AN ADAS SURVEY ON THE UTILISATION AND PERFORMANCE OF FIELD CROP SPRAYERS

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Summary ADAS Mechanisation Advisory Officers visited ninety-one farms throughout England and Wales to monitor the performance of field crop sprayers operating under commercial conditions. The first part of the investigation took the form of a pre-season check. The throughputs from individual nozzles were measured and wide variations were identified on several farms. A dynamic calibration compared the actual application rate with the operator's intended rate. The second part of the study took place during the spraying season. The sequence of operations was recorded and analysed. The amount of time spent filling the tank was high in some cases, and travel to and from the field caused further deterioration in the overall rate of work. The relative importance of these individual operations making up the spraying cycle is demonstrated, and the likely impact of new nozzle designs to reduce spray liquid volumes is discussed.

Résumé Les officiers de l'ADAS se spécialisant en mécanisation agricole ont visité quatre-vingt-onze fermes dans tous les coins de l'Angleterre et du pays de Galles pour contrôler le comportement de pulvérisateurs en plein champ dans des conditions normales. La premiére partie de l'enquête consistait en un contrôle préliminaire d'avant-saison. Les débits de buses particulières ont été mesurés et de grands écartements se sont révélés dans plusieurs fermes. Un réglage au cours du travail à comparé le volume appliqué en réalité avec celui que l'opérateur avait voulu. La deuxième partie de l'enquête à eu lieu pendant l'époque des pulvérisations. La suite des opérations à été notée et analysée. Le temps passé à remplir le réservoir était grand dans certains cas et le trajet jusqu'au champ à contribué davantage à diminuer la vitesse de travail. L'importance relative de ces opérations particulières, qui se concertent pour créer le cycle de la pulvérisation, se fait voir, on considère également l'effet probable de l'introduction de buses de forme nouvelle dans l'intention de réduire le volume de bouillie utilisée.

INTRODUCTION

It is ten years since a NAAS survey on the effectiveness of commercial chemical application was reported (Hughes 1966). A recent survey (UK MAFF 1976), from which information in this report is derived, is more concerned with the engineering and logistics of spraying systems, no attempt being made to evaluate the efficiency of the herbicide on the weeds or crop yield.

INFORMATION ABOUT THE SAMPLE

The investigation was carried out by ADAS Mechanisation Advisers on ninety-one farms throughout England and Wales. The larger arable farm predominated with 65% of the sprayers covering over 200 ha per season. Two thirds of the machines were less than three years old and most makes available on the UK market were represented. A surprising number of operators, 57%, had not received special instructions on the operation of the field crop sprayers.

PRE SEASON CHECK AND CALIBRATION

ADAS Mechanisation Advisers visited the farms before the main spraying season having previously asked the operator to prepare his machine to work at his normal application rate. The throughput from each nozzle was measured and the operator was informed of the location of any nozzle varying by more than 10% from the mean. Table 1 shows the variability in throughputs within sets of nozzles used on some sprayers.

Table 1

Frequency of nozzles with faulty throughputs

Numbers of nozzles worse than 10% variation from the mean on the sprayer							
0	1	2	3	4	5	6–10	> 10
Proportion of sprayers, %							
24	17	12	12	7	6	12	10

The extremes of throughput between the highest and lowest nozzle along the boom were very large in some instances as shown in Table 2.

Table 2

Extremes of indivudual nozzles/sprayer

Maximum/minimum throughputs, %					
100–110	110–125	125–150	150–200	200–300	> 300
Proportion of sprayers, %					
4	30	33	15	13	5

DYNAMIC CALIBRATION

Having adjusted his machine to his satisfaction, the operator sprayed a known area. The amount of water required to refill the spray tank to the original level allowed the actual application rate to be calculated and thereby to be compared with the intended. The results are given in Table 3. When questioned about the errors and methods of calibration used, it was found that over one-third of the operators did not attempt to check and then, if necessary, recalibrate their machine in the field.

Table 3

The difference between operators' calibrations and actual spray volume rate

Errors from the operators' intended rate, %					
< 10	10–20	20–30	30–40	40–50	> 50
Proportion of sprayers, %					
54	26	11	6	2	1

FIELD PERFORMANCE

The farms were visited again during the spring to study the machines at work under commercial conditions. Details of the time spent on filling, travelling, spraying and delays were recorded.

Filling

Although considerable publicity has been given to the need for rapid filling, many farms spent a high proportion of the spraying cycle on this activity. Table 4 summarises the data.

Table 4

Variation in time spent filling spray tank

Filling time as a % of spraying time							
< 20	20–30	30–40	40–50	50–60	60–70	70–80	> 80
Proportion of sprayers, %							
4	8	34	17	19	6	6	6

Travelling

Travelling to and from the water source still further reduced the rates of work on many farms (Table 5).

Table 5

Time spent travelling to and from water source

Ferrying time as a % of spraying time			
< 10	10-20	20-30	> 30
Proportion of sprayers, %			
31	40	12	17

Application rates

Large quantities of diluent and the need for frequent refilling also adversely affected the rate of work on some farms.

Rates of work

a) Spot rate of work (ha/h) = speed (m/s) x effective width (m) x 0.36

This is the 'theoretical' rate of work and was calculated from the speed measured above and the actual width recorded from 10 measurements taken while the machine was at work in the field.

b) Net rate of work

This is the rate of work recorded while the machine was actually applying the chemical. It includes turning on the headland, and any time taken to fold the booms. It excludes any delays to make adjustments, clear blockages, etc., and all travelling and filling times.

c) Overall rate of work

This is the overall rate of work recorded during the ADAS study including filling, travelling and delays for adjustments etc. It excludes breaks for meals.

Details of spot, net and overall rates of work were recorded. To eliminate the variable of boom width, overall rates of work are expressed in Table 6 as a specific rate of work (ha/h per m width).

Table 6

Sprayer rate of work

Hectare/hour/metre of boom

< 0.2	0.2-0.3	0.3-0.4	0.4-0.5	> 0.5
Proportion of sprayers, %				
12	32	28	15	13

The logistics of the spraying operation

The importance of the various activities in the spraying cycle is demonstrated by considering a typical system and then changing each parameter in turn. Figure 1 summarises this information from which it is clear that improvement to the filling and travelling part of the cycle has a very important effect on the overall rate of work. By reducing the diluent, even greater output is achieved, and the outcome of development work on controlled droplet application (CDA) field crop sprayers, which may be able to exploit reduced spray volumes, is awaited with interest.

Swath matching

Several systems of swath matching were observed with the machines at work. While mean measurements showed that 65% of the machines were within 5% of the target spacing, individual swath measurements revealed large errors. This appeared to be associated more with the skill of the driver than the marking system. A few examples of 'tramlines' were observed and these were promising, with the drivers enthusiastic about the system, and appeared to offer more accuracy in the matching of swaths.

CONCLUSIONS

ADAS Mechanisation Advisers found that the standard of sprayer operation was at a similar level to that which prevailed ten years ago. Although many systems are now operated efficiently, there is considerable room for improvement, and more effort should be devoted to publicising the need for good maintenance, field calibration and attention to detail for optimum performance of this exacting and important task of chemical application.

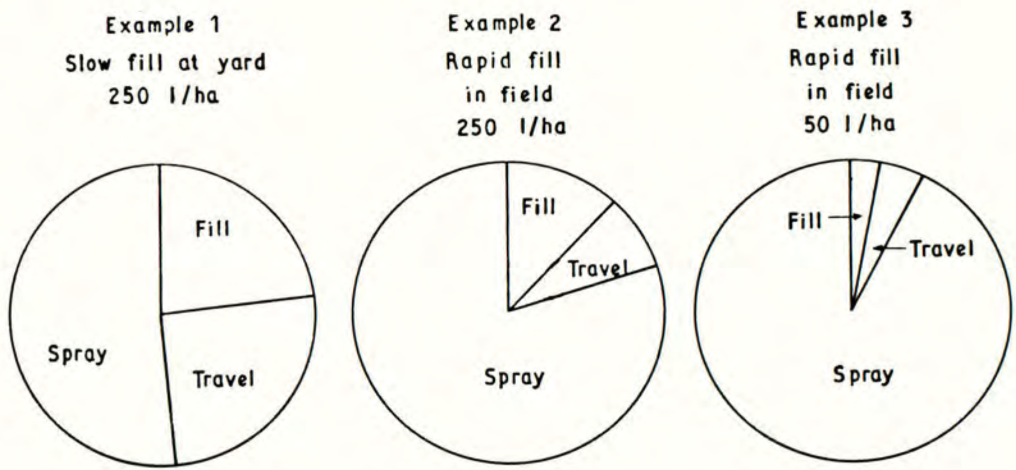
References

HUGHES, R. G. (1966) Project N.A.E. 30 The Efficiency of Weed Control in Cereals on Commercial Farms - Eighth British Weed Control Conference, 1 200-203.

UK MAFF (1976) Farm Mechanisation Study No. 29 - Utilisation and Performance of Field Crop Sprayers.

Fig. 1

Cycle times for alternative application systems



THE SCOPE FOR THE USE OF CONTROLLED DROP APPLICATION (CDA) ON LARGE CEREAL-GROWING FARMS

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Summary Of about 2.8×10^6 ha of cereals in the main growing areas in the east and south of England, some 35% are on farms with more than 120 ha. On these farms there are probably as many trailed sprayers as tractor-mounted ones and the greater part of the area is treated by them. Spraying times and speeds encountered in a recent survey of large-farm spraying have been used to predict the potential value of CDA. It is concluded that it should find a use in this context with a tractor-mounted sprayer having a wide boom. It opens up prospects for more rapid spraying if the capital now used for filling facilities is put into a sprung vehicle.

Résumé Environ 2.8×10^6 hectares sont consacrés à la culture des céréales dans l'est et le sud d'Angleterre et près de 35% de cet espace se trouve dans des exploitations agricoles où la superficie céréalière excède 120 hectares. Il y a probablement autant de pulvérisateurs tractés que d'appareils portés dans ces exploitations et la plupart de la superficie est traitée par ceux-là. On se sert de données pour la vitesse d'avancement et le temps de pulverisation, tirées d'une enquête récente touchant la pulvérisation dans les exploitations de grande envergure, pour predire la perspective éventuelle de ce procédé de "gouttes d'une finesse contrôlée". On juge que la technique devrait avoir des chances de succès dans système de pulvérisation caractérisé par l'emploi d'appareils portés et de grandes rampes. En plus des possibilités d'une pulvérisation accélerée se présentent si l'on réduit le capital investi dans le matériel pour remplir la cuve et si l'on emploie un véhicule suspendu.

INTRODUCTION

The data presented were obtained as part of a more general consideration of the sprayer requirements of the larger arable farms in England. The special machinery needs of these larger units are reflected in the difference between the sprayers now used on them and the more popular tractor-mounted models. The fact that larger, more expensive, conventional sprayers are now used implies that the potential savings from the use of much smaller volumes of spray liquid may be greater than on small farms. Certainly the economics of the operation and the sprayer requirements differ and it was in order to determine these factors that the information here given was obtained.

METHOD

Information on the distributions of farms in the English counties by size in major crop groupings is regularly obtained in the Ministry of Agriculture, Fisheries and Food (MAFF) agricultural censuses. Although the specific information about a farm is confidential the statistics derived therefrom are available so that the distribution of farms and their sizes could be obtained.

The next step was to obtain data on sprayer usage on a representative sample of farms. A pesticide usage group at the MAFF Plant Pathology Laboratory at Harpenden has, on several occasions, obtained information on the spraying machinery used on farms where it has been obtaining information on pesticide sprays. By combining their information on spraying machinery used on farms visited in the course of their surveys, with the national farm statistics, it was possible to obtain a reasonable estimate of the number and type of sprayers in use in 1969. The two main limitations of these data are, firstly, that the sample of farms visited in any survey is truly representative only of acreages of the particular crop which is the subject of the pesticide study and, secondly, only some counties are usually taken for the national survey. A vegetable survey in 1969 took samples in Bedfordshire, Kent, Lancashire, Lincolnshire (Parts of Holland and Lindsey), Norfolk and Worcestershire. Large farms of interest are almost all east and south of a line which includes the Yorkshire wolds passes east of the industrial midlands around Birmingham and east of Bristol and down to the south coast to include the Wiltshire downs. The counties included by this line (excluding Greater London) have a farming pattern not very different as a whole from the above sample, and they contain about $\frac{7}{8}$ of the country's cereal acreage. The Plant Pathology Laboratory survey had covered about 300 farms of which about 100 had 90 ha of vegetables. Reference back to the holding statistics showed that a similar number would have had over 180 ha of cereals, most of the larger farms being common to these two groups.

The pattern of mounted sprayer usage has changed in recent years only in a gradual move towards a larger size of tank. It was therefore decided that an up-to-date picture could be obtained from the old base by considering recent changes in the sprayers used on the largest farms only. A survey of spraying operations on 23 farms in the largest size group was made in 1975. This was based on half-day visits to each farm during which details of field size, filling arrangements, sprayers and filling facilities were obtained. Details of spraying rates were obtained from farm records and discussions with managers.

RESULTS

Table 1 gives figures of cereal areas in the counties in question and the proportion on the larger farms.

Table 1

Distribution of cereals in England

	Area of cereals, ha x 10^4	Proportion of national total, % x farm size, ha			
		81-122	>122	>203	all
Beds, Bucks, Cambs, N'thants, Herts	43	2.42	6.06	3.20	13
Essex, Norfolk, Suffolk	55	2.89	8.07	4.46	17
Berks, Dorset, Hants, Oxford, Wilts	42	1.85	7.01	4.11	13
Humberside, N & S Yorks, N'thumberland	46	2.64	4.75	2.18	14
Leics, Lincs, Notts	43	2.12	6.05	3.57	14
Kent, Sussex	16	0.85	1.97	1.03	5
Glos, Hfds, Worcs, Salop, Staffs, Warw	34	1.59	2.85	1.27	10
Other	41	(totals exclude these)			13
Total	320	14	37	20	100

The 1969 survey gave an estimate of 160 trailed sprayers and 3800 mounted sprayers in the counties surveyed, in the four smallest categories of farm size. In the next category, which had a mean area of cereals of 57 ha, there were 150 trailed sprayers and 500 mounted ones. In the largest size group, with a mean of 81 ha of cereals, there were 220 trailed and 300 mounted sprayers.

Table 2 gives the machines used on the very large farms in the recent survey. This table also gives rounded figures for filling times on the more distant parts of the farm, application rates, working speeds and boom widths. Towed water tanks of capacities around 10000 l are listed as "bowsers". Smaller tanks on farm trailers were usually of less than a quarter of this capacity.

Table 3 gives calculated spraying rates for these current operations for combinations of boom width and tank capacity, taking 8 km/h driving speed. Figures are given for an application rate of 200 l/ha. Table 2 shows that this speed and application rate are only departed from significantly, in current practice, in limited situations. A mounted sprayer of 700 l capacity and two sizes of trailed tank were considered. The potential for sprayers treating a very wide swath and for a sprung vehicle which could travel at 18 km/h are shown. Working rates for applications of 15 and 35 l/ha have been calculated and are given for comparison. The figures are expressed as areas treated in a 4 hour working session with good and poor tank filling arrangements.

Table 2

Sprayers used on large farms in 1975

Farm area	Cereal Sprays	Sprayers used, boom width and tank capacity						Spraying speed	Applied volume	Filling time, up to	
		Mounted			Trailed						
ha	No.	No.	m	l	No.	m	l	km/h	l/ha	min.	Water supply
290	?				1	12	1150	8	250	30	main
330	3				1	12	1140	8	225	30	static tank
360	2 or 3				1	12	1400	8	225	30	static tank or brook
400	2				1	12	1360	8	?	?	tank on trailer
410	2 or 3				1	12	1360	8	225	20	ponds and wells
450	3				1	24	2050	7.2	225	30	static tank
510	4				2	12	2050	8	225*	20	main
510	3				2	12	1010 & 2050	8	170*	15	bowser
530	1 or 2	1	9	680	1	12	2050	8.8	225	15	tank on trailer
530	4	1	12	590	1	12	2050	9.6	250	15	bowser
550	?				1	12	1360	8	?	?	tank on trailer
630	2				1	12	1360	8	225	75	main
700	3	1	18	680	1	12	2050	8	225	15	bowser
740	3				1	12	1400	8	225	15	bowser
760	2 or 3				1	12	2050	9.6	225*	15	bowser
890	1 or 2	1	9	680	1	12	1360	9.6	170	15	bowser
900	3				2	9	1360 & 2050	7.2	225	30	static tank
970	2 or 3				2	12	1360 & 2050	8	225	45	bowser
1010	2 or 3				1	12	1400	9.6	225	30	ponds
1060	2 or 3	1	18	680	2	12	1360	8	250	15	bowser & 3 tanks on trailers
1100	3				2	12	1590 & 1370	8	170*	30	main and river
1230	3				2 + 4	12 & 18	1370 & 2050	4.8	170*	20	dykes
2840	3	3	9	570	7	12	1370	8	225	15	bowser

*larger volumes used on occasion

Table 3

Working rates in relation to applied volume, tank size and boom width, ha in 4h

	Conventional application @ 200 l/ha Sprayer tank capacity, l (mounted)	(trailed)		Reduced volume 35 l/ha (mounted)	15 l/ha (mounted)
	700	1400	2100	700	700
9m swath, 8 km/h					
spraying only	29				
30 minute filling	14	19	21	24	27
10 minute filling	21	25	27	27	28
12m swath, 8 km/h					
spraying only	38				
30 minute filling	16	23	26	31	35
10 minute filling	26	31	33	36	37
18m swath, 8 km/h					
spraying only	56				
30 minute filling	19	28	34	42	50
10 minute filling	34	43	47	51	55
12m swath, 20 km/h					
spraying only	98				
30 minute filling	22	not applicable		60	76
10 minute filling	45	not applicable		80	88

DISCUSSION

The rates of apraying attainable in fields are limited by the width of swath treated and driving speed. In tractor operations the speed is fixed by the comfort of the driver on an unsprung vehicle, rather than by any spray application factor. Boom width is limited by field undulations and the need to keep nozzles fairly close to the crop to avoid gross variations in deposit and to limit wind drift. These two factors set limits around the figures for a 12 m boom sprayer at 8 km/h given in Table 3. The potential benefits from the use of smaller volumes of spray are generally (i) a reduction in the proportion of time spent in travelling to refill and refilling, or (ii) reduction in the weight of water carried. With a tractor-mounted sprayer the vehicle itself is so heavy that the second consideration is not likely to be important. While small, light sprayers capable only of applying small volumes of spray have their place in other contexts, they will not be appropriate to the routine treatment of large fields of cereals. In the context of this paper the potential use of controlled drop application is with a tractor-mounted sprayer travelling at about 8 km/h or a sprung vehicle at up to 20 km/h, and in each case capable of carrying 700 l of spray fluid.

Provided that a tankful of fluid will treat one field, which even on large farms is usually less than 20 ha in area, there is little further to be gained by reduced filling frequency. The gain in reduced filling by a reduction from 200 l/ha to 35 l/ha is about 40% with a tractor-carried 12m boom and "in field" water supply or, about 50% with poor filling facilities. Gains from a further reduction in applied volume are relatively insignificant.

Work rates can however be increased by a further 50% by the use of very wide booms, of the order of 18 m (or doubled by going to 24 m) but booms of this size pose great problems on most farms. An alternative means of achieving high rates is the use of a sprung vehicle. At such increased working speeds elimination of excessive filling times would be even more important but again most of the saving has been made by a reduction to 35 l/ha.

The general conclusion which can be drawn from the data is that in this situation the introduction of controlled drop application is most likely to eliminate the additional cost of trailed sprayers and the additional work and cost of the bowsers or static water supplies needed to make conventional application at all efficient. It can however only give working rates which tend to limits set by driving speeds and swath widths so that it is unlikely to be used in any form which restricts boom size. The capital saved from investment for water supplies and very large tractor-powered sprayers might, on large enterprises, well be applied to the purchase of a sprung vehicle with a 12 m boom and carrying, say, 700 l of spray; this could treat 20 ha/h at 35 l/ha.

Acknowledgements

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POTENTIAL AND DESIGN OF CDA FROM AN ENGINEER'S VIEWPOINT

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Summary Commercial prototype equipment for the application of pesticide at 20 l/ha is described. This equipment utilises the spinning disc to produce a uniform size of drops of spray liquid, 250 µm in diameter. The biological evaluation of such applications is being done in liaison with the agricultural industry and A.D.A.S. Results obtained in the field are encouraging enough to continue the development of an overall applicator for controlled drop application (CDA).

INTRODUCTION

If controlled drop application controls weeds at 20 l/ha of total spray liquid as effectively as conventional hydraulic nozzle spraying, then there is a market for specialised equipment which we, as manufacturers, would wish to develop. But who do we look to for evaluation of such a development ? Obviously, chemical companies have no real incentive to do so, and the restricted budgets of our official research establishments limit their capacity.

Being one of the initiators of the concept of CDA, it would be all too easy to get carried away with one's own beliefs and ideas, and, in any case, we are engineers, without any biological training. Normally, engineering design is based on known applied principles, but, in this instance, we found ourselves establishing principles upon which to base our design. Our work on conventional spraying equipment was of little help and we are, therefore, indebted to the WRO and Mr. E. Bals for the invaluable information and assistance afforded us during our development programme.

Once having established certain parameters within which to work, we decided at an early stage to enlist the help of A.D.A.S. and the major chemical companies to carry out a series of trials to investigate the efficacy of chemicals applied by CDA and to observe the mechanical performance of prototype equipment.

METHOD AND MATERIALS

There is a great temptation to think first about the potential advantages of a complete machine, such as its work capacity, without considering what is required biologically. With CDA an accurate distribution pattern is the first priority. We see as the prime objective the distribution of the active ingredient on the target and not necessarily the amount of wetted area of spray cover. Naturally, there is a minimum area of wetting required from spray deposits and this is one reason why we sought the help of the A.R.C. Weed Research Organisation. On their advice, we decided on an optimum volume rate of 20 l/ha and we achieved this at a forward speed of 8 km/h.

The field trials programme formed two different groups based on the use of either

i. Pedestrian equipment with a 1.25 m swath width <u>or</u>

ii. Landrover mounted equipment with a 5 m swath width

The pedestrian equipment was supplied as a trials kit which enabled the various agronomic teams to carry out small plot treatments to observe biological reactions. An added bonus to this scheme was of course to enable them to gain first hand experience of the CDA technique.

In total, eighteen such kits were made available and distributed as follows:

i. Thirteen to chemical companies and manufacturers

ii. Four to A.D.A.S. regions

iii. One to the British Sugar Corporation

The information we wished to obtain was:

i. The biological comparison between 20 l/ha CDA and 225 l/ha applied in a conventional manner.

ii. Were existing chemicals as effective through CDA as conventionally applied materials, without the need for re-formulation?

Although all results are not yet available, there is sufficient evidence to suggest that CDA compares favourably in most cases.

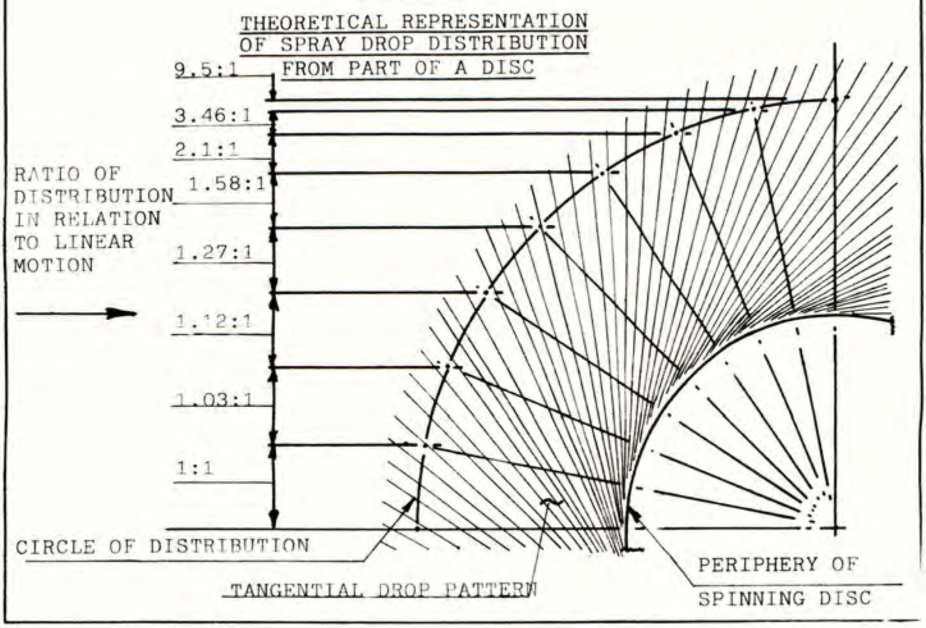
Our Landrover mounted machine, operated by our own staff, has completed some 53 trials to date, 21 in 1975 and 32 in 1976, the majority of which involved supervision by chemical companies and official research workers. The two seasons we have spanned have not been ideal, as we have experienced extremes in climatic conditions.

It is therefore likely that we shall continue our trials programme into 1977 with the hope that further developments with more data will be forthcoming.

Whilst the mechanical aspects of these trials proved successful, inevitably, variations in biological performance occurred in some instances. These variations we understand are not unknown in conventional spraying, which suggests that to produce a drop of a given size is not enough and this has led us to study very carefully the boom width and vehicle stability, accurate forward speed control and calibration. Any thoughts on simple inexpensive equipment must be abandoned as performance suffers with such economies. Efficient, reliable CDA machinery may perhaps cost marginally more than equipment of equivalent boom widths, but the 'built-in' advantages of CDA should certainly justify this expense.

DESIGN PARAMETERS

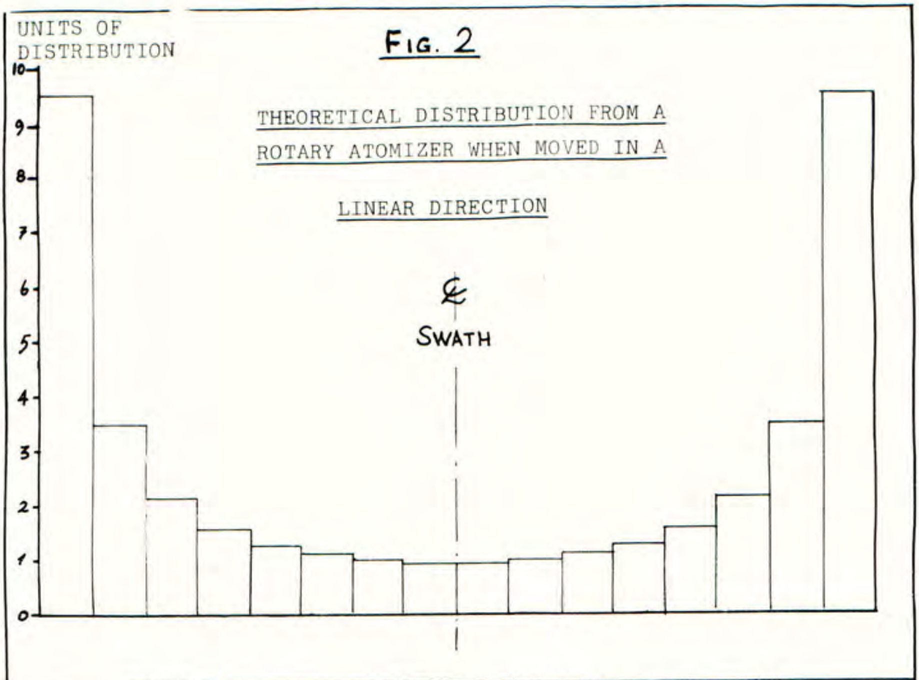
FIG. 1.



From the diagram (Fig. 1), it will be seen that the theoretical circular distribution pattern from a rotating disc results in a 9.5:1 error, which, if ignored or overlapped either within or between swaths is quite unaccaptable. If the drops are controlled to equal size, they will travel the same distance and therefore conform to theoretical patterns. To produce a wide spectrum of drop sizes may, of course, improve distribution, but as smaller drops fall towards the centre of the pattern, the overall distribution of random drop sizes would be far from the norm required, and the risk of evaporation and drift would also be increased.

Having initially captured and measured sample drops, it is then essential to prove their consistency in size by producing the theoretical pattern for Fig. 2. This shows the peaks which form on the outer edges of the pattern and illustrates the inaccuracies which have to be corrected. The actual distribution pattern obtained (see Fig. 3) confirmed the consistency in uniformity of the drops produced.

FIG. 2


UNITS OF DISTRIBUTION
THEORETICAL DISTRIBUTION FROM A ROTARY ATOMIZER WHEN MOVED IN A LINEAR DIRECTION
℄ SWATH
10
9
8
7
6
5
4
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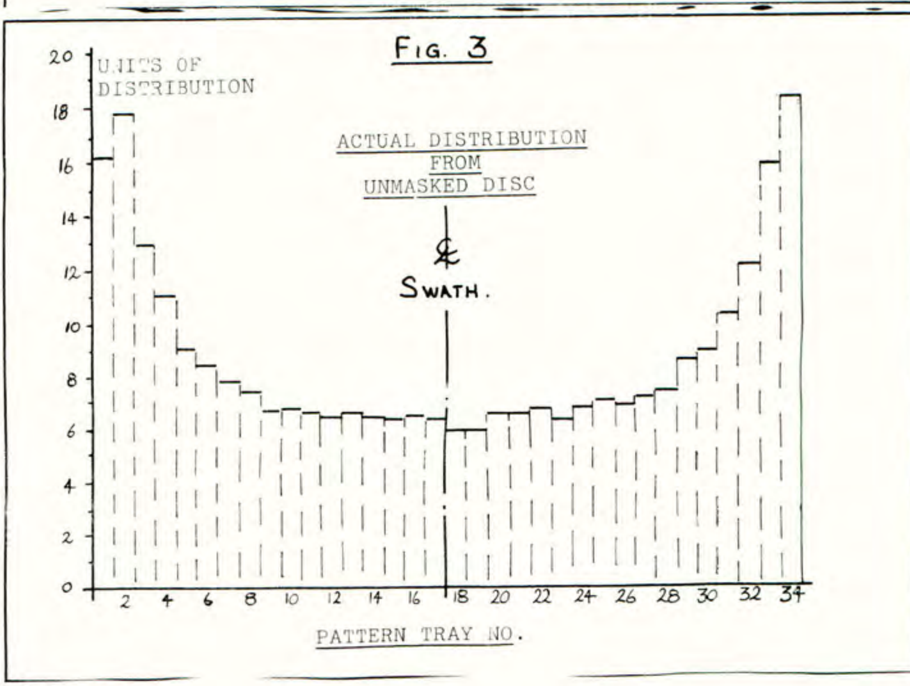
0

FIG. 3


UNITS OF DISTRIBUTION
ACTUAL DISTRIBUTION FROM UNMASKED DISC
℄ SWATH.
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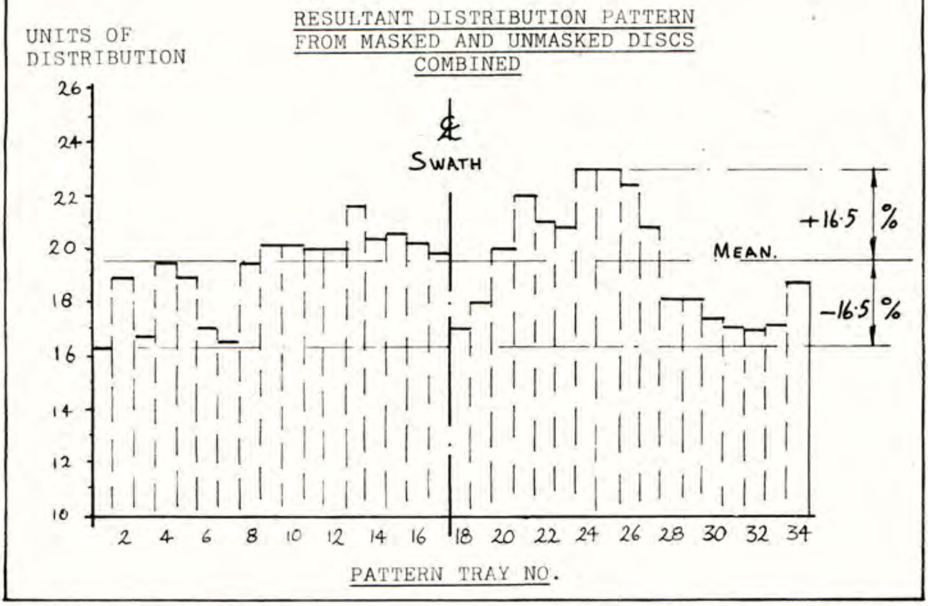
2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34
PATTERN TRAY NO.

Pattern correction is effected by the development of a masking technique which restricts the emmittance of drops to specific areas, and thereby enables us to produce a uniform lateral distribution (Fig 4) with errors of +/- 16.5% over troughs 3.3 cm across. Latest developments have produced improved performances with errors of +/-10% but we would expect the former figures to be more representative of those obtained in field conditions. The improved performance is achieved by feeding two masked upper discs, with the captured drops being fed onto an exposed third lower disc to complete a 'total spray-loss system'.

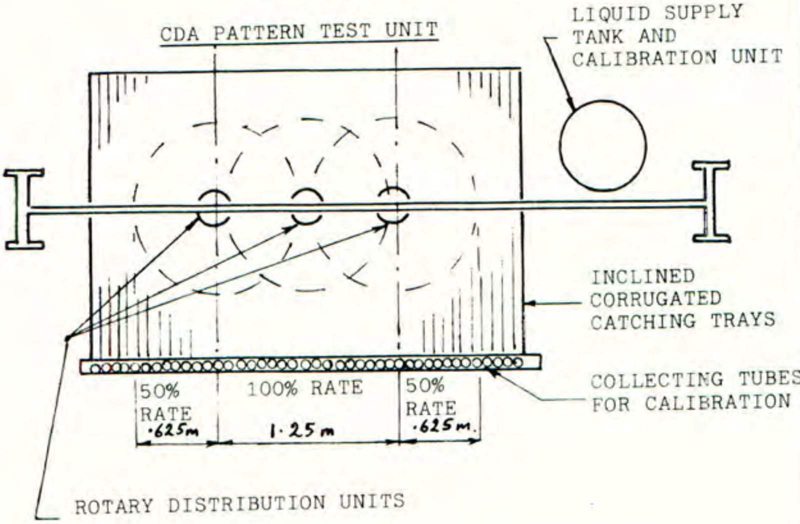
FIG. 4



The equipment used to determine distribution pattern is illustrated by Fig. 5. One to three rotary distribution units are placed in line over a series of corrugations and the liquid deposited is then collected in individual test tubes. This then gives us an immediate visual indication of the resultant pattern. Accurate weighing of the individual tubes establishes the percentage of error. Because we always set ourselves a target of the ideal pattern, the nearer we come to achieving that, the more accurate will the resultant distribution be in the field. Again, it is the controlling of drop sizes that enables the prediction to be achieved. For instance, if, as in conventional spraying, drop sizes were to vary up to 1000 μm, then the 14 drops/cm^2 obtained at 20 l/ha with 300 μm drops would be reduced to 1 drop/2.65cm^2 Add to this the losses incurred by drift and evaporation with small drops, and one can see how volumes as low as 20 l/ha can be applied in a favourable way to 225 l/ha conventionally sprayed.

Calibration and disc feeding have occupied a great deal of our time during the two years we have been working with CDA. Whilst our search for a pulse free, positive displacement metering system continues we have yet to improve upon our low-pressure continuous flow system,

FIG. 5



which has proved accurate within +/- 2%. It may however be criticised for being somewhat superficially involved, but completely inexperienced members of our own staff have operated it after very little instruction.

The final design specification depends mainly on a satisfactory conclusion to discussions already initiated with various safety and approval authorities, the outcome of which we trust will confirm our long held beliefs in the increased safety of the CDA technique. Time and caution have excluded so far any toxic materials from our trials programmes, but we may include such materials in next year's trials.

BIOLOGICAL ASSESSMENT

In a similar manner to other chemical companies, Union Carbide UK Limited loaned a CDA kit. Thus their own impartial evaluation was made in a series of trials during 1976 using commercial formulations of those growth regulators extensively used for the production of cereals. These included : mecoprop alone, and the following mixtures: dichlorprop/MCPA, mecoprop/2,4D and dicamba/mecoprop/MCPA.

Five trials were conducted on winter wheat, comparing identical rates of active ingredient applied at volume rates of 20 l/ha and 314 l/ha respectively. Each trial was laid down in a randomized block design, using a plot size of 2.50m x 15m.

Weed counts were made eight weeks after spraying, using ten quadrats of 0.5m^2 per plot. At the same time, percentage ground cover by weeds in each plot was assessed. The results are presented in the attached table (Fig. 6).

Site	Weed Species present	Treatment	Rt. of Use of A.I. kg/a.e/ha	Average no. of weeds present per 0.5 m. sq. 8 weeks after spraying			% ground cover by weeds		
				CDA 20 1/ha	Higher Volume 312 1/ha	Control (Untreated)	CDA 20 1/ha	Higher Volume 312 1/ha	Control (Untreated)
Thetford (Norfolk)	Stellaria spp Veronica spp	DICAMBA MECOPROP MCPA	0.08 0.80 0.88	7.9	6.1	19.8	5.2	4.6	35.6
Weston Colville (Cambs)	Galium spp Veronica spp	MECOPROP	2.70	5.9	5.1	10.1	11.3	7.8	30.6
Necton (Norfolk)	Stellaria spp Veronica spp	2,4D MCPA	1.96 0.84	7.4	6.8	14.6	9.0	9.0	85.0
Long Stratton (Norfolk)	Stellaria spp Cirsium spp Tripleuro-spermum spp	MECOPROP 2,4D	2.80 0.70	7.2	6.0	16.7	7.3	5.0	85.0
Holme (Cambs)	Papaver spp Urtica spp Tripleuro-spermum spp Stellaris spp	DICAMBA MECOPROP MCPA	0.08 0.80 0.88	3.9	4.4	8.2	2.0	5.0	10.0

Overall means:	CDA at 20 1/ha	Higher volume at 312 1/ha	Control (untreated)
No. of weeds:	6.5	5.8	13.9
% ground cover:	7.0	6.3	49.2

Fig.6

In four out of five trials, the CDA technique gave results marginally inferior to those produced by high volume spraying, perhaps due to decreased crop penetration. At Holme, using a dicamba/mecoprop/MCPA mixture, the CDA treatment performed slightly better. At Long Stratton using mecoprop/2,4D mixture, the CDA technique produced crop scorch three days after spraying which disappeared completely within a further two days. These initial results are particularly encouraging and justify continued technical development.

Further biological results may well be made available by individual chemical companies and researchers.

DISCUSSION

The practical experience and knowledge accumulated over the past two years leads us to believe that there are a set of standards to be attained by the machinery manufacturer and our opinions, as engineers, are as follows:

1. 20 l/ha is a volume which offers commercially acceptable results with a range of products.

2. Drops should be 250 - 300 µm in diameter, not only to ensure reliable weed control but both to minimise the occurrence of drift and to increase operator safety.

3. Forward speed should not be in excess of 8 km/h

4. Uniform drop production is essential.

5. Accurate calibration of spray liquid and forward speed control is necessary both within and between the spray units.

6. Boom widths and performance are of paramount importance and require special design features (A 10 or 12 metre boom has already proved viable).

7. The inherently poor pattern produced by exposed discs must be corrected as CDA cannot tolerate the same discrepancies as conventional sprayers.

8. CDA is already commercially acceptable over a wide range of chemicals, although certain contact herbicides need further exploration.

9. Using herbicides of the growth regulator type, safety to the operator is probably increased.

10. Future trials will be concentrated on vehicle mounted equipment.

Finally, assuming that CDA will eventually be used commercially, by the farmer, a question would seem to be posed. If, as would appear from our trials, some chemicals are more adaptable to CDA than others, will the farmer's choice be effected by their suitability for the application rather than for the crop? This may well be so, and therefore, a close liaison between all concerned is essential, to avoid the exclusion of desirable compounds.

THE APPLICATION OF SOME CEREAL HERBICIDES BY CONTROLLED DROP APPLICATOR

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Summary The control of either broad-leaved weeds or *Avena* spp. by a controlled drop applicator (CDA) was examined in five trials, one of which was on Winter Wheat and four on Spring Barley. Spray liquid volumes of 10, 20 and 40 l/ha were applied with the controlled drop applicator and, for comparison, 225 l/ha with a conventional fan-jet sprayer. The recommended dose of one proprietary herbicide was applied at each site. Although the control of weeds by the CDA was reduced midway between the spray swaths, results suggest that the CDA unit at 10 l/ha produced weed control comparable with the fan-jet sprayer. At 20 and 40 l/ha weed control was less good. Sample harvesting showed that the higher yields and better barley seed grading was obtained with the CDA at 10 l/ha and the fan-jet sprayer at 225 l/ha, when compared with the CDA at both 20 and 40 l/ha.

INTRODUCTION

The mean diameter of drop produced by a conventional fan-jet sprayer can be altered by using differing nozzle orrifices or altering pressure but a wide range of drop sizes is always produced. Spinning discs may have a possible advantage as drop formation can be better controlled. Another potential advantage of controlled drop application (CDA) is that total amount of spray liquid used for application may be as low as 5 l/ha whereas conventional systems normally use 225 l/ha. It is necessary to identify the least volume of water which can be used without reducing the performance of the herbicide. Controlled drop applicators are produced by Horstine Farmery Ltd., using spinning discs from Micron Sprayers Ltd. and was loaned as the 'Micro drop' kit for small-plot trial purposes. This equipment was used in five trials, four of which were on Spring Barley and one on Winter Wheat for the control of *Avena* spp. and annual broad-leaved weeds.

METHODS AND MATERIALS

Trials used only one chemical at each site. The chemical, where possible, was that which was used on the field in order to have most relevance to the commercial crop and was applied at normal doses. Three volumes of spray liquid 10, 20 and 40 l/ha were used for the CDA and 225 l/ha for the fan-jet sprayer at a pressure of 2.1 bars. Treatments were replicated four times.

The 'Micro drop' spray kit was assembled to give a swath width of 2.5 m. The flow rate to each unit was calibrated at 85 ml/min so that the required volumes could be obtained at the following walking speeds.

Volume l/ha	Speed km/hr	Time (s) for 20m plot
10	4.08	17.7
20	2.04	35.4
40	1.02	70.8

RESULTS

Weed counts and sizes were recorded at the time of spraying and four weeks after, (Tables 1 and 2). The plots at Gleadthorpe Experimental Husbandry Farm were cut with a combine harvester to make yield comparisons on the crop. The sites at Bardney and Thorpe were sample harvested by hand, (Table 3).

Table 1

Site Details

Location	Crop	Variety	Weeds	Herbicide	Dose Kg ai/ha	Product	Dose l/ha
Bardney Lincs	Winter Wheat	Maris Huntsman	*Avena* spp	benzoylprop-ethyl	1.12	Suffix	5.61
Glead-thorpe EHF	Spring Barley	Lofa Abed	*Chenopodium album* *Polygonum aviculare* *Spergula arvensis*	bromoxynil +ioxynil +dichlorprop	0.77	Oxytril P	1.41
Thorpe Notts	Spring Barley	Mazurka	*Avena* spp	difenzoquat	1.00	Avenge 620	1.6 kg
Nocton Lincs	Spring Barley	Maris Mink	*Polygonum persicaria* *Stellaria media* *Fumaria officinalis*	dichlorprop +2,4-Damine	2.75	Curbisol	5.51
Navenby Lincs	Spring Barley	Proctor	*Veronica* spp *Polygonum convolvulus* *Stellaria media* *Aphanes arvensis*	MCPA+ 2,4-D ester	1.24+ 0.23	Chafer MCPA+ Isoplanotox	5.51+ 0.351

Table 2

Weed Control Assessments

Location	At Spraying Date	Crop Stage	Weed Stage	Assessments as weeds/m^2 %(control in brackets) Date	Volume of Application l/ha 10	20	40	225	Untreated
Bardney Lincs	14/5	31	2-3 tillers	20/6	1.4	4.0	3.6	0	23.4
					(94)	(83)	(85)	(100)	
Glead-thorpe EHF	30/4	21	Cot-4 leaf	27/5	14	24.8	36.6	6.8	122.4
			Cot-2 leaf		8.6	15.8	7.2	11.2	15.6
			<5cm high		1.8	2.8	4.6	1.6	10.4
				Total	24.4	46.2	48.4	19.6	148.4
					(84)	(69)	(67)	(97)	
Thorpe Notts	7/5	26	2-3 leaves	8/7	9.8	19	40	6.6	52.2
					(81)	(64)	(24)	(87)	
	Corrected for lack of control in plot centres				3.2	6.6	11.4		
					(94)	(87)	(78)		
Nocton Lincs	15/5	26	2 leaves	3/6	10	14.8	22.8	8.8	32
			<10cm high		10.4	12.4	20	8	28.8
			<5cm high		3.2	13.6	6.8	3.6	4
				Total	23.6	40.8	49.6	20.4	64.8
					(64)	(37)	(24)	(69)	
Navenby Lincs	18/5	26	3-5cm high	18/5					
				Total	24.4	14.4	26.4	13.6	22.6
					(0)	(37)	(0)	(40)	

Weeds are listed in the same order as in Table 1.

DISCUSSION

The main problem with the controlled drop applicator as used as the trials kit was that the two units did not produce a uniform spray pattern across the swath. The effect of this was particularly noticeable on the *Avena* trials where an uncontrolled strip was seen along the centre of each plot. It was assumed that either the setting of the two discs was too wide or that the swath produced by each unit was too narrow. Since the calibration of the machine was based on a 2.5m swath being sprayed more spray liquid than was predicted would have been used, making biological comparisons difficult to assess. There was also difficulty in reliably calibrating the flow of spray liquid to the units.

Table 3

Effect on Crop Yield and Quality

Location	Crop	Assessment	Volume of Application - l/ha 10	20	40	225	Untreated
Bardney Lincs	Winter Wheat	Yield t/ha	7.73	7.13	7.21	7.48	6.85
		Specific Wt kg/hl	76.5	76.5	76.5	76.5	76.5
		1000 Grain wt - g	48.5	48.5	48.0	48.5	48.0
		Grading-mm					
		>2.8 - %	83.5	82.0	83.5	82.4	83.1
		2.0-2.8 - %	10.9	11.5	10.6	12.2	10.1
		<2.0 - %	5.6	6.5	5.9	5.4	6.8
Thorpe Lincs	Spring Barley	Yield t/ha	2.17	1.96	1.85	2.15	1.62
		Specific Wt kg/hl	67.0	66.5	67.5	67.5	65.5
		1000 Grain wt - g	38.0	36.4	34.0	36.8	33.2
		Grading-mm					
		>2.8 - %	13.6	9.1	9.9	15.0	7.7
		2.2-2.8 - %	64.4	56.7	59.1	62.3	52.1
		<2.2 - %	22.0	34.2	31.0	22.7	40.2
Gleadthorpe EHF	Spring Barley	Yield t/ha	2.08	2.12	2.28	2.11	2.21

Despite the mechanical limitations, the results suggest that the fan-jet sprayer produced a higher control of both annual broad-leaved weeds and *Avena* spp. when compared with the CDA at 20 and 40 l/ha but the CDA at 10 l/ha produced comparable results. Thus the efficiency of the CDA decreased as water volume increased. On the difenzoquat trial at Thorpe, when allowance was made for the poor control in the plot centre, the CDA at 10 l/ha produced 94% control of *Avena* spp. compared with CDA at 20 l/ha and fan-jet sprayer 87% control and CDA at 40 l/ha giving 78% control when assessing plant numbers.

Poor results were obtained at Navenby; this was attributed to insufficient spray reaching the weeds through the laid crop which had severe mildew. During the season the prominant weed species on the plots changed; *Veronica* spp., *Aphanes arvensis* and *Stellaria media* comprised the weed population at spraying whilst *Polygonum convolvulus* and *Viola arvensis* dominated later.

The figures for crop yield are only comparative due to the small sample sizes. At Bardney and Thorpe the highest yields were produced on the CDA at 10 l/ha and fan-jet sprayer plots, with lower yields on CDA at 20 and 40 l/ha; the untreated plots were even lower.

The specific weights of the crop samples varied little. Furthermore, there was little variation in the 1,000 grain weights or size-grading of the wheat at Bardney. However the barley from Thorpe showed higher 1,000 grain weights for the CDA at 10 l/ha and fan-jet sprayer plots with lowest value from the untreated plots. From the grading data, CDA at 10 l/ha and the fan-jet sprayer both had higher proportions of large grain and less below 2.2mm. The untreated plots had less large grains and more below 2.2mm. The barley at Gleadthorpe produced the highest yield on the CDA at 40 l/ha plots. The fan-jet sprayer plots and CDA at both 10 and 20 l/ha gave lower yields, with the untreated plot slightly above these.

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Proceedings 1976 British Crop Protection Conference - Weeds

THE RESULTS OF A CONTROLLED DROP APPLICATION TECHNIQUE FOR HERBICIDES IN CEREALS

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Summary Normal dosage rates of post-emergence herbicides were sprayed at very low volumes (10, 20 and 40l/ha), using a Controlled Drop Application method, on wild oats and broad-leaved weeds in winter wheat and spring barley. The herbicides used were:- mecoprop, MCPA, dicamba with mecoprop and MCPA, ioxynil with mecoprop, barban, difenzoquat and flamprop-methyl. The result of each treatment was compared with spraying the same dosage rate at a conventional volume, viz 225 l/ha. The low volume rate (10 l/ha) consistently produced very poor results. The application of 20 and 40 l/ha sometimes resulted in a good level of weed control but, in general, the conventional spraying volume gave a more consistent and reliable control of both wild oats and broad-leaved weeds.

INTRODUCTION

The application of agricultural chemicals at very low volume (VLV, 5-55 l/ha) and ultra low volume (ULV, below 5 l/ha) has received a certain amount of attention from research workers during recent years. There are several logistic advantages to be gained from such a technique.

Firstly, conventional spraying requires that a good deal of time be used for filling up tanks and transporting large volumes of water to the field where it is to be applied. Very low volume spraying would require less water, and the time could be spent more efficiently. Another advantage is that associated with spray-timing. The ideal time for spraying, in terms of crop or weed stage of growth, or pest vulnerability, need not necessarily coincide with the soil being fit for the passage of heavy spraying vehicles. Spraying under these conditions could then damage the soil whilst a delay may result in a mis-timed spray application. Very low volume spraying, however may require only a light spraying vehicle which could be capable of travelling over the land without causing damage to soil structure, over a much wider range of soil conditions. Thus, chemical applications may be more correctly timed, which could in turn result in better weed or pest control and less crop damage. (Tottman and Phillipson, 1974; Evans, 1974).

Very low volume spraying does require, however, that none of the spray be wasted in the form of large drops which may run off the target or small drops which drift from the target; a drop of constant size commensurate with the target is required. This has led to the introduction of a new term - CDA (Controlled Drop Application).

CDA is becoming increasingly used to apply systemic insecticides and fungicides (Mass, 1971) and investigations are now under way to determine whether CDA has a role in herbicide application. Field trials with 2, 4 - D ester, barban and tri-allate applied in spray volumes of 5-20 l/ha showed no major loss of effectiveness in weed control when compared with applications in 165 or 200 l/ha from a conventional sprayer (Taylor and Merritt, 1974). The present work was undertaken to determine the relative effectiveness of CDA and conventional spraying volumes as used for post-emergence herbicides in spring and winter cereals under a wide range of conditions.

METHOD AND MATERIALS

The CDA sprayer used was of the rotating disc type, and kindly supplied by Horstine Farmery Ltd. The design of the spray forming units is described by Farmery (1975). Two such units were used mounted on a boom carried by two men. A spray swath of 2.50 metres was produced. The machine was designed to produce a constant drop size of 200-300 µm in diameter.

The field trials were established on nine sites, at 6 of which two chemicals were tested, whilst a single chemical was tested on sites no. 7, 8 and 9. Each experiment was laid down with a randomised block design, there being four replicates per trial. Each chemical was sprayed at 4 volumes:- 10, 20 and 40 l/ha with the CDA sprayer and 225 l/ha with the conventional hydraulic nozzle sprayer. The CDA rate was obtained by adjusting walking speed. Also included in each replicate were two unsprayed plots, from which the level of weed infestation was calculated. The individual plot size was 15 metres by 2.5 metres.

The efficiency of the spray application, in the case of broad-leaved weed herbicides, was obtained by estimating the number of weeds present at the beginning of June. The trials were visited again 6 weeks later, by which time natural mortality, partly as a result of suppression by the crop, would be complete.

In the case of wild oat herbicides, the panicles growing in a given area were harvested and subsequently counted, after classification as small, medium or large.

The herbicides selected were translocated herbicides except in one instance where a contact herbicide, ioxynil, was used in a mixture. The complete list is as follows:- mecoprop, MCPA, dicamba with mecoprop and MCPA, ioxynil with mecoprop, barban (23.5% formulation), difenzoquat (62% s.p. formulation, with 0.5% wetter), flamprop-methyl.

RESULTS

(a) Broad leaved weeds in winter wheat and spring barley

The numbers of broad-leaved weeds remaining after each treatment were expressed as a percentage of the number in the unsprayed plots. The difference between this figure and 100 will represent the percentage control of broad-leaved weeds obtained by each treatment. The data are presented in Table I. Some weed species are resistant to particular chemicals and it was felt inadvisable to include these in the counts. Therefore, only those species which are generally considered to be susceptible to a particular herbicide are included in the results for that herbicide, as indicated in the Table.

Table 1

Percentage control of broad-leaved weeds with CDA and conventional volume spraying

Site	Crop	Herbicide	Date of application	Main weed species present	Weed numbers present in unsprayed plots/m^2	Percentage control at each volume of application 10 l/ha	20 l/ha	40 l/ha	225 l/ha
1	Winter Wheat	Mecoprop	28/4	*Galium aparine*	13	51.7	64.9	31.7	82.9
2			29/4	*G. aparine* and *Sinapsis arvensis*	69	90.3	96.5	98.1	98.6
1		Dicamba with mecoprop and MCPA	28/4	*G. aparine*	14	32.7	23.4	44.9	57.0
2			29/4	*G. aparine* and *S. arvensis*	70	88.6	94.4	93.0	94.6
3			5/5	*G. aparine*, *Polygonum aviculare* and *Polygonum convolvulus*	147	55.7	55.9	65.8	86.4
3		ioxynil with mecoprop	5/5	*G. aparine*. *P. aviculare*, *P. convolvulus* and *Veronica* spp	250	65.9	54.9	72.7	89.0
4	Spring Barley	MCPA	23/4	*S. arvensis*	22	88.3	95.6	98.1	100.0
5		Dicamba with mecoprop and MCPA	6/5	*P. aviculare* and *P. convolvulus*	192	55.3	54.6	58.9	83.4
4				*S. arvensis* and *P. colvolvulus*	43	78.5	83.6	84.8	93.4

It can be seen that in 6 out of 9 trials, the conventional spraying technique gave a much better control of broad-leaved weeds than did the CDA sprayer at each volume. In the remaining 3 instances, there was little difference between conventional spraying and CDA spraying at 20 or 40 l/ha, but CDA at 10 l/ha gave a reduced level of control. Thus under the conditions of these trials, it appears that conventional spraying of broad-leaved weeds in cereals was better than spraying with the CDA sprayer.

(b) Wild Oat Control in Cereals

Direct comparison of the number of panicles of wild oats surviving after each treatment was felt to be inadequate, as no account would be taken of a treatment that greatly reduced panicle size without killing the plant. Therefore, to obtain a more accurate measure of the effectiveness of each herbicide, the panicles were removed and sorted into 3 groups:- small ($<$ 10 seeds/panicle), medium (10-30 seeds/panicle), and large ($>$ 30 seeds/panicle). The panicles were counted, and an assessment of spikelet production made. The results are presented in Table 2.

Table 2

Percentage control of *Avena* spp. with CDA and conventional volume spraying

Site Number	Crop	Herbicide	Date of application	Growth stage of *Avena*	Panicle numbers present in un-sprayed plots m/2	Percentage control at each volume of application 10 l/ha	20 l/ha	40 l/ha	225 l/ha
6	Winter Wheat	Difenzoquat	6/5 (10 l and conventional) 7/5 (20 l and 40 l)	4	18	48.7	69.5	98.0	98.2
7			18/5	6	10	Nil	50.6	76.8	87.0
6		Flamprop-methyl	6/5	4	18	93.1	83.6	92.1	100.0
8			17/5	6	7	56.5	52.0	76.4	74.9
9	Spring Barley	Difenzoquat	7/5	3	21	29.4	96.5	66.9	100.0
9		Barban	7/5	3	21	Nil	Nil	51.0	75.1

It will be observed that the results form a similar pattern to those obtained with the broad-leaved weeds. In 3 trials out of 6, the conventional spray volumes gave markedly better control of wild oats than all CDA volumes. Of the remaining instances the CDA at 40 l/ha produced equivalent control twice, and the CDA at 20 l/ha produced equivalent control once. Therefore, the conventional spraying volume would appear to give the better result.

A convenient method of summarising the above results is to compare the total number of occasions on which each treatment was found to give a moderate level of control, eg 75%. This data is provided in Table 3, along with similar comparisons at better levels of control up to and including 100%.

Table 3

The number of trials in which a particular level of weed control was obtained by each treatment

Level of control obtained	volume of application 10 l/ha	20 l/ha	40 l/ha	225 l/ha
75%	5	6	8	13
90%	2	4	5	7
98%	Nil	Nil	3	5
100%	Nil	Nil	Nil	3

It becomes apparent that in these trials herbicides sprayed at the conventional volume provide a more effective control of weed species than the same herbicides sprayed at lower volumes.

DISCUSSION

The purpose of the investigation was to determine whether a reduction in volume of diluent applied with a herbicide led to any decrease in weed control in cereals. The CDA technique, as adopted for the present work, demonstrated a marked loss of herbicidal activity. This would appear to be a general effect throughout the list of herbicides investigated, and not confined to one particular chemical.

A previous paper (Taylor and Merritt, 1974) reported what initially appears to be a somewhat different result. Their results showed that a CDA technique may give an increased level of weed control compared with conventional volume spraying. This difference is not due to a difference in the chemicals chosen for investigation, as one herbicide (barban) although of a different formulation, was common to that investigation and the present work. However, in the experiments reported here, the dosage rate chosen for comparison was that recommended by the manufacturers for conventional volume spraying, whereas in the previous work, lower doses were sometimes used so as to allow slight differences in effectiveness of weed control to become apparent. Hence the levels of weed control obtained were generally lower than those obtained in farm practice. The dosage rates recommended by herbicide manufacturers are chosen partly because they are the rates found to give good weed control at conventional spraying volumes. It may be that both rate and formulation would require adjustment if the volume applied were substantially different from the approved use. However comparison of CDA with conventional volume spraying requires that in these trials the conventional volume treatment be applied at a recommended rate, not a reduced rate. If CDA techniques are to be adopted on a wide scale, they must be proven to be capable of achieving a level of weed control equivalent to that obtained by conventional spraying at recommended rates.

The present results indicate that the CDA technique adopted here for trial work was not capable of producing a satisfactory level of weed control. It must be borne in mind, however, that this does not necessarily reflect upon the principle of CDA for herbicides in general. It is possible that the average size and distribution of drops obtained with the present sprayer was not ideal for the herbicides examined, and it may be that a slight alteration in these will produce markedly improved results. The present results show an increased level of weed control with increasing volume of CDA, ie greatest control obtained with 40 l/ha and least with 10 l/ha. The fact that this trend is not borne out by the result from other ADAS regions (reported in this session) may indicate that the applications used, although of similar design, are capable of functioning differently and providing a different drop size and distribution.

Acknowledgements

The machine sprayer used for the present work was kindly supplied by Horstine Farmery Ltd.

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FIELD TRIALS COMPARING THE BIOLOGICAL EFFECTIVENESS OF 'CONTROLLED DROP APPLICATION' WITH CONVENTIONAL HYDRAULIC PRESSURE SPRAYING

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Summary Two seasons work is described in which controlled drop application at volume rates from 15 to 40 l/ha was compared to conventional hydraulic spraying at 225 l/ha for the application of herbicides to cereal crops. The results have been generally promising but in a number of cases considerable variation between different controlled drop application volume rates occurred which might be related to equipment design. Results with a later design of equipment were generally less variable but the number of trials carried out and the many variables involved, prevent firm conclusions being drawn; rather should these results be considered along with those of other workers. The need for resolving the equipment factor and for further co-ordinated nationwide trials is proposed.

Resumé Le travail de deux saisons est décrit au cours duquel CDA à des taux volumiques de 15 à 40 l/ha a été comparé à l'épandage hydraulique classique 225 l/ha pour l'application d'herbicides sur des céréales. Les résultats se sont révélés prometteurs d'une manière générale mais dans un certain nombre de cas se sont produites des variations entre différents taux volumiques de CDA susceptibles d'être dues à la conception de l'équipement. Des résultats obtenus avec emploi d'un type d'équipement plus récent se sont avérés généralement moins variables mais le nombre des essais effectués et les nombreuses variables entrant en jeu empêchent de tirer des conclusions nettes. Il est préférable de considérer ces résultats avec ceux des autres chercheurs. Proposition est faite concernant la résolution du facteur équipement et d'autres essais coordonnés et effectués à l'échelle nationale.

INTRODUCTION

Arising from the use of rotary atomisers for ultra low volume (5 l/ha) application of pesticides to control, for example, locusts, mosquitoes and pests of cotton (Bals 1973 and 1975) there has been much recent interest in the possibility of using this technique, suitably modified, for the application of herbicides in the U.K. farming context. The main advantages of the system compared with conventional hydraulic spraying, as postulated in recent papers (Bals, 1975; Taylor and Merritt, 1975; Farmery, 1975) are, a) more even deposition of chemical on to the weeds, b) reduced susceptibility to drift and c) much reduced water requirement (15 cf. 225 l/ha). These advantages, if substantiated by field experience, would lead to much more effective and economic use of herbicides. Accordingly, a programme of field trials was commenced at Lenton Research Station in 1975 using prototype 'microdrop' equipment designed and loaned by Horstine Farmery Limited.

METHOD AND MATERIALS

All the work reported was carried out using Land Rover mounted Horstine Farmery prototype equipment as referred to by Farmery (1975) and again mentioned by Farmery et al (1976). The basic unit comprises either two or three 8cm diameter plastic discs mounted on the same vertical spindle, and partially enclosed in a cylindrical sheet metal housing.

Chemical, fed on to the upper disc whilst the spindle is rotating at 1,800 rev/min is distributed in a 1.25 m diameter ring pattern of even sized (200-250 µm) drops. Ten such units, each driven by an individual electric motor and spaced so that their spray patterns doubly overlap, are mounted on a frame attached to the rear of a Land Rover, giving a total spray swath of approximately 5 m.

In the earlier double disc version the spray liquid is fed at 80 ml/min on to the upper rotary disc, which is partly masked to compensate for the inherent discrepancy in distribution that arises when an annular spray deposit is moved forward. The non-emitted liquid is collected on to a lower unmasked disc, the distribution discrepancy of which is also compensated in the masking of the upper disc. In the later triple disc version the chemical is fed individually at 80 ml/min on to each of the two upper masked discs, the non-emitted liquid being collected on to an unmasked lower disc. Both types of unit can be calibrated to the same output in terms of litres per hectare by varying forward speed, the triple disc units by virtue of x 2 flow rate (i.e. 160 ml/min) being capable of performing at higher and more practical speeds.

In 1975, all work was carried out using the double disc units at a volume rate of 15 l/ha. In 1976, the first four trials were carried out with the same double disc units that were used in 1975, these being replaced later in the season by triple disc units when they became available. It was not anticipated by Horstine Farmery that the field performance of the two types would differ and consequently no provision for their comparison was made in the collaborative programme. In both years, the units were fitted to the same Horstine Farmery Land Rover.

In the 1976 trials with the double disc units the following volume rates were compared 15, 20, 25 and 30 l/ha. It had been planned to test 40 l/ha but it was not possible for the Land Rover to travel at the slow speed necessary to achieve this volume. With the availability of the triple disc units it became possible to fulfil the planned comparison between 15, 20, 30 and 40 l/ha in the remaining three trials that were carried out. Climatic vagaries prevented the execution of the much larger number of trials planned with these units.

The hydraulic sprayer used for comparative purposes at all sites except Oxton 1975, was an Evers and Wall Land Rover mounted sprayer fitted with Lurmark F80 30 fan nozzles calibrated to an output of 225 l/ha and 2 bars pressure with boom width of 9 m. In the exceptional case, a Dorman sprayer fitted with cone nozzles also calibrated to 225 l/ha and 2 bars was used.

Plot size varied between trials from 500 to 1,200 m^2. Treatments were replicated and 1 m discards left between plots to monitor weed distribution and weed reaction to environmental factors across the trial.

All trials reported were carried out using normal production formulations of the following active ingredients at dosage rates indicated in Tables 1 and 2: mecoprop 64% potassium salt; dichlorprop + MCPA 54% potassium salts; benazolin + dicamba + dichlorprop 42% potassium salts; 3,6-dichloropicolinic acid + dichlorprop + MCPA 51% potassium salts and difenzoquat 62% methyl sulphate salt.

Results were recorded in three ways. In the 1975 trials visual scores only were made. In the 1976 series, visual scores of broad-leaved weed control were supported whenever possible by percentage control data based on weight of weeds per unit area. It was planned always to make these measurements at the last assessment before harvest but an early combining season made this impossible in all cases. In the two wild oat trials, the results are presented as percentage control based on counts of panicles per unit area.

RESULTS

1975 Trials (see Table 1)

Early assessment at all sites revealed in areas of thin crop, greater effect on weeds in the CDA than in the conventionally sprayed plots. In areas where crop cover was thicker, though by no means unusually dense, there was evidence of poorer control in the CDA plots. At the two Yorkshire sites severe crop scorch appeared in the CDA plots, probably due to local overdosing through variation in forward speed combined with the severe overnight frost that followed spraying. The conventionally sprayed plots showed only a normal, acceptable level of scorch which occurred also in all plots at Oxton.

Assessments made 33 days after spraying the Yorkshire trials and 41 days in the case of Oxton showed a very good level of control in the conventionally treated plots at Holme Upon Spalding Moor II and Oxton. Control with CDA was only slightly inferior, the difference being due to the survival of the weeds which were seen to be less well controlled at the early assessments. At both sites a combination of hot weather, dry soil and in the case of Oxton, a vigorous competitive crop, resulted in all weeds including those in the control plots, dying off well before harvest.

At Holme Upon Spalding Moor I, the level of control in the conventionally sprayed plots was inferior to that at the other sites, the CDA results being still poorer. In this trial on organic carr type soil, the vigorously growing *Polygonum persicaria* remained until harvest, the final result showing an unacceptable level of control in the CDA plots with moderate control following the conventional treatment. Once the early crop scorch became outgrown no adverse symptoms were to be seen at any of the sites.

The general conclusion drawn from these trials was that CDA appeared to be a promising form of application that could perhaps be improved by an increase in volume rate to improve crop penetration.

1976 Trials (see Table 2)

Of the five trials carried out against broad-leaved weeds, two showed CDA in an unfavourable light while in each of the remaining three trials, at least one CDA treatment achieved a standard of weed control equal to that of the conventional treatment.

At Thoroton, the thin open crop, hard growing *Matricaria recutita* and low temperature conditions combined to provide a very exacting test environment. Assessment approximately one month after spraying showed conventional application of benazolin + dicamba + dichlorprop to have given a degree of control that was barely commercially acceptable, all CDA treatments being much inferior. The latter gradually improved during the following 2-3 weeks but remained inferior to conventional application which did not improve. The final assessment in terms of percentage weed control showed conventional application to have achieved moderate control with no CDA treatment reaching near the commercially acceptable level. No crop effect appeared at any stage in this trial.

The trial at Orston, three miles from the Thoroton site was sprayed on the following day under similar climatic conditions. At this trial the crop had been 'striped' by faulty nitrogen application which resulted in bands of very tall, thick crop, alternating with shorter, thinner crop. This feature had not been visible at the time the site had been selected and so plots were orientated to be sprayed across the banding. Mecoprop at the rate used would normally have given good control of the large Stellaria media plants but under the adverse conditions prevailing, gave a barely acceptable level of control applied conventionally and was always inferior by CDA. It was noticeable that in the taller, denser crop of the high nitrogen bands, weed control in all CDA plots was always much inferior to that in the areas of shorter, thinner but still competitive crop. No adverse crop effects due to herbicide treatment occurred at this site.

The three sites at which CDA gave favourable results differed greatly one from the other. The trial at Holme Upon Spalding Moor was adjacent to the site numbered I in the 1975 series and was situated on the same carr type soil. The crop was short, of moderate to poor stand at the time of spraying and by harvest had reached a height of only 50-60 cm. The predominant weed, Polygonum persicaria, was both dense and vigorous at the time of spraying and well exposed to the herbicide. Assessment eight days after spraying showed that the weed in all plots was reacting equally to treatment. At the last assessment just prior to harvest, CDA at 40 l/ha, was indistinguishable from conventional application. Unfortunately pressure to combine the field precluded the taking of samples for percentage control determination.

The trial at Kneeton was carried out on the same day as that at Thoroton some five miles distant and the weather pattern was similar. The Matricaria recutita was at the same stage as at Thoroton but less dense and the crop was much more even and of fuller stand. Assessment soon after spraying showed good effects against both Matricaria recutita and Stellaria media in conventionally sprayed plots and in parts of the CDA treated areas. The latter tended however to contain small isolated patches where there appeared to be little herbicidal effect. Some six weeks after spraying, control at the 20 l/ha volume rate was equal to that of conventional application but the 15 and 25 l/ha treatments were appreciably inferior and still showed the patchy control observed earlier. Weed sampling and weighing was carried out on 6th June but the technique failed to detect the differences seen and an early harvest season prevented further work on this.

In the trial at Dowsby, the initially thin and patchy crop suffered further from the drought and never thrived. The main weed, Galeopsis tetrahit, also suffered from moisture deficiency and never exceeded 30 cm in height. All treatments achieved full control.

The two trials against wild oats using difenzoquat, gave markedly dissimilar results. In the winter wheat trial at Shelton I, rain after spraying is assumed to have been responsible for the atypically poor control by conventional application. Application of CDA treatments in order of increasing volume commenced very shortly after conventional treatment and were all much inferior to the latter. Since the most effective CDA treatment happened to be the last it would appear that CDA application under the conditions of this trial was more vulnerable to rainfall. In the second wild oat trial carried out almost a month later in spring barley on the same farm, the potentially adverse effect of rain showers occurring intermittently during the course of spraying, appears to have been countered by a drying wind, for the control achieved by conventional application and certain CDA volume rates was of a very high level.

DISCUSSION

The three trials in 1975 showed CDA to be a promising technique and indicated the possible need to increase volume rate above 15 l/ha to improve crop penetration. The seven trials carried out in 1976 have shown no consistent correlation between volume rate and herbicide efficacy. At Thoroton, 15 l/ha was by far the least effective treatment and yet there was certainly no crop penetration problem. At Orston, where there was an obvious crop penetration problem in the high nitrogen bands and no CDA treatment was particularly effective, 15 l/ha was certainly not the worst. At Kneeton where there was no crop penetration problem, 15 l/ha and 25 l/ha treatments were equally and consistently inferior to all other volume rates including 20 l/ha. These strangely anomalous results with no indication of volume response pattern, point to a variable factor in the use or design of the equipment. Since at all trials of the reported 1975 and 1976 series, the driving of the Horstine Farmery Land Rover was by a member of that company's staff, the possibility of operator error is appreciably reduced. It may however, be of significance that at the three sites where these anomalous results occurred, double disc units were used. Of the cases where triple disc units were used it is interesting that the trial at Holme Upon Spalding Moor, conducted under very exacting conditions, showed little difference between CDA volume rates nor between these and conventional application. It may also be of importance that at Dowsby, the other broad-leaved weed site where the triple disc units were used, CDA and conventional application were equally effective. Furthermore, of the two wild oat trials, Shelton I, was conducted with double disc units and Shelton II with the triple disc version. A lower standard of wild oat control at the former site was to be expected since rain fell soon after spraying but there was also the extreme and inexplicable variation in control between the different CDA volume rates - a patternless variation that is reminiscent of the results of the broad-leaved weed trials where the double disc units were used.

The authors appreciate that the number of trials reported here is too small to enable firm conclusions to be reached and the results in this paper must be considered along with those of other workers in this field. Nevertheless, one is prompted to wonder whether in the case of equipment fitted with double disc units, there may be some factor responsible for fluctuation in spray deposit during application of a given volume rate, that masks any real differences between the various volume rates under test. Is this perhaps a factor that has been inadvertently overcome in the triple disc units by the X2 flow rate? Environmental conditions at spraying were also very different for the two types of application and this may well affect both the nature of the target weed and subsequent herbicide performance. Furthermore the skill of the operators can only increase with a new technique and this may well have favoured the triple disc units. The only practical way to be sure of these points is to make critical comparison between double and triple disc units in motion, in the field.

The authors still feel that CDA is a promising technique with considerable potential advantages over conventional spraying. It is important therefore to know whether the variable and unsatisfactory results experienced to date with the double disc units can be overcome by fitting three or even more discs, before further effort is expended in investigating the effects on CDA of factors such as crop competition, growth conditions, weed stage etc. It is also felt that if this technique is to be successfully introduced into British agriculture, all work carried out by interested parties from now on should be co-ordinated into one tightly knit nationwide programme. Only in such a manner can there be any hope of satisfactorily resolving the considerable problems that remain.

Table 1 1975 Trials

Location	Crop and stage	Herbicide g a.i./ha	Date and weather conditions at application	Main weeds and stage	Assessment date	Assessments by scores volume rate, l/ha 15	225
Holme upon Spalding Moor, Yorks. (I)	spring barley 6-7 leaf 30 cm stand variable vigour - fair	dichlorprop + MCPA 3024	30.5.75. Dull, cool. Slight showers 5 & 15 minutes after spraying.	*Polygonum persicaria* yp	4.6.75. 2.7.75.	1-4 5-6	3 7-8
Holme upon Spalding Moor, Yorks. (II)	spring barley 5-6 leaf 20 cm stand variable vigour - poor	dichlorprop + MCPA 3024	30.5.75. Sunny, cool breeze. Showers 10 minutes after application.	*Polygonum persicaria* yp *Chenopodium album* yp-mp	4.6.75. 2.7.75.	1-4 8	3 10
Oxton, Notts.	spring barley 5 leaf 15-20 cm stand variable vigour - good	benazolin + dicamba + dichlorprop 3063	6.6.75. Warm and sunny, slight breeze.	*Matricaria* spp. mp-bd *Stellaria media* mp-fl	13.6.75. 17.7.75.	1-3 8	2 9

Key to weed stage:
- sd = seedling, cotyledon-2 leaf
- yp = young plant, 2-4 leaf
- mp = mature plant, 4 leaf-bud
- bd = bud stage
- fl = flowering

Weed control scores
- 0 = no effect
- 7 = minimum commercially acceptable effect
- 10 = complete kill

Assessment types Table 2 - (a) = score
(b) = % control

Table 2 1976 Trials

Location Crop and stage	Herbicide g a.i./ha	Date and weather conditions at application	Main weeds and stage	Assessment date and type	Assessments volume rate, l/ha 15	20	25	30	40	225
Thoroton, Notts: w.w. cv. Bouquet, fully tillered, 25 cm, stand and vigour poor	benazolin + dicamba + dichlorprop 3063	12.4.76. dull light, gusty wind, 6°C	Matricaria recutita yp	13.5.76. (a)	3	3	3	-	-	6
				1.6.76. (a)	3.5	3.5	4	4.5	-	6
				9.6.76. (b)	18	34	40	55	-	84
Orston, Notts: w.w. cv. Huntsman, fully tillered, jointing, stand & vigour poor	mecoprop 2240	13.4.76. dull, sunny, moderate to high wind, 6°C	Stellaria media bd-fl 15-20 cm across	13.5.76. (a)	2	3	2	3	-	5.5
				1.6.76. (a)	2.5	3	3.5	2	-	7.5
				11.6.76. (b)	45	43	62	36	-	70
Holme upon Spalding Moor, Yorks: s.b. cv. Mink, 5-6 leaf, 15 cm, stand moderate, vigour poor	dichlorprop + MCPA 1800	24.5.76. sunny, strong winds, 16°C	Polygonum aviculare sd-yp	2.6.76. (a)	3	3	-	3	3	3
				5.8.76. (a)	5.5	5	-	5.3	6	6
Kneeton, Notts: w.w. cv. Bouquet, fully tillered, 10-15 cm, stand & vigour good	benazolin + dicamba + dichlorprop 3063	12.4.76. dull, windy, 6°C	Matricaria recutita yp	13.5.76. (a)	5.5	7	5.3	7.5	-	8
				1.6.76. (a)	7	10	7	8	-	9.5
			Stellaria media bd	13.5.76. (a)	6	8	5.5	5.8	-	9
				1.6.76. (a)	7	9	7	9	-	10
Dowsby, Lincs: s.b. cv. Mink, 10-15 cm stand - patchy vigour - good	3,6 dichloro-picolinic acid + dichlorprop + MCPA 4050	10.5.76. dull, hazy, moderate breeze 12.8-15.6°C	Galeopsis tetrahit sd-yp	5.6.76. (a)	7	7	-	7	7	7
				23.7.76. (a)	10	10	-	10	10	10
Shelton, Notts (I): w.w. cv. Freeman, fully tillered, 25 cm, stand & vigour good	difenzoquat 1000	13.4.76. cold, windy, dull, rain showers	Avena fatua mostly 2 leaf	26.7.76. (b)	25	0	12	36	-	74
Shelton, Notts (II): s.b. cv. Mink, 5 leaf stand - good vigour - moderate	difenzoquat 1000 dichlorprop + MCPA 1800	11.5.76. cool, dull, gusty wind, showers	P. convolvulus sd	9.6.76. (a)	8	8	-	8	-	8
			P. aviculare sd-yp	9.6.76. (a)	8	8	-	8	-	8
			A. fatua 2-4 leaf	21.7.76. (b)	99	94	-	90	-	100

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MEASUREMENTS OF DROP SIZE AND SPRAY DISTRIBUTION FROM A MICRON HERBI DISC*

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Summary Measurments were made of the physical performance of a Micron Herbi* disc operating over a range of flow rates from 0.5 ml/s to 2.0 ml/s. The results showed that the wettability of the surface of the disc affects both drop size and spray distribution. The effect of wind on deposits was also examined.

Resume On a mesuré la précision d'application d'un disque Micron Herbi à des débits qui variaient de 0.5 à 2.0ml/s. Les résultants démontrent que la mouillabilité de la surface du disque agit sur le diamètre des gouttes autant que sur la répartition de la pulvérisation. On a aussi étudié l'action du vent sur les dépôts de pulvérisation.

INTRODUCTION

Techniques being used at the N.I.A.E. in a research project aimed at developing a low volume sprayer (Lake 1972, Byass et al, 1976) were used to measure the physical performance of a Micron Herbi disc (Bals, 1975) over a range of flow rates. The work was carried out at the request of the A.D.A.S. Liaison Unit.

The discs were operated at the normal speed of 2000 rev/min, with a spray solution of water containing 0.1% (v/v) Agral+.

SPRAY FORMATION

Spray formation was examined using short duration flash photography giving exposures of less than 10^{-6}s. Flow rates of 0.5, 1.0, 1.5 and 2.0 ml/s were used. There are three recognised mechanisms by which spray can be produced from a spinning disc, namely direct drop formation, ligament formation and film formation (Hinze and Milborn, 1950). With the untreated disc some ligaments were formed at all flow rates, but direct drop formation predominated at 1 ml/s (Fig. 1a, b and c). When the sand-blasted disc was used direct drop formation occurred at all flow rates and no ligaments were seen (Fig. 1d). This was presumably due to more even wetting of the surface of the disc (Frost, 1974).

*Markeded by Micron Sprayers Limited.
+Marketed by Plant Protection Limited.

When ligaments were formed from the untreated disc they often came from only one part of the periphery. This effect was caused by uneven flow of liquid over the surface due to the feed being eccentric.

DROP SIZE

A projection microscope was used to measure drops from photographic plates. Cumulative drop size data for a sand-blasted disc fed at 1.5 ml/s are shown in Fig. 2. The mass median diameter of the spray was 210 µm.

Examination of photographs of the untreated disc showed that direct formed drops were about 250 µm diameter, while drops from ligaments were about 120 µm diameter.

SPRAY DISTRIBUTION

The distribution of spray from single untreated disc moving at 2.2 m/s was measured by using a fluorescent dye (0.2% w/v Fluorescein LTS*) in the spray solution and collecting the spray on strips of 50 mm wide chromatography paper laid out at right angles to the direction of travel. The work was carried out indoors with the unit attached to an overhead conveyor. The amount of spray deposited on the paper was determined for each successive 50 mm length by using an automatic direct-reading fluorimeter (Sharp, 1974).

Examples of the results obtained for a disc 0.5 m above the ground and fed at 1 ml/s and 2 ml/s are shown in Fig. 3a. At 2 ml/s the distribution is asymmetrical due to uneven flow of liquid across the surface of the disc. Reducing the height of the disc to 0.3 m had little effect on distribution (Fig. 3b).

EFFECT OF WIND ON DEPOSITS

The effect of wind on deposits was examined in the field using a stationary untreated disc at a height of 0.5 m, and with a flow rate of 1 ml/s. The spray was collected on a length of 50 mm wide chromatography paper laid out down wind of the unit. Wind speed was recorded 0.5 m above the ground using a cup anemometer.

An example of the results obtained is shown in Fig. 4, the mean wind speed being 3.0 m/s. The deposits on the paper strip were measured every 50 mm with the automatic fluorimeter. The main effect of the wind was to spread the spray pattern and displace its centre about 1.3 m, but deposits of 0.2% of the total collected on the paper were obtained 12 m downwind.

DISCUSSION

The wettability of the surface of a disc has an important effect on drop formation and therefore the uniformity of drop size of the spray. In this respect the sand-blasted disc performed better at 2 ml/s than did the untreated disc at 1 ml/s. However, it is not known whether the sand-blasted surface would continue to remain easily wetted after prolonged use.

:Obtained from Skilbeck Dyestuffs & Chemicals Ltd.

The measurements of spray distribution showed that high flow rates of liquid onto the disc can result in an uneven distribution of the spray as well as a wider range of drop size. Studies of rotary atomisation at the N.I.A.E. have shown that the position of the feed of liquid onto a disc is also important as this can affect the flow of liquid over the disc surface.

Although only a few runs were carried out with discs in wind it is evident that most of the spray tends to be displaced down wind rather than become airborne and drift some distance away from the disc. This confirms the findings of Taylor and Merritt (1975). It was calculated that 250 µm drops from a Herbi disc 0.5 m above the crop take about 0.6 s to enter the crop (Marchant, 1976). This is at least ten times as long as a similar size drop from a hydraulic nozzle at the same height, so it would be expected that the drops from the disc would be more susceptible to wind.

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Fig.1a. Untreated disc (1·0ml/s)

Fig.1b. Untreated disc (1·5ml/s)

Fig.1c. Untreated disc (2·0ml/s)

Fig.1d. Sand-blasted disc (1·5ml/s)

Fig. 2. Drop size spectrum

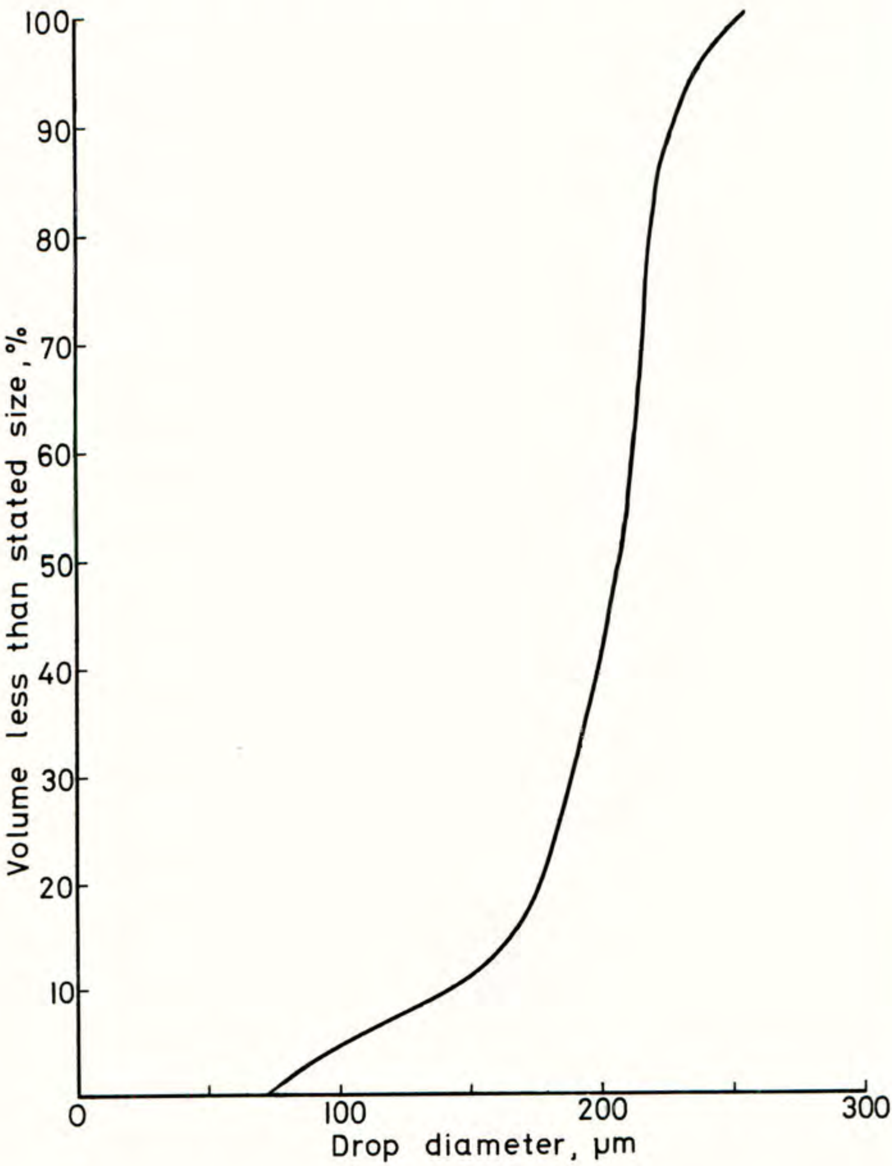


Fig.3. Spray distribution

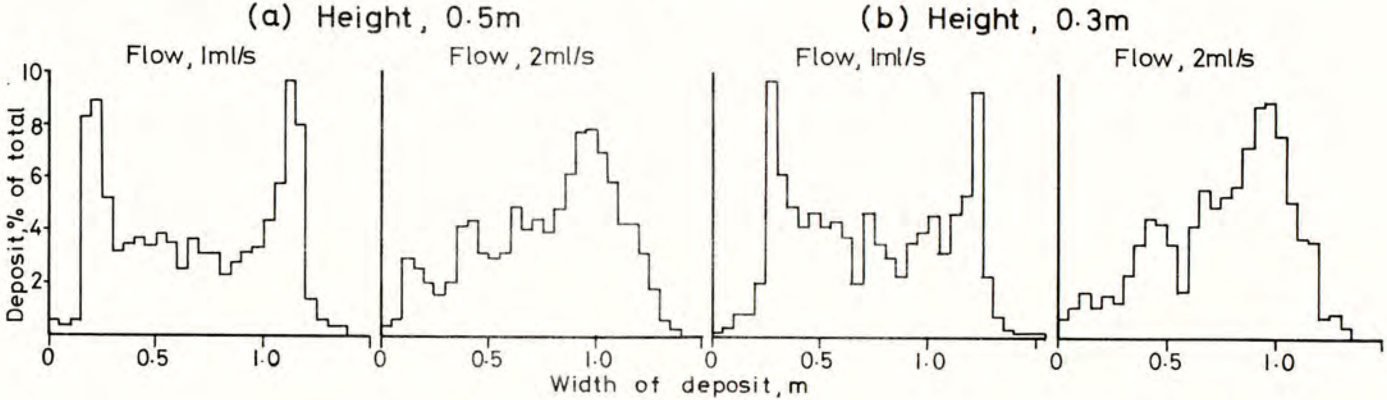
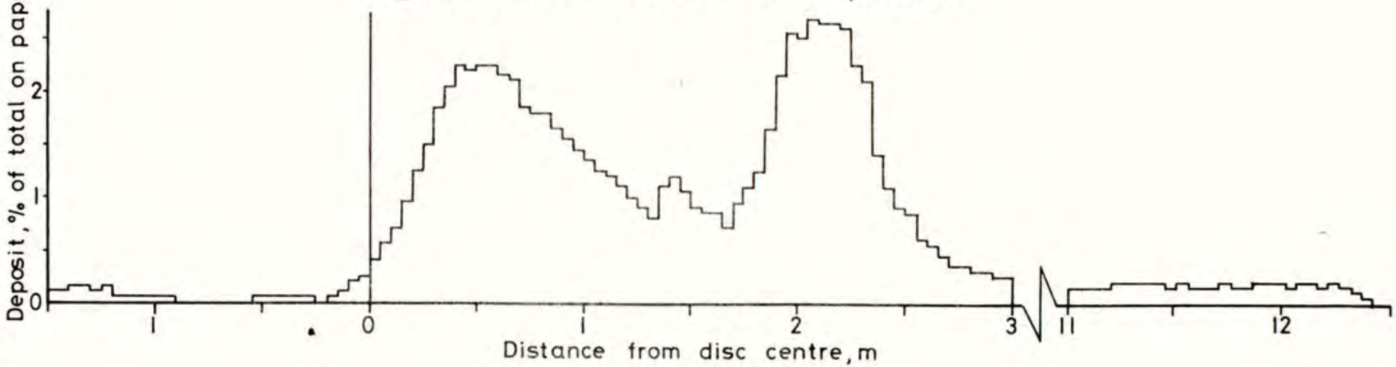


Fig.4. Effect of wind on deposits



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EFFECT OF FORMULATION, VOLUME RATE AND APPLICATION METHOD ON PERFORMANCE AND RAINFASTNESS OF GLYPHOSATE ON AGROPYRON REPENS

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Summary *Agropyron repens* was treated with glyphosate formulated either as an aqueous solution incorporating surfactant or as an oil-in-water emulsion or as a solubilized solution in oil. These formulations were applied by conventional hydraulic sprayer or controlled drop application (CDA). Performance and rainfastness were judged by effects on fresh weight of foliage and rhizome and on the numbers of nodes on the rhizome. The emulsion formulations had the poorest performance and rainfastness. The CDA oil at 20 l/ha was superior to the emulsion and aqueous formulations applied at 413 l/ha, but was not as effective as aqueous CDA at 20 l/ha which was the most economical treatment in terms of water and surfactant use and speed of application.

INTRODUCTION

The post-spraying environment, especially with regard to temperature, humidity and the occurrence of rain, can have a considerable influence on the performance of glyphosate against *Agropyron repens* (Baird and Begeman, 1972 and Caseley, 1972). The deleterious effects of heavy rain soon after spraying are greatest when other environmental factors do not favour activity. Thus subjecting the plant to heavy simulated rain or washoff two hours after spraying substantially reduced activity at 45% RH but had little effect at 95% RH (Caseley *et al*, 1975). Coupland *et al* (1976) observed that increasing the dose of herbicide helped to overcome the effect of adverse environments on the control of wild oats with difenzoquat. Additionally, it is often possible to alter the activity of many foliage-applied herbicides by modifying the formulation, volume rate and spray characteristics (Foden, 1972). The objective of the work reported here was to investigate whether improved performance and rainfastness of glyphosate could be obtained by the use of various formulation and application techniques. The treatments included conventional hydraulic application of aqueous and emulsion spray solutions, and controlled drop application (CDA) of solubilized oil and aqueous formulations.

MATERIALS AND METHODS

Plants. Single node rhizome fragments of *A. repens* (Beauv.) clone 31 were planted in a peat/sand compost in 9 cm pots in a glasshouse where the controls were set to 14 ± 5°C. The temperature rarely fell below this, but in warm weather often exceeded 21°C. Humidity ranged between 40-80% RH. The stage of growth of plants at treatment varied between experiments and ranged from 1-2 tillers and 4-6 tillers.

Herbicide. Glyphosate (MON 0139) without wetting agent containing 480 g a.i./l was used throughout these experiments.

Formulation. The aqueous spray solutions all contained 0.2% v/v Agral 90 surfactant. The solubilized oil formulation contained Agral 90, glycerin monooleate and Shellsol T and was prepared as described by Turner and Loader (1974). Oil-in-water emulsions were prepared by adding the required volume of water to the same solubilized oil formulations. The solutions for 'control' treatments contained these formulation ingredients without any herbicide.

Application. A hydraulic laboratory pot sprayer fitted with Spraying Systems 'Tee-jet' nozzles or a spinning disc apparatus similar to that described by Byass and Charlton (1968) was used. The original metal disc of the latter machine was replaced by a nylon disc (Bals, 1975) for some experiments. Details of the application method and volume rate used for each formulation are given in Table 1.

Table 1

Experimental spraying conditions

Formulation	Volume (l/ha)	Nozzle*	Pressure (bars)	Disc	Table ref.
Aqueous	413	8002E	2.11	-	2,4
	165	8001	2.81		3
	78	8001	2.81		6
	20	-	-	Nylon	5,6
Emulsion	413	8002E	2.11		2
	165	8001	2.81		3
Solubilized oil	20	-	-	Metal	3
	20	-	-	Nylon	4,5,6

* From the Spraying Systems 'Tee-jet' range.

Rainfastness. The intense washing treatment described by Caseley et al (1975) was used 2 h after herbicide application. With this method, all visible traces of tartrazine dye added to the spray solution applied at 165 l/ha were removed from the foliage. It is assumed that most of the herbicide is removed as the plants do not develop phytotoxic symptoms when this treatment is applied immediately after spraying. In this way an approximation can be made of the effects of application method and formulation on rainfastness of the herbicide.

Procedure. Plants were selected for uniformity of growth, sprayed and returned to the glasshouse where they were arranged in a randomised block design. Two hours after spraying, designated plants were washed and immediately returned to their original position on the glasshouse bench. The plants were harvested 5-6 weeks later when fresh weights of foliage and rhizome or total number of nodes on the rhizome were recorded.

RESULTS

When aqueous and emulsion formulations were applied at 413 l/ha, the latter performed relatively poorly (Table 2). Similar results were obtained when the volume rate was reduced to 165 l/ha (Table 3). However, 0.2 kg/ha of glyphosate applied as the CDA formulation in a volume of 20 l/ha had a greater effect in reducing foliage fresh weight than either the aqueous or the emulsion formulations (Table 3). The difference was significant only in the case of the emulsion. The CDA oil formulation was more effective than the aqueous formulation applied at 413 l/ha when subjected to a washoff treatment (Table 4). In a comparison of CDA aqueous and solubilized oil

Table 2

Effect of aqueous and emulsion formulations of glyphosate ± washoff on *Agropyron repens*

Glyphosate (kg/ha)		0		0.2		0.4	
Washoff		+	-	+	-	+	-
Formulation	l/ha	Foliage fresh weight (g)					
Aqueous	413	13.4	15.4	7.0	7.2	5.4	3.6
Emulsion	413	12.5	11.8	11.6	8.9	8.2	5.3
S.E. 1.30							
		Rhizome fresh weight (g)					
Aqueous	413	3.9 (0.52)	7.3 (0.83)	4.4 (0.64)	2.5 (0.39)	3.1 (0.42)	1.4 (0.09)
Emulsion	413	5.5 (0.72)	5.8 (0.68)	4.9 (0.69)	5.2 (0.69)	4.0 (0.57)	3.6 (0.49)
(S.E. 0.11)							

S.E. are for comparing means of four replicates. The S.E. for rhizome fresh weight applies to transformed logarithmic values shown in brackets.

Table 3

Effect of aqueous, emulsion and oil solubilized formulations of glyphosate on *Agropyron repens*

Glyphosate (kg/ha)		0	0.2	0.4
Formulation	l/ha	Foliage fresh weight (g)		
Aqueous	165	13.5	5.5	4.6
Emulsion	165	11.7	8.2	5.7
Oil	20	12.8	4.4	3.1
S.E. 1.0				
		Total nodes		
Aqueous	165	30.0 (1.47)	10.8 (0.89)	7.8 (0.82)
Emulsion	165	28.3 (1.44)	12.5 (1.09)	12.0 (1.08)
Oil	20	32.8 (1.51)	5.5 (0.78)	8.5 (0.97)
(S.E. 0.13)				

S.E. are for comparing means of four replicates. The S.E. for total nodes applies to transformed logarithmic values shown in brackets.

formulations both applied at 20 l/ha, the former was more effective (Table 5).

The aqueous formulation applied in 20 l/ha (CDA) had a greater effect on foliage fresh weight and number of nodes than an aqueous solution applied at 78 l/ha by the hydraulic sprayer. This was the case both with and without a washoff treatment (Table 6).

Table 4

Effect of hydraulic aqueous and CDA oil solubilized formulations of glyphosate ± washoff on *Agropyron repens*

Glyphosate (kg/ha)		0	0.32		0.62	
Washoff			+	-	+	-
Formulation	l/ha		Foliage fresh wt. (g)			
Aqueous	413	14.0	8.0	3.0	5.6	3.4
Oil	20	12.5	4.5	3.3	4.8	4.0
S.E. 1.24						
			Total nodes			
Aqueous	413	46.3 (6.7)	29.3 (5.3)	12.3 (3.5)	14.0 (3.3)	13.0 (3.2)
Oil	20	49.7 (7.0)	17.0 (4.0)	14.7 (3.7)	10.7 (3.2)	12.0 (3.5)
(S.E. 0.76)						

S.E. are for comparing means of 3 replicates. The S.E. for total nodes applies to the transformed square root values shown in brackets.

Table 5

Effect of CDA aqueous and oil solubilized formulations of glyphosate on *Agropyron repens*

Glyphosate (kg/ha)		0	0.05	0.1	0.2
Formulation	l/ha		Foliage fresh wt. (g)		
Oil	20	11.1	8.2	7.0	4.3
Aqueous	20	11.0	7.6	4.9	4.2
S.E. 0.61					
			Total nodes		
Oil	20	50.7 (1.7)	33.1 (1.3)	8.9 (1.0)	6.9 (0.9)
Aqueous	20	40.6 (1.6)	14.2 (1.1)	6.8 (0.8)	5.5 (0.8)
(S.E. 0.09)					

S.E. are for comparing means of 8 replicates. The S.E. for total nodes applies to transformed logarithmic values shown in brackets.

Table 6

Effect of hydraulic and CDA aqueous formulations of glyphosate ± washoff on Agropyron repens

Glyphosate (kg/ha)		0		0.1		0.2		0.4	
Washoff		+	-	+	-	+	-	+	-
Application	l/ha	Foliage fresh wt. (g)							
Hydraulic	78	7.7	8.0	6.5	5.6	5.6	4.4	4.0	2.9
Disc	20	7.7	8.0	5.4	4.9	3.6	3.3	3.5	1.5
S.E. 0.34									
		Total nodes							
Hydraulic	78	27.8	23.6	26.8	19.4	26.3	12.6	7.6	3.3
		(5.2)	(4.8)	(5.1)	(4.2)	(4.8)	(3.2)	(2.3)	(1.6)
Disc	20	27.8	23.6	18.4	8.5	7.3	4.6	5.0	2.3
		(5.2)	(4.8)	(4.0)	(2.6)	(2.2)	(2.0)	(1.6)	(1.1)
(S.E. 0.45)									

S.E. are for comparing means of 8 replicates. The S.E. for total nodes applies to the transformed square root values shown in brackets.

DISCUSSION

Formulation of glyphosate as an emulsion rather than as the more usual aqueous solution reduced its performance and rainfastness. Reducing the volume rate and increasing the spraying pressure, which Taylor et al (1974) found improved the performance of two wild oat herbicides formulated as emulsions, increased phytotoxicity slightly, but not to the level of the aqueous formulation applied at the same volume rate. Turner and Loader (1974) found that the use of an oil solubilized as compared with an aqueous formulation of glyphosate at 148 l/ha to the foliage of several woody species increased phytotoxicity by a factor of up to four. In the present experiments, the oil solubilized formulation (CDA) was evaluated only at 20 l/ha. At this volume rate this treatment was superior to the emulsion formulation applied at 165 l/ha and the aqueous formulation at 413 l/ha. When however the oil-based CDA formulation was compared with the aqueous formulation applied in the same way and at the same volume rate, it was less effective. The improvement in performance in the woody species reported by Turner and Loader (1974) was perhaps due to the different volume rates and method of application used and to the different morphological and anatomical characteristics of the target plants, particularly those which affect retention and penetration. Unfortunately the present experiments did not include a direct comparison of rainfastness of CDA aqueous and oil solubilized formulations, but the former was significantly more efficacious than the hydraulic aqueous at 78 l/ha.

The main conclusion of these experiments is that most benefit, in terms of performance and rainfastness, can be achieved by applying glyphosate as an aqueous formulation at 20 l/ha using CDA. The reasons for this are still under investigation, but preliminary experiments indicate that retention of active ingredient on the foliage of A. repens probably plays an important role.

It is worth stressing that the most effective treatment was also the most economical treatment with regard to water and surfactant usage.

Acknowledgements

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THE INTERACTION OF SURFACTANT TYPE AND CONCENTRATION WITH CONTROLLED DROP APPLICATIONS OF MCPA AND DIFENZOQUAT

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Summary In glasshouse trials four non-ionic surfactants were applied in various concentrations in both conventional and controlled drop applications of MCPA (on *Raphanus sativus* L.) and difenzoquat (on *Avena fatua* L.). With a hydrophilic surfactant (Tween 20) applications of 200 l/ha were more effective than those of 15-20 l/ha at high surfactant concentrations but less effective at low concentrations. This was not the case with a lipophilic surfactant (Monolan PB).

INTRODUCTION

It is well established that surface-active agents or surfactants can improve the activity of many foliage-applied herbicides. As a result they are a major constituent of many commercial formulations. Although much is known of their mode of action in this respect the picture is by no means complete. It is likely that the most important effect of surfactants on aqueous sprays is the increased retention on plant surfaces (Foden, 1972). This is largely due to a lowering of the surface tension. However, there are undoubtedly other important effects such as changes in degree of herbicide uptake (Foy and Smith, 1969) and movement within plant tissues (Bland and Brian 1975). Many considerations affect current usage of surfactant type and concentration in present formulations. Evidence is based largely on empirical trials with conventional applications using hydraulic nozzles and relatively high volume rates. Conversely little work has been done to establish the requirements of application at volume rates of around 20 l/ha.

The experiments described here compared four surfactants at various concentrations with both conventional (200 l/ha) and controlled drop (15-20 l/ha) applications of difenzoquat and MCPA using glasshouse grown plants.

MATERIALS AND METHODS

Plant raising. Seeds of wild oats (*Avena fatua*) and radish (*Raphanus sativus*) cv long black spanish were sown 10 mm deep in sandy loam topsoil contained in 90 mm diameter plastic pots. All plants were grown in a temperate glasshouse. Wild oats were treated when they had 4 leaves, radishes when they had 2 leaves.

Treatments. Three experiments are described. In experiment 1 difenzoquat was applied to *A. fatua* at two doses, 0.05 and 0.15 kg ai/ha. Two volume rates were used, 200 l/ha applied with a hydraulic nozzle (a Spraying Systems 'Tee-jet' 8001 at a pressure of 2.1 bars) and 15 l/ha applied with a rotary atomiser producing a drop size of 250 μm diameter. Agral, a non-ionic surfactant was included in the spray solution at three concentrations, 0.01, 0.1 and 0.5 v/v.

In experiment 2 difenzoquat was applied to A. fatua at three doses (0.05, 0.2 and 0.8 kg ai/ha). In experiment 3 MCPA was applied to R. sativus at three doses (0.4, 0.8, 1.6 kg ae/ha). Other treatments were similar with these two experiments. Two volume rates were applied, 200 l/ha with a hydraulic nozzle and 20 l/ha with a rotary atomiser producing drops of 250 μm diameter. Three non-ionic surfactants were used and chosen to cover a range of HLB (hydrophile-lipophile balance) values. The three were Tween 20 (HLB 16.7), Ethylan TU (of a similar chemical composition to Agral and with a HLB 12.2) and Monolan PB (a low foaming surfactant having an HLB about 8-10). Each surfactant was applied in three concentrations, 0.05, 0.5 and 5.0 % v/v with difenzoquat and 0.01, 0.1 and 1.0% v/v with MCPA (the medium concentration in each case being the normal).

Assessment. The fresh weight of foliage was recorded in each experiment. Assessment times were 29, 26 and 26 days after spraying for experiments 1, 2 and 3 respectively.

RESULTS

Experiment 1. (difenzoquat)

At the normal concentration of Agral (0.5% v/v) there was no difference in effect of difenzoquat between applications of 200 l/ha and 15 l/ha. However, at reduced concentration of Agral there was a much greater loss in effect at 200 l/ha than at 15 l/ha.

Experiment 2. (difenzoquat)

With Tween 20 at all three doses difenzoquat and Ethylan TU at the highest dose (0.8 kg ai/ha) 200 l/ha was less effective than 20 l/ha at the lowest surfactant concentration (0.05%) whilst at the higher surfactant concentrations (0.5 and 5.0%) the reverse was true.

With the lower doses using Ethylan TU and with all three doses of Monolan PB there were no major differences between volume rates at any surfactant level.

Experiment 3. (MCPA)

As with difenzoquat the effectiveness of MCPA applied at 20 l/ha with the lowest concentration of Tween 20 (in this case 0.01% v/v) was not reduced to the same extent as at 200 l/ha, whilst there was no difference at other concentrations.

With the other two surfactants, applications of 200 l/ha were generally more effective than those of 20 l/ha although results with Monolan PB were somewhat erratic.

DISCUSSION

Controlled drop applications of 15 or 20 l/ha are more reliable at lower than normal surfactant concentrations. This is particularly so with A. fatua which has a surface which is difficult to wet, and with the more hydrophilic surfactants (especially Tween 20).

At normal or higher concentrations of surfactants applications of 200 l/ha are often more effective than 15 or 20 l/ha. However, it must be appreciated that such applications involve a tenfold difference in the total amount of surfactant used for a given concentration, and often the loss in effect due to the lower volume rate could be mitigated simply by using the same amount of surfactant. These results seem to suggest that the response to surfactant rate is in some cases more dependent on the amount of surfactant than the resultant concentration in the spray sólution.

It must be remembered that these results were obtained using glasshouse grown plant material which undoubtedly differs from outdoor grown material. However, whilst only general conclusions can be drawn from this work the results clearly demonstrate that the requirements of surfactant type and concentration may not always be the same with controlled drop application at volume rates around 20 l/ha as with hydraulic applications at volume rates around 200 l/ha.

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Fig.1 Effect of difenzoquat (mean of 2 doses) on the fresh weight of Avena fatua, when applied at two volume rates with three concentrations of Agral

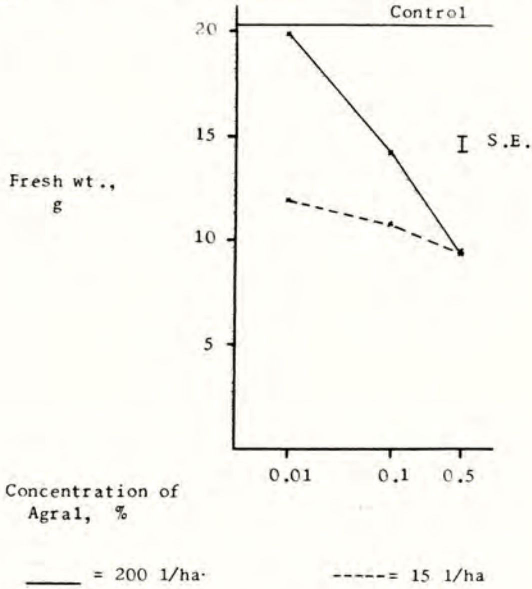

Fig. 2 Difenzoquat: effect at 3 doses on the fresh weight (g) of *A. fatua*, when applied in two volume rates with three surfactants at three concentrations.
_____________ = 200 l/ha ---------------- = 20 l/ha

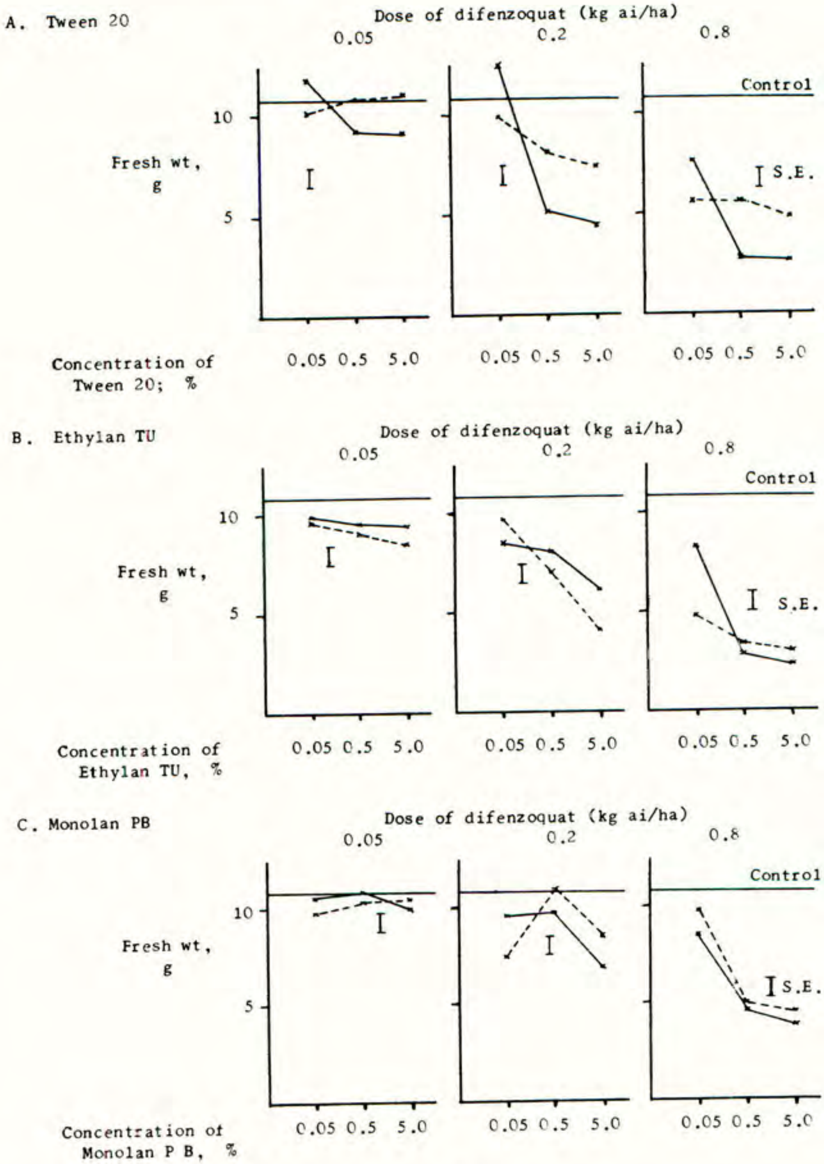

Fig. 3 MCPA: effect at 3 doses on the fresh weight (g) of R. sativus when applied in two volume rates with three surfactants at three concentrations.

______________ = 200 l/ha ---------------- = l/ha