery so that labels can be cleared and Approved so that the grower has the opportunity to put the method to the test on his farm crops.

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